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Relationships between marine litter and type of coastal area: implications for the design of monitoring plans

Mestrado em Ecologia Marinha

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Porque sem ti nada disto seria possível mãe

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Resumo

O lixo marinho é uma das ameaças mais preocupantes à conservação dos Oceanos embora os estudos sobre este problema só tenham começado há relativamente pouco tempo. Na década de 30 foram avistados os primeiros animais emaranhados e, na década de 60, começaram a ser reportados animais mortos pela ingestão de plástico. Atualmente, este problema afeta todos os oceanos em todas as profundidades e uma quantidade significativa de lixo continua a ser produzida diariamente. Esta ameaça, resultado de anos de um deficiente tratamento de resíduos e da ignorância face ao destino dos materiais depositados no mar de forma descontrolada, tem-se tornado mais conspícua. Isto deve-se à acumulação de resíduos sólidos nas zonas costeiras, provenientes tanto de terra como de mar. Assim, o aspeto estético do lixo acumulado nestas zonas, juntamente com o aumento de avistamentos de animais emaranhados atraiu, nos últimos anos, a atenção da população e da comunidade científica. O problema do lixo marinho intensificou-se devido à evolução da composição dos materiais descartados. Antigamente, apesar dos materiais serem descartados de forma imprópria, estes eram biodegradáveis, o que provocava impactos reduzidos para o ecossistema. Com a intensificação do uso do plástico como material de baixa densidade, duradouro, resistente, relativamente barato e extremamente versátil, o ato de descartar incorretamente estes resíduos passou a ter graves consequências. A lenta degradabilidade do plástico, o facto de a maioria ser constituído por poluentes orgânicos persistentes (POP) e de apresentar uma elevada toxicidade, são algumas das características que tornam o material mais usado atualmente, uma grave ameaça ao meio ambiente. Apesar da relevância dada ao plástico, o lixo marinho, de origem antropogénica inclui muitos outros materiais, também prejudiciais ao meio ambiente, como o vidro, papel, resíduos sanitários, resíduos médicos, metal, vestuário, olaria e outro tipo de poluentes. Esta problemática tem-se revelado de tal forma importante que a sua monitorização é essencial para avaliar a quantidade, o tipo, a distribuição e a origem do lixo marinho. É neste sentido que o lixo marinho foi designado como um dos descritores da Diretiva Quadro Estratégia Marinha (DQEM), diretiva esta que tem como principal objetivo alcançar ou manter o Bom Estado Ambiental das águas marinhas e costeiras até 2020. O descritor 10 da DQEM, que indica que as propriedades e a quantidade do lixo marinho não prejudicam o meio costeiro e marinho, necessita de uma boa caracterização do mesmo. Para tal, a diretiva estabelece dois grandes indicadores: as características do lixo marinho no meio costeiro e marinho e os impactos do lixo na vida marinha, sendo a monitorização um dos principais componentes deste primeiro indicador. Atualmente, as amostragens realizadas na praia são o tipo de monitorização mais comum da zona costeira, uma vez que estas não só permitem a recolha de uma grande quantidade de informação, como podem ser realizadas sob praticamente quaisquer condições atmosféricas, apresentando custos reduzidos. Existem vários fatores que influenciam a ocorrência do lixo marinho nas praias, sendo que as principais são: as características do lixo; a dinâmica das praias; as condições atmosféricas; os padrões de circulação oceânica, a limpeza das praias e as práticas recreativas e comerciais realizadas em águas oceânicas. Neste âmbito foi realizado um estudo para relacionar a presença do lixo marinho com as características da costa, de modo a perceber como esta relação pode influenciar possíveis programas de monitorização, enquadrando a necessidade de monitorizar o lixo marinho no âmbito da DQEM. Esta dissertação de mestrado teve também como objetivo relacionar os diversos tipos de lixo marinho encontrados com as suas fontes, encontrando indicadores que auxiliassem essa identificação. Foram assim amostradas onze praias em Portugal, entre o outono de 2014 e a primavera de 2015. A quantidade e o tipo de lixo foram amostrados adaptando o *design* da Convenção para a Proteção do Meio Marinho do Atlântico Nordeste (OSPAR). Foram atribuídas determinadas características às praias como a extensão da praia; o tipo de substrato (classificado de acordo com a sua granulometria) e a existência de urbanização (se as praias eram ou não urbanizadas). O declive e a distância ao estuário foram caracterizadas por comparação entre as diferentes praias. Estas características foram posteriormente relacionadas com a quantidade do lixo através de uma PERMANOVA. As diferenças significativas obtidas na análise anterior foram exploradas utilizando o teste SIMPER. Para visualizar estas relações foi realizada uma Análise de Coordenadas Principais (PCO). Para identificar as possíveis fontes do lixo encontrado, foram estabelecidos indicadores baseados nos três principais tipos de lixo encontrados para cada praia e para cada estação do ano. A principal categoria de lixo encontrado nas praias foi o plástico (plástico < 2.5cm e os *pellets*), sendo seguido pelo papel (beatas) e pelos resíduos sanitários (cotonetes). A quantidade de lixo foi influenciada tanto pelas diferentes praias como pelas diferentes estações do ano. Todas as estações do ano apresentaram também diferenças significativas e as praias com uma maior média de dissimilaridade foram Sesimbra e Maçãs, Maçãs e São Lourenço e, por fim, Figueirinha e Maçãs. O plástico foi o principal tipo de lixo responsável por estas diferenças. A PCO não mostrou uma boa relação entre as diferentes características das praias e o lixo,

destacando, no entanto, a praia das Maçãs das restantes. As praias que foram classificadas como urbanas apresentaram maior quantidade de lixo, bem como as praias que se encontravam mais perto de estuários. No geral, verificou-se uma maior quantidade de lixo no outono e na linha da maré alta, e não na linha da vegetação como aconteceu noutros estudos desta temática. Embora não tenha sido possível identificar a maioria da origem do lixo, que foi, na generalidade, considerado como lixo de origem mista, as categorias de lixo que corresponderam ao conjunto de indicadores específicos, propostos pela OSPAR, foram os cotonetes (resíduos sanitários) e as linhas de pesca e caixas de pescadores (pescas, incluindo aquacultura). É ainda de salientar a elevada presença de beatas de cigarros, cuja origem foi atribuída, por experiência dos investigadores, à restauração e às pessoas que frequentaram as praias. Estes resultados demonstram que o lixo identificado como terrestre teve maioritariamente origem na restauração e nos frequentadores das praias e num potencial défice na gestão de tratamento de águas. No lixo identificado como de origem marinha, a maioria foi devida à atividade pesqueira e ao transporte de mercadorias por via marítima, devido à quantidade de *pellets* encontrados. Devido à elevada quantidade de lixo de reduzidas dimensões encontrada (como pedaços de plástico < 2.5cm, *pellets*, beatas e cotonetes), pode-se deduzir que a limpeza da praia é, de certa forma, ineficaz para o lixo de reduzidas dimensões. É importante referir que também foram identificados vários tipos de embalagens alimentares e de bebidas, bem como copos de plástico e palhinhas. Estes items, embora não tenham correspondido à maior percentagem dentro da categoria de plástico, evidenciam a falta de sensibilização da população para o problema do lixo marinho. Considerando a enorme importância da monitorização do lixo marinho e da determinação da sua fonte é interessante realizar estudos futuros de modo a eliminar o problema na origem. Estes estudos poderão relacionar os diferentes transportes do lixo marinho, como o vento e as correntes, com a sua distribuição. Analisar em que medida as condições atmosféricas influenciam a quantidade de lixo na zona costeira é também um dos possíveis objetos de estudos futuros.

Abstract

Marine litter has been recognized as a serious environmental problem and therefore, it has become an important field of study. With an estimated eight million items being discarded, every day, in oceans and seas, marine litter represents a threat to the marine environment. Monitoring marine debris became a relevant topic of research as marine litter is one of the descriptors of the Marine Strategy Framework Directive. This study relates the different characteristics of the coast of Portugal (urbanization, slope, distance to estuary and length) with the type and abundance of marine litter found on eleven beaches. The surveys were conducted following a transect approach method, according to the OSPAR design. After identified, the litter was related to the coast characteristics through a PERMANOVA, a SIMPER and a PCO analysis. Specific indicators were established in order to determine the source of the litter. The main types of litter found were plastic, paper and sanitary waste. The majority of litter was classified as having mixed origin, despite some litter could be identified as having land and marine origin. The sources of marine litter identified were sanitary and sewage-related waste, as well as fisheries, including aquaculture. This study related the assessed litter with the characteristics of the coast and, when possible, attributed their sources.

KeyWords: Marine litter, Monitoring, MSFD

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Chapter 1: General Introduction

Marine litter is defined as items that were made and used by people and that were deliberately discarded into the rivers, sea or on beaches; that were brought indirectly to the sea with sewage, rivers, winds or storm water; that were accidentally lost (including material lost at sea in bad weather conditions), or that were deliberately left by people on beaches and shores (UNEP 2009). This problem started to receive more attention in the 60s and nowadays it is well visible in all oceans and in almost all depths (Ryan, 2015) being recognized as one of the most insidious ocean pollution issues (Sheavly, 2005). A significant amount of litter is produced every day and the trend is an increase in the overall production (Bergmann et al., 2015).

Marine litter can have its origin in either land or ocean-based sources, although it is estimated that about 80% of the litter existing in the ocean comes from land (Sheavly et al., 2005). The litter originated on land can come from multiple sources and sites near the coast, normally associated with activities related to the sea, such as ports, marinas and docks. The litter that is transported by rivers, the one that comes from the waste water treatments and the one that comes from untreated sewage can also be considered as land origin. The litter that is brought by storms, winds and rain is also considered of land origin, since it is washed from coastal areas and can end in the marine environment. Ocean- based litter comes mainly from the various activities that occur in the sea, such as touristic related activities like personal watercraft and cruises, and transportation of goods and fishing (UNEP, 2009).

Marine litter can be classified into several categories like plastic, wood, medical and sanitary waste, clothes, metal, glass and paper. Each type has its own properties and therefore they are usually found in different sites, wherein plastic is undoubtedly the most common type (Derraik, 2002; Santos et al., 2008). Due to its characteristics, such as light weight, durability, strength and buoyant properties (Andrady and Neal, 2009), plastic was considered by Madzena and Lasiak (1997) the most difficult type of debris to control, since it disperses far from origin. Plastics are usually found in all sites, from the bottom to the surface of the seas, as well as on beaches (Galgani et al., 2000; Moore et al., 2001; Reisser et al., 2013).

Over the years the impacts caused by marine litter have been documented worldwide. Entanglement and ghost fishing can cause superficial injuries but it can also

lead to more serious problems as injuries that, although not causing death, damage the animals' feeding and reproductive abilities. What started as superficial injuries can also develop to serious infections. These impacts can also decrease the ability to escape from predators and cause changes in the behavior of animals.
(Lais, 1997; Trouwborst, 2011). Over the years, the entanglement problem has been documented in multiple studies and organisms, such as in marine mammals (Henderson, 1985; Kraus, 1990); in marine birds (Day et al., 1985) and turtles (Balaz, 1985). The ghost fishing problem has also been reported in a few studies as Carr et al. (1985) showed for New England. The ingestion of debris, mainly of plastics, is also worrying since the animals can get a false sense of satiation (Secchi and Zarzur, 1999). This ingestion can also be responsible for the introduction of toxic chemicals into the marine food webs, such as Persistent Organic Pollutants (POP) that affect not only those who ingest them but also top predators (Trouwborst, 2011).

Marine litter can also be a transport and dispersion vector of invasive species, which can jeopardize the endemic species of certain regions (Gregory 2009). The smothering of the ocean floor caused by the litter that sinks is also a less known but also important impact (Trouwborst, 2011), as well as the public safety that can be threatened by injuries caused on beaches or by leaching of poisonous chemicals (Cheshire et al., 2009). It is also relevant to consider that the aesthetic impact caused by marine litter diminishes the well-being of the population and that can cause negative impacts in the tourism of the affected area (Cheshire et al., 2009).

The rate at which litter enters the system and at which it is removed influences the litter accumulation (both in seas and beaches) (Cheshire et al., 2009). Besides that, the proximity to large cities, the occupation and use of the shore and the maritime and hydrodynamics activities can also influence the accumulation rates of debris (Galgani et al., 2015). Tidal cycles, ocean currents, winds and regional-scale topography are responsible for marine litter deposition and distribution (UNEP, 2009). Coastal regions are where litter accumulates the most, since they suffer an extreme pressure with the population growth and with the uncontrolled development that are related to estuaries activities (Kennish, 2002). Estuaries do not escape from marine litter, what is worrying considering their ecological importance (Blaber et al., 2000).

Considering that when the litter that reaches the sea becomes part of the common ocean, Thor Heyerdahl (1971) stressed out the importance of the mistake of considering the existence of territorial waters when it comes to this problem, highlighting the importance of international agreements to protect the common ocean for future generations (Morrison, 1999). It is important to consider this question since, from the moment that litter reaches the sea, it becomes an international problem. Therefore, the litter has no owner and no one can be legally responsible for it (McIlgorm et al., 2011).

As a result, it is crucial to monitor this problem in order to identify the source and minimize or reduce the problem. Therefore, marine litter was considered one of the eleven descriptors used to define the Good Environmental Status until 2020, under the Marine Strategy Framework Directive (MSFD). Acting as a binding directive, MSFD can be considered as a supplementary community legal framework that can be used by present and future community members to develop new conservation measures, or enhance existing ones (Markus et al., 2011). This directive is the pillar of the Integrated Maritime Policy (IMP) of the European Union (Markus et al., 2011) and obliges the member states to follow an action plan that includes the initial assessment of the environmental status and to establish a series of environmental goals and the associated indicators (Van Franeker et al., 2010; Galgani et al., 2014). The Descriptor 10 of the MSFD defined good environmental status as the situation when properties and quantities of marine litter do not cause harm to the coastal and marine environments. To support the characterization of this descriptor, four indicators were described: trends in amount of litter washed ashore and/or deposited on coastlines; trends in amount of litter in water column (including floating on the surface) or deposited on sea floor, trends in amount, distribution and, when possible, composition of micro-particles and, finally, trends in the amount and composition of litter ingested by marine mammals (Galgani et al., 2013).

Despite the consensus in monitoring marine litter, to assess the status of debris found on beaches, the method to be applied can be variable (Araújo & Costa, 2007). Studies on marine litter have been conducted on beaches (e.g. Caulton & Mocogni, 1987; Ross et al., 1991; Moore et al., 2001), on the sea floor (e.g. Watters et al., 2010; Mordecai et al., 2011) and in open waters (Thiel et al., 2013). However, to monitor trends in the amount of litter washed ashore and/or deposited on the coastline (as described in one of the indicators of Descriptor 10), beach surveys are the approach used since it allows a larger sample size at minimal cost and it can be done in almost all weather conditions. Beach surveys are also cheaper since they require very little equipment (Rees & Pond, 1995) and have an important role in raising awareness of the population to this problem, since they can use volunteer work. Besides, debris tends to accumulate on beaches and when there is non-floating debris, it can be stranded on the shore (Dixon & Dixon, 1981).

In this way it is possible to assess the quantity of types of litter that would be difficult to assess in any other way (Dixon & Dixon, 1981). Although having these numerous advantages, this type of survey has its flaws. Dixon and Dixon (1981) referred that beach surveys gives a distorted picture of the composition of marine litter, because each type of litter has its own characteristics, which means that some litter tends to accumulate on beaches whilst other types degrade more easily, never reaching the beaches. This can cause an underestimation of the surveyed litter.

Many different beach methodologies have been used, ranging from different types of transects (e.g. Rosevelt et al., 2013; Frost & Cullen, 1997), to the identification of specific (e.g. Martins & Sobral, 2011; Wright et al., 2013) and/or all types of litter (e.g. Moore et al., 2001). This causes an incompatibility problem since the results with different methodologies can hardly be compared (OSPAR, 2010). Taking into consideration, programs have been created to try to unite countries regarding this matter and to try to create a single methodology that can effectively enable comparison of the results.

OSPAR, the Convention for the Protection of the marine Environment of the North-East Atlantic, is a conventiom to which Portugal is a signatory country. Under this framework the signatory parts have the obligation to fight and prevent the pollution, as well as to protect the seas against the human activities. The convention released a guideline for monitoring litter that was tested in OSPAR Pilot Project 2000-2006 (OSPAR, 2010). This was an important step to survey and monitor marine litter, guiding the North-East Atlantic countries in monitoring of marine litter of MSFD.

Given the importance of monitoring marine litter, and the fact that the Portuguese coastline is vulnerable to the accumulation of plastic (Martins & Sobral, 2011) and possibly to other types of litter, it is important to analyze the influence of the different types and characteristics of the coastline in the abundance of marine litter. This is the fundamental objective of the present study, since the purpose was to analyze the main patterns of occurrence throughout the year, in coastal areas with different characteristics, aiming to provide recommendation for monitoring plans design.

Chapter 2: Relationships between marine litter and type of coastal area: implications for the design of monitoring plans

2.1. Introduction

In recent years, marine litter has become an extremely important issue that has promoted studies with the purpose of understanding the effects of marine debris in organisms and to assess the damages in the marine ecosystem, at a short and a medium term. This problem has been neglected for a long time as a result of the common practice of ocean dumping. In the past decades, this practice was not so harmful because the residues then were biodegradable (Sheavly & Register, 2007), contrary to today. It was the aesthetic aspect that initially brought the attention of the scientific community and general public (Gregory 2009).

Marine debris has been defined as items that were made and used by people and that were deliberately discarded into the rivers, sea or on beaches; that were brought indirectly to the sea with sewage, rivers, winds or storm water, that were accidentally lost (including material lost at sea in bad weather) or that were deliberately left by people on beaches and shores (UNEP, 2009). It is estimated that 8 million items are being dumped, every day, in oceans and seas, accumulating 6.4 million tons per year (www.unep.org/regionalseas/marinelitter - accessed 28/09/2015, 22:07; www.ospar.org – accessed 28/09/2015, 22:23).

Marine litter can originate from two major sources: the ocean-based sources and land-based sources. The ocean-based sources are all the activities that take place at sea, such as merchant shipping, ferries and cruise liners, including fishing and aquaculture. Litter from all the land-based sources come from coastal or inland areas, as well as from rivers or other water bodies (UNEP, 2009). However, whichever the source, marine litter can have various impacts on the environment. Serious impacts on wildlife have been reported, such as entanglement of many marine species, which is a serious mortality factor (Gregory, 1999; Galgani *et al.*, 2010). The accidental ingestion of plastic that mimic prey causes serious injuries (in special the ingestion of microplastics) and the consequent entry and input on the food chain of Persistent Organic Pollutants (POP) and other chemicals (Katsanevakis *et al.*, 2007; Martins & Sobral, 2011). The dispersion and the spread of invasive alien species caused by floating debris and the accumulation of litter on the seabed are also of concern. This accumulation, sometimes in large quantities, changes the local biotope characteristics, affecting the benthic communities and consequently the mobile communities that depend on them (Sheavly & Register, 2007; Martins & Sobral, 2011). Besides all the impacts to the wildlife, marine litter is also a serious problem regarding the presence of medical and hygiene wastes that are not retained in the treatment system of wastewater, which represents a risk to public health (Sheavly & Register, 2007). Tourism is also very affected by this problem, which leads to economic losses, especially due to beach cleaning activities of the bathing areas (Corbin & Singh, 1993; Galgani *et al*., 1995; Sheavly & Register, 2007).

The type and abundance of marine litter found on the coastline depends on several factors, among which are the proximity to urban and industrial centres, the circulation patterns of the oceanic currents and the shipping routes (Sheavly & Register, 2007). The coastal waters are the most critical areas regarding this problem. According to Dixon & Dixon (1981), the composition of marine litter is also more variable closer to the shore, because coastal waters are normally shallower, directly affected by the river flows (Holdgate & McIntosh, 1986) and because they have the pressure from urban and industrial centres (Santos *et al*., 2005).

Marine litter can be classified into several categories: plastic; wood; medical and sanitary waste; clothes; metal, glass and paper. The majority of studies shows that the major type of residues is plastic, that have many forms and sizes (Derraik, 2002). Due to their abundance (Rees & Pond, 1995) and non-degradable nature (Laist, 1987), plastics deserve a special attention, since these properties enhance the severity of its impacts. Considering the widespread distribution of litter (e.g. Carpenter & Smith Jr.., 1972; Dixon & Cooke, 1977) and the need to protect and conserve the marine environment, a series of conventions and initiatives at an international level was triggered. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention), signed in 1972, was the first international convention for the protection of the marine environment from human activities. The aim of this convention was to promote the control of all sources of marine pollution and the prevention of pollution by dumping of wastes and other materials in the sea (www.imo.org,- accessed 11/08/2015, 10h50). The International Convention for the Prevention of Pollution from Ships (MARPOL), adopted in 1973, is the main international convention that covers marine pollution by ships. Its Annex V (Prevention of Pollution by Garbage from Ships) defines the different types of litter whose discharged is prohibit and specifies the distances to the coast and the methods used to dispose of residues. (www.imo.org – accessed 11/08/2015, 17h10).

At the regional level, the Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention), was signed in 1974 and it is governed by the Baltic Marine Environment Protection Commission (HELCOM). It has the purpose of protecting the marine environment from all types of pollution (www.helcom.fi - accessed 10/08/2015, 13h12). The Mediterranean Countries adopted, in 1976, the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). Among the various objectives, this convention aims to assess and control marine pollution (http://www.unepmap.org – accessed 10/08/2015, 14h00).

A mechanism to approach marine litter problems was created, in 1992, through the establishment of a cooperation between fifteen Governments and the European Union to cooperate in the protection of the marine environment of the North-East Atlantic. It is the result of the union of the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircrafts (Oslo Convention, 1974) and the Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris Convention, 1978) (Galgani *et al*. 2010; www.ospar.org – accessed 5/07/2015, 10h48). The signatory parts of OSPAR (Convention for the Protection of the marine Environment of the North-East Atlantic) have the obligation to fight and prevent the pollution, as well as protect the seas against the human activities (http://www.dgrm.mam.gov.pt – accessed 05/07/2015, 11h40; http://www.ospar.org – accessed 05/07/2015, 12h01). The United Nations Environment Programme (UNEP) was created as a global environmental authority that promotes the implementation of the environmental dimension of sustainable development within the United Nations system, acting as an authoritative advocate for the global environment (http://www.unep.org - accessed 05/07/2015, 14h56).

Considering that the most effective measure to reduce marine litter is to find the source and reduce it (Gilligan *et al.*, 1992; Cullen & Frost, 1997; Earll *et al.*, 2000; Williams & Tudor, 2001; Cunningham & Wilson, 2003; Santos *et al.*, 2005; Araújo *et al.*, 2006; Araújo & Costa, 2007), linking the marine debris to their source is an extremely difficult task that can only be achieved with monitoring actions. Thus, marine litter is one of the descriptors of the Marine Strategy Framework Directive (MSFD), which is fundamental to achieve the good environmental status of marine waters until 2020 (Directive 2008/56/CE; Galgani et al., 2013). This descriptor is referred as Properties and quantities of marine litter do not cause harm to the coastal and marine environments. One of the steps to characterize it is assessing the trends in amount of litter washed ashore and/or deposited on coastlines (Galgani *et al.*, 2013).

There have been multiple monitoring studies with the purpose of assessing marine litter, wherein beach surveys have been the most chosen methodology to assess coastline (Ribic, 1990; Ribic *et al*., 1992). This method allows a reproducible and representative sample (Cunningham & Wilson, 2003), guaranteeing a large amount of samples at a minimum cost, since the equipment required is minimal. These surveys can also be performed virtually under any weather conditions (Rees & Pond, 1995; Cuomo *et al*., 1998) and it is a place that tends to accumulate several objects that come from different sources, through the action of winds, waves and currents (Martinez-Ribes *et al*., 2007). Despite these numerous advantages, this method also has some disadvantages, like the underestimate of the amounts of debris, since not all litter items reach the shore (Dixon & Dixon, 1981). The data collected on beach surveys can also be considered non representative of the condition of the coastline, because the choice of beaches depends on its easy access (Rees & Pond, 1995).

Because the quantity of debris on a beach depends on debris characteristics, beach dynamics, weather conditions, oceanic circulation patterns, beach cleaning and the offshore recreation and commercial practices, there are different sampling strategies accordingly to the various types and sizes of debris (Rees & Pond 1995). Gilligan *et al*. (1992) surveyed the litter in all the length of the surveyed sites, from the low tide line to the high tide line. Frost & Cullen (1997) established 5 transects with a width of 10m, from the low tide line to the vegetation line, separated 10m from each other. Valender & Mocogni (1998) assessed marine litter within the 5 main strand lines that are formed as the tide recedes. Debrot *et al*. (1999) also surveyed transects that were placed in the middle of the beach, with a width of 8.5 to 150m. Cunningham & Wilson (2003) established 27 parallel to the shoreline transects of 5m width and Araújo *et al*. (2006) used 4 transects of 50m width, placed from the low tide line to the vegetation line. Araújo *et al*. (2007) observed the entire study area by walking along the shoreline, starting the survey two hours before low tide. Ribic *et al*. (2010) sampled 500m and Topçu *et al*. (2012) placed 2m width transects parallel to the coast. Finally, Rosevelt *et al*. (2013) established 2 transects against the wrack line, separated by 5m. Given the variability of each site features, the methodologies applied varied relative to the extension of the sampling area and the way marine debris was surveyed (Quintela *et al*., 2012).

Considering the non-comparability of the results obtained in many of the previous studies, in 2010, OSPAR published Guidelines for Monitoring Beach Litter, as a formal monitoring instrument (Galgani *et al*., 2010), based on a pilot project. This instrument was delineated to generate data on marine litter, following a standardized methodology, ensuring a practical and cost-effective way to conduct monitoring. The selection of the beaches should take into account that beaches should be composed by sand or gravel, as well as being exposed to the open sea; be of easy access to the removal of litter and be accessible all year round; have a minimal length of 100m or over 1km, be free of buildings all year round and, ideally, should not be subject to other litter cleaning activities. However, in this document it is also noted that each coastal area has its own characteristics and that this protocol should be adjusted if necessary (OSPAR, 2010). According to OSPAR, the researchers should choose one of the survey lengths (100m or 1km). If the chosen one was the 100m survey, all the surveyed litter has to be removed from the site and, in case it is large object, it should be marked to avoid being surveyed again. This guideline recommended that the surveys should be done four times per year, according to the seasons and also provided a survey form, a multilingual photo guide, a photo guide for regional and unusual items and a practical field photo guide to assist the fieldwork.

The OSPAR Pilot Project on Monitoring Marine Beach Litter (2007) was the first region-wide project in Europe to develop a unique methodology for monitoring the debris on North-East Atlantic beaches (Galgani *et al.*, 2010). This study presented the results of the types and amount of litter surveyed in six years, including the description of indicator items that could correspond to a specific source. Although this study has showed that the Iberian coast did not register as much litter as the northern regions, it was registered that Portugal has canyons with large quantities of litter (Mordecai *et al*., 2011), despite being as distant as is the case of the seamount in Açores (Pham *et al*., 2013). Martins & Sobral (2011) also referred the vulnerability of the coast of Portugal to plastic accumulation on beaches (both from land and marine sources). Therefore, Portugal is no exception regarding the influence of marine litter and it is important to monitoring this problem. As such, the purpose of this work is to relate the presence of marine litter with some coastal characteristics, in order to analyze how this relationship influences the monitoring that should exist within the scope of Marine Strategy Framework Directive (following the methodology of OSPAR) and assess the main origins of the surveyed litter.

2.2. Material and Methods

2.2.1. Study Area

In order to assess the type and amount of marine litter, beach surveys were conducted, similar to what has been done in several other studies (e.g. Frost & Cullen, 1997; Cunningham & Wilson, 2003; Araújo *et al*., 2007; Ribic *et al*., 2010; Topçu *et al*., 2012; Rosevelt *et al*., 2013). These surveys have been accepted as the best cost-effective methodology to study marine litter (Rees & Pond, 1995) because of the simple logistic involved and because beaches allow accumulation of litter that does not float. Considering the importance of relating the amount of marine litter with some characteristics of the coast, eleven beaches (Figure 1) were randomly chosen and surveyed.

Almost all surveyed beaches had sandy substrate and they all are highly frequented in the summer. Santo Amaro, Carcavelos, Sesimbra, Portinho da Arrábida and Figueirnha are facing south, while São Lourenço, Maçãs, Grande, Castelo and Fonte da Telha are facing West. São Lourenço, Maçãs, São João, Castelo and Fonte da Telha have North/Northeast prevailing winds, while the others had Northeast as prevailing winds (APA, 2013). Two beaches belong to the Arrábida Marine Protected Area, which highlights the importance of marine conservation. The selected beaches also presented the recommended characteristics by OSPAR to monitor the marine litter (Guideline for Monitoring Marine Litter on the Beaches of the OSPAR Maritime Area, 2010).

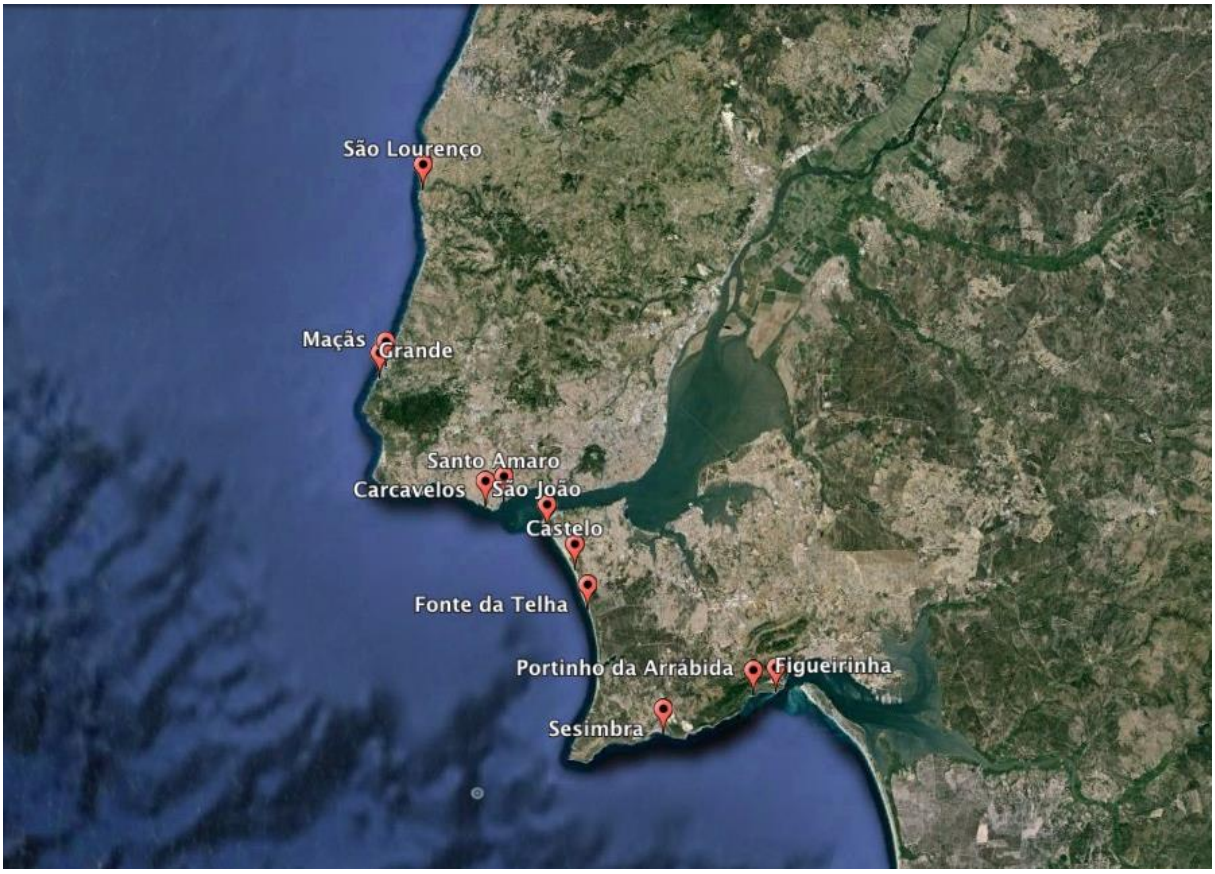

Figure 1 - Surveyed beaches in this study: São Lourenço (39º0’43.87”N; 9º25’15.88”W), Maçãs (38º49’31.44”N; 9º28’10.93”W), Grande (38º48’49.18”N; 9º28’40.29”W), Carcavelos (38º40’44.67”N; 9º20’10.55”W), Santo Amaro (38º41’5.45”N;9º18’37.26”W); São João (38º39’30.79”N; 9º15’8.31”W), Castelo (38º36’49.44”N; 9º12’59.05”W), Fonte da Telha (38º34’23.23”N; 9º11’43.94”W); Sesimbra (38º26’32.31”N; 9º5’55.42”W), Portinho da Arrábida (38º28’49.23”N; 8º58’45.84”W) and Figueirinha (38º29’2.38”N; 8º56’40.50”W

Since the type and abundance of marine litter are influenced by the morphology and topography of the beach (Valender & Mocogni, 1999), a good classification of the surveyed sites allows a better understanding of the litter present in the coast. Considering this, the surveyed beaches were characterized according to length, substrate, slope, distance do estuary and urbanization, as shown in Table 1. For such characterization, it was used information of the “Perfil de Água Balnear do Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território”. The features slope and distance to the estuary were defined, through comparison between the surveyed sites, since the purpose was to classify the beaches in groups.

Table 1 – Characteristics of surveyed beaches

Beach	Length (m)	Substrate	Slope	Distance to estuary	Urbanization
S. Lourenço	330	Coarse Sand	High	Far	Non-Urban
Maçãs	200	Sand	Medium	Far	Urban
Praia Grande	600	Sand	Shallow	Far	Non-Urban
Carcavelos	1250	Sand	Shallow	Close	Urban
Sto. Amaro	700	Sand	Shallow	Close	Urban
S. João da Caparica	1360	Sand	Shallow	Close	Non-Urban
Castelo	420	Sand	Shallow	Close	Non-Urban
Fonte da Telha	7253	Sand	Medium	Medium	Non-Urban
Sesimbra	1000	Sand	Shallow	Medium	Urban
Figueirinha	600	Sand	Medium	Close	Non-Urban
Portinho da Arrábida	690	Gravel and Sand	Shallow	Close	Non-Urban

The sampling scheme followed in this study was adopted from OSPAR. Transects were used to survey the beaches, as done in multiple studies such as Thornton & Jackson (1998) and Williams & Simmons (1999). The three transects were placed in the centre of the beaches, separated by 50 m, from the low tide line to the vegetation line. The placement of these transects was recorded by photograph in order to assure that the same stretch of the beach was consistently surveyed during the study period. Each transect was marked by a nylon cable of 4/5mm thickness and distance was measured with a measuring tape. It is important to notice that each beach had different widths and that, in order to be possible to compare the amount and type of litter present in the different zones of the beach (low tide line, high tide line and vegetation line), it was necessary to divide each transect into areas of twenty square meters (10 m x 2 m). These areas were marked directly in sand and this scheme is represented in Figure 2.

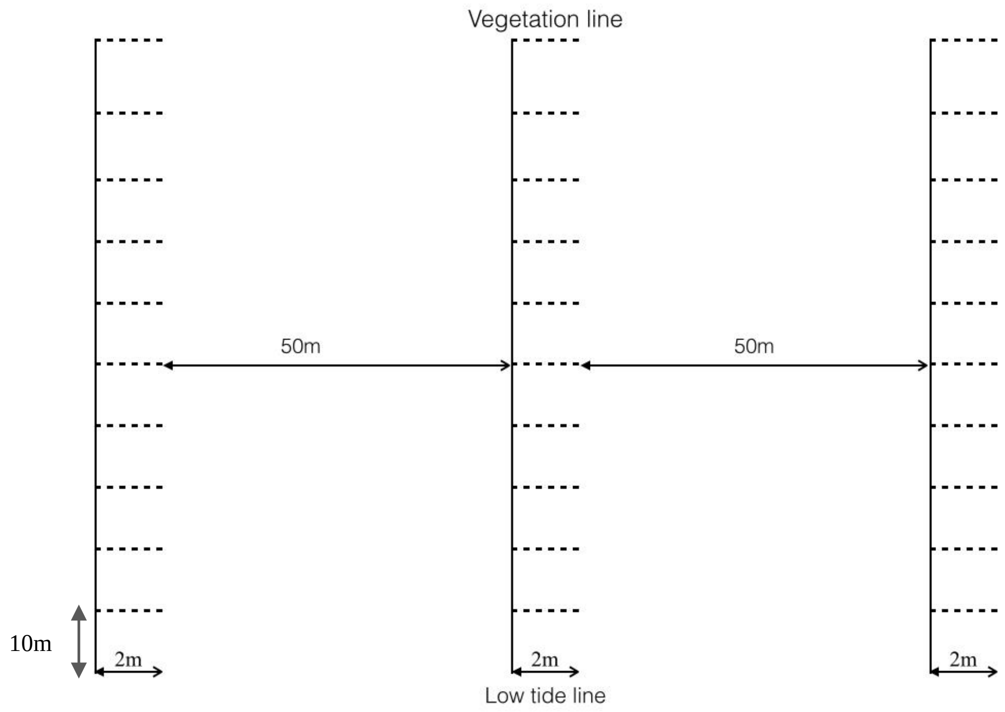

Figure 2 - Survey's scheme representing the three transects (distanced by 50m each), established from the low tide to the vegetation line. Each transect was divided into squares of 10x2m.

The fieldwork consisted in scraping the sand with a rake, covered with a 5 mm mesh in order to retain the smaller objects, in each area, in order to collect the litter in the surface as well as the litter buried in the shallow sand. The buried litter was considered important since it is significant and has to be considered for a more correct analysis and monitoring of the marine litter in beaches (Kusui & Noda, 2003). The litter was collected and stored for later analysis in the laboratory, following the Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (2010).

With the purpose of sampling the maximum area possible, the surveys were conducted on days with equinoctial tides, according to the methodology of Frost & Cullen (1997) and Rosevelt *et al*. (2013).The beaches were also sampled one hour and a half before the low tide, since this time was enough to cover all the extension of the selected beaches. The surveys were conducted quarterly from September, 2014, to June, 2015.

The OSPAR Marine Litter Monitoring Survey Form was followed in order to identify and register the type of debris. However, after the survey trial it was verified that some amendments to the survey form were necessary. The category plastic/polystyrene pieces (0-2.5 cm; 2.5-50 cm and >50 cm) was separated into two different categories due to the high number of individual polystyrene pieces encountered, which could influence the final results. Considering its relevance in recent marine litter studies (Carpenter & Smith Jr., 1972; Andrady, 2011; Claessens *et al*., 2011) and because a high number of this type of item was recorded during the trial survey, the category pellets was added to the list of marine debris. Thus, the material required for this work was three nylon cables; two rakes with a net covering of 2x2 mm; plastic bags to collect the litter items; labels to identify the bags, gloves to catch the litter and a measuring tape.

2.2.2. Sampling method

To assess the influence of the characteristics of beaches and season in the marine litter recorded, a permutational multivariate ANOVA (PERMANOVA) was done (using the program Primer 6 version 6.1.13 & Permanova + version 1.0.3). The data was transformed using a square root transformation, so that the results were not influenced by the dominant or rare categories. A resemblance matrix was built using Bray-Curtis similarity (Mckinley *et al*., 2011; Castro *et al*., 2013;). If PERMANOVA showed significant effects, pair-wise tests were carried out, among all factors. A SIMPER test was made to identify the types of litter responsible for the significant differences among beaches and seasons. A PCO was made to visualize the relationship between litter and the beach characteristics. All this analysis were done using the Primer 6 version 6.1.13 & Permanova + version 1.0.3.Sesimbra and Grande beaches were withdrawal of the analysis for Winter and Spring for having too many null values that affected the results.

Considering that tackling the source is probably the most important outcome of monitoring marine litter, in order to identify possible sources of the litter surveyed in this study, indicator objects for land and marine activities were used. The objective was to find some specific type of litter that could be considered an indicator, representing possible sources for marine litter. To consider a litter item as a marine litter indicator, the items should be typical for the source it represents, common and frequent in the survey area and easy to identify, find and count (OSPAR, 2007).

First, for each beach and each season, the most abundant type of litter was determined. Thereafter, this type was identified as having either a terrestrial or a marine origin, following the methodology of Silva-Iñinguez *et al.* (2003). When the items had a doubtful origin, they were designated as having mixed origin. After this general characterization, general and specific indicators were identified, with the purpose of assessing the origin of the litter surveyed. These indicators were established following the criteria of OSPAR (OSPAR Pilot Project on Monitoring Marine Beach Litter - Monitoring of marine litter in the OSPAR region, 2007), taking into account the information from Ribic *et al.* (1998). This characterization was done based on the three most abundant types of debris found on each beach and at each season. The litter that was more represented in a particular beach and that was an important indicator of the origin, was also taken into account. .If some type of litter was not dominant but it was distinctive of a specific beach, it was also taken into account.

2.3. Results

A total of 7 743 items belonging to eleven litter categories were collected from all beaches (0.55 item m^{-2}). Plastic, paper and sanitary waste were the predominant types of litter in this study, with plastic as the most abundant item (Table 2). The litter showed a clear spatial pattern whereas the high tide line was the one with more litter, with a total of 4 783 items (2.3 items m^{-2}), followed by the vegetation line, with 1 681 items (1,50 items m^{-2}) and by the low tide line, with 1 279 items (0.58 items m^{-2}) (Table 3). Only the low and high tide lines had statistical significant differences ($H (2, N=33)=6.2494$; $p=0.044$)), with a p-value of 0.048. The amount of litter was higher in the autumn season (4569 items), followed by winter (2269 items) and spring (905 items).

Of the 11 surveyed beaches, Maçãs was the one with a higher number of marine of litter (3 483 items), followed by Carcavelos (987 items). São Lourenço and Sesimbra were the beaches with less litter registered (201 and 113 items, respectively).

Maçãs had the greatest amount of plastic (2817 items) and sanitary waste (382 items), whereas Santo Amaro had the greatest amount of paper (327 items) and presented the highest diversity of types of litter, along with Fonte da Telha (Table 2).

Table 2 – Number of items of each type of litter collected in each beach

	Plastic	**Rubber**	**Cloth**	**Paper**	**Glass**	**Sanitary Waste**	**Medical Waste**	**Wood**	**Metal**	**Pottery**	**Other Pollutants**
São Lourenço	118	0	0	60	5	6	0	0	7	0	5
Maçãs	2817	6	4	228	17	382	7	12	12	0	10
Grande	390	0	0	3	0	9	0	0	0	0	1
Carcavelos	644	0	0	195	2	133	6	2	4	0	1
Santo Amaro	194	2	3	327	2	35	2	5	20	1	4
São João	285	4	0	50	1	39	4	2	2	0	0
Castelo	185	1	0	41	1	26	3	0	4	0	0
Fonte da Telha	242	1	1	176	7	26	2	4	5	2	1
Califórnia	96	0	0	8	3	4	1	1	0	0	0
Portinho da Arrábida	457	1	0	35	14	23	2	3	6	16	4
Figueirinha	138	0	1	141	4	24	1	4	10	2	0
Total	5566	15	9	1264	56	707	28	33	70	21	26

Table 3 - Number of items of marine litter found in each beach zone (low tide line, high tide line and vegetation line)

	Low tide line	High tide line	Vegetation line
Fonte da Telha	35	303	129
Figueirinha	139	144	42
Portinho da Arrábida	59	374	108
Sesimbra	2	2	109
São João	31	68	288
Castelo	39	94	128
Santo Amaro	162	317	116
Carcavelos	97	584	274
Maçãs	676	2642	177
São Lourenço	34	102	65
Grande	5	153	245

The PERMANOVA results show that both the beaches (Pseudo-F = 7.675, p = 0.001) and the seasons (Pseudo-F = 8.281, p = 0.001) have an influence in the amount of litter found (Table 4). Regarding the seasonal variation, there were significant differences between the amount of litter in all the seasons ($p<0.05$), as presented in Table 4. The majority of beaches, when compared with each other, showed significant differences in the amount of the surveyed litter ($p<0.05$). However, there were some exceptions: Fonte da Telha showed no significant differences with Figueirinha (p=0.104), São João ($p<0.115$), Castelo (p=0.063) and Santo Amaro (p=0.063); Figueirinha showed no significant differences with Sesimbra (p=0.075), Castelo (p=0.115) and Portinho da Arrábida (p=0.051); Portinho da Arrábida showed no significant differences with Grande (p=0.166); Sesimbra showed no significant differences with Castelo (p=0.119) and Grande (p=0.061); São João showed no significant differences with Castelo (p=0.889). To Fonte da Telha, Figueirinha, Sesimbra, São João, Castelo and Santo Amaro, the amount of litter showed seasonal homogeneity (Table 5). Autumn was significantly different from winter (p=0.027) and winter was significantly different from spring (p=0.039) in Portinho da Arrábida. Autumn was significantly different from spring and winter from spring in all the other beaches: Carcavelos (p=0.011; p=0.017), Maçãs (p=0.003; p=0.045) and São Lourenço (p=0.017; p=0.033) (Table 6).

Table 4 - Results of the PERMANOVA analysis made to compare the amount of litter for the categories beach and season

Source	df	SS	MS	Pseudo-F	P (perm)	Unique perms	P (MC)
Be	10	43321	4332.1	7.675	**0.001**	998	0.001
Se	2	9348.3	4674.2	8.281	**0.001**	998	0.001
BexSe**	17	28170	1657.1	2.9358	**0.001**	998	0.001
Res	60	33867	564.44				
Total	89	1.1586E5					

Table 5 – Results from PERMANOVA analysis, showing which seasons are significantly different ($p<0.05$)

	São Lourenço	Maçãs	Grande	Carcavelos	Santo Amaro	São João	Castelo	Fonte da Telha	Sesimbra	Figueirinha
Maçãs	**0.001**									
Grande	**0.002**	**0.001**								
Carcavelos	**0.001**	**0.001**	**0.042**							
Santo Amaro	**0.001**	**0.001**	**0.005**	**0.002**						
São João	**0.001**	**0.001**	**0.017**	**0.01**	**0.001**					
Castelo	**0.006**	**0.001**	**0.012**	**0.001**	**0.001**	0.889				
Fonte da Telha	**0.006**	**0.001**	**0.008**	**0.038**	0.063	0.115	0.063			
Sesimbra	**0.017**	**0.001**	0.061	**0.002**	**0.001**	0.052	0.119	**0.004**		
Figueirinha	**0.044**	**0.001**	**0.005**	**0.003**	**0.015**	**0.038**	0.115	0.104	0.075	
Portinho da Arrábida	**0.009**	**0.001**	0.166	**0.002**	**0.001**	**0.004**	**0.007**	**0.005**	**0.006**	0.051

Table 6 - Table 7 - Results of PERMANOVA made for autumn, spring and winter

Groups	t	P (perm)	Unique perms	P (MC)
Autumn, Winter	2.1051	**0.001**	998	0.002
Autumn, Spring	4.0109	**0.001**	998	0.001
Winter, Spring	2.1634	**0.004**	999	0.006

The results of the Simper test revealed that the most different beaches, with the higher average dissimilarity value, were Sesimbra and Maçãs (72,05%), Maçãs and São Lourenço (66.28%) and Figueirinha e Maçãs (63.08%). The beaches with the lowest average dissimilarity were São João and Castelo (32,62%) (Table 7). The main type of litter responsible for the dissimilarity in the surveyed beaches was plastic, with the exception of Fonte da Telha, São João and Castelo, in which paper was the main reason of dissimilarity. Regarding the seasonal variability, plastic was the major responsible for the dissimilarities between seasons.

Table 8 - Dissimilarity average between the beaches that were significantly different in Table 5.

	São Lourenço	**Maçãs**	**Grande**	**Carcavelos**	**Santo Amaro**	**São João**	**Castelo**	**Fonte da Telha**	**Sesimbra**	**Figueirinha**
Maçãs	**66.28**									
Grande	56.38	38.66								
Carcavelos	50.59	42.61	39.35							
Santo Amaro	46.61	52.95	53.65	39.95						
São João	45.81	54.12	41.52	40.77	41.09					
Castelo	41.19	57.49	43.55	42.02	41.18					
Fonte da Telha	41.97	52.61	44.75	38.38						
Sesimbra	52.29	**72.05**		60.75	62.28			54.68		
Figueirinha	47.48	**63.08**	56.5	49.93	43.18	45.13				
Portinho da Arrábida	53.26	61.88		54.31	54.62	51.15	49.59	49.2	58.84	

The PCO analysis does not show a very clear separation between beaches. PCO axis 1 explained 39.4% of total variation inherent in the resemble matrix, and slightly separated Maçãs from the bulk of the other beaches. PCO axis 2 explained 16.7% of total variation. This analysis explains 56.1% of total variation. It is possible to observe that urbanization is negatively correlated with PCO1, and that distance to estuary, length, slope and substrate are positively correlated with PCO1. Maçãs showed a relation with the variable urbanization (Figure 3).

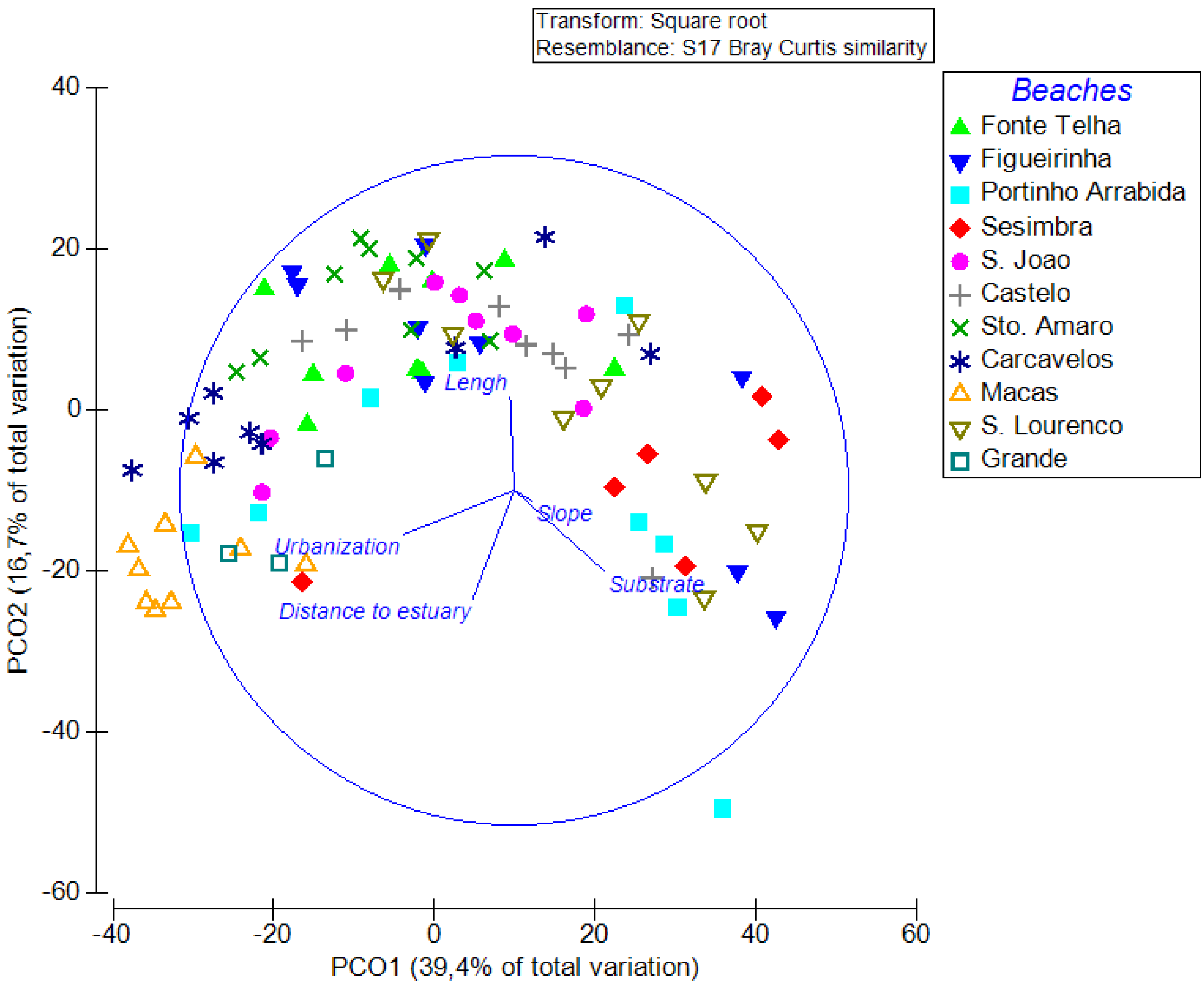

Figure 3 - PCO for the amount of litter found in each beach and it's relation to the characteristics of the beaches: urbanization, distance to estuary, length, slope and type of substrate.

Regarding the sources of marine litter, the majority of items was considered to have mixed origin, since the most abundant type of debris was plastic and polystyrene pieces (0-25cm). In autumn, litter collected on the beaches of Portinho da Arrábida and Sesimbra were identified as having marine origin (since pellets were the most common item). In winter, litter found in Santo Amaro was considered of land based origin, since the main litter item was cigarette butts. Maçãs's litter was considered of marine origin (main type was pellets). It is important to point out that the litter found in Fonte da Telha, Portinho da Arrábida, São João, Castelo, Carcavelos and Grande had land-based origin, due to the presence of cigarette butts found, that were related to beachgoers and the presence of restaurats.

It is important to point out that with the exception of Sesimbra a lot of debris was from land-based origin, including the amount of cotton bud sticks found in all beaches,.

The majority of cigarette butts was found in the last squares, what can be due to beachgoers. Maçãs was the site where the largest amount of fisheries and aquaculture related waste was recorded, since a large number of fish boxes, rope (with a diameter bigger than 1cm), string and cord (diameter less than 1cm), nets and pieces of net < 50cm and light sticks (tubes with fluid) was collected from this beach. Figueirinha, where a large number of stripping bands was found, had a considerable amount of litter from shipping, including offshore activities

2.4. Discussion

The purpose of this work was to relate the presence of marine litter with some coast characteristics, in order to understand how this relationship influences the monitoring that should exist within the scope of Marine Strategy Framework Directive (following the methodology of OSPAR) and assess the main origins of the surveyed litter.

The amount of litter found along the coastline was inferior to the values of litter registered in other studies, as registered by Silva-Iñinguez *et al*. (2013), 1.52 items m2, and it was superior to others studies such as Smith & Markic (2013), with 0.24 items m2. The surveyed sites in this study suffered the influence of Tejo and Sado estuaries which, according to Vasconcelos *et al*. (2007), are subject to high pressure, with Tejo being more affected by population and industry and Sado, from port activities and resource exploitation. Tejo also has the port of Lisboa, which is the second largest port in Portugal (Vasconcelos *et al*., 2007), which has a strong influence in the pollution verified. Considering these characteristics, it was expected that the beaches closer to the estuaries had more litter than the others (Araújo & Costa, 2007).

In general, the group of beaches that were classified as far from the estuary, that included three beaches (Maçãs, São Lourenço and Grande), revealead a higher abundance of litter than the group of the remaining six beaches (Figueirinha, Portinho da Arrábida, São João, Castelo, Santo Amaro and Carcavelos) classified as closer to estuaries. This result can only be explained by the high amount of litter found on Maçãs since, if Maçãs was removed from the analysis, the group of beaches closer to the estuary would have more debris, as expected. However, there is not an explanation for Maçãs to have more debris than the beaches closer to estuaries, such as Carcavelos because, even with Colares stream reaching the sea next to Maçãs beach, the beaches closer to estuaries should have more litter. Two possible explanations could be the behaviour of the beachgoers and the fact that the other beaches, due to their proximity to a large urban tourist centre, like Cascais, are cleaned more regularly contributing to minimizing the accumulation of marine litter. Another possible explanation can be simply because Maçãs is located in the West coast, more exposed to prevailing winds that come from North and to wave influence (Instituto Hidrográfico, 2013). Sesimbra and Grande were interesting cases because both of them did not have litter in winter and, in spring, low amounts of litter were recorded.

The beaches that were considered urban were expected to have more litter than the non-urban (Ariza *et al*., 2008). This was verified in Maçãs, Carcavelos and Santo Amaro. Sesimbra beach was an exception since, although it was classified as urban, it was the one with less abundance of marine litter. This can be due to Sesimbra having a smaller width, when compared to the others, which implies that the litter does not have time to accumulate on the beach, due to influence of the tides.

Determining the source of debris was extremely difficult because all beaches had almost all types of litter, which meant all types of origin. So, in general, the majority of litter was designated as mixed origin. However, it was possible to identify the specific sources of the most common litter in some beaches. In Sesimbra (autumn) and Maçãs (winter), the source of litter was identified as marine origin, which could mean that, in these sites, there is a high influence of ocean currents or winds. On the contrary, Santo Amaro's litter (winter) was identified as land origin, which demonstrates a clear terrestrial influence, mainly from the beachgoers. It is interesting to notice that, the source of litter found in Portinho da Arrábida, varied according to the season. In winter, it was identified as marine origin and in autumn as land origin. This could mean that this beach may be more influenced by winds and/or currents in winter that in autumn, bringing during this season the litter from marine origin. A great number of cotton buds was collected in almost all beaches, which shows that as in other countries (e.g. Moore *et al.*, 2001; Santos *et al*., 2005), this is a problem, and the same happens with the presence of medical waste. This is worrying since syringes and medication packages found, can cause injuries in beach goers and, ultimately, represent a risk to human health. Plastic was the most abundant item, as in other studies (*e.g*. Santos et al.,2009; Gago et al.,2014)..

It was not possible to obtain a good relationship between the surveyed litter and the beach characteristics. This lack of relation can be due to the homogeneity of the surveyed litter. The only identifiable pattern was Maçãs that showed a clear separation from the other beaches. Maçãs was also related to the urban occupation, which corresponds to its characterization as an urban beach.

It is important to notice that, as expected, a spatial pattern along the coastline was observed. The high tide line was expected to have more litter, as well as the vegetation tide line, due to the fact that in the first case the tide tends to bring the litter to the beach (Valender & Mocogni, 1999) and in the second ,because the vegetation usually traps and retain debris (Araújo & Costa, 2007).

The seasonal variability observed in the abundance of marine debris on beaches was not in agreement with the expected one since it was expected to collect more litter in winter due to the periods of heavy seas, storms and rain, as registered by Ribic *et al*. (2010). The higher abundance of litter during autumn may be a consequence of the exceptional good weather conditions that were registered in the autumn if 2014, which brought beachgoers to visit the beach, when the cleaning operations were not so common.

It is important to notice that despite the recommendations of OSPAR, the surveyed beaches were cleaned by the municipality during the time of the experience. However, this situation was minimized by the fact that, in the period of the surveys, the beaches were only cleaned sporadically. Also, if there was evidence that the beach had been clean, the sampling was carried out on another day. In this way, it was guaranteed that the beaches were not surveyed in the same day that were cleaned.

There are also some aspects related to the methodology chosen to survey the beaches, *i.e.*, the width and number of transects, that need to be discussed. Several studies have used transects wider than the ones used in the present study, as was the case of Debrot *et al.* (1999), who used a 8.5 to 150 m width transect, as Kusui & Noda (2003) with 10 m width transect and as Bravo *et al*. (2009), with 3 m width transects. In the case of Araújo *et al*. (2006), it was demonstrated that it was necessary to have a transect with minimum 20 m width to qualitatively characterize the plastic items. Despite Araújo *et al*. (2006) study focused on plastics, their results may be applied to other types of litter. As for the number of the transects, although this study had only three, Valender & Mocogni (1999) showed that for a medium panorama evaluation 10 transects would be acceptable, from the vegetation line to shoreline. Despite all of this, the methodology of this study was adopted because there were only two investigators and, if there were more and wider transects, the effort would be enormous.

It is also important to notice that as demonstrated by Williams & Tudor (2001), the beaches have the capacity to bury the debris. Therefore it is necessary to be cautious about this study's results since the litter that was considered as a new input could only be buried and for some reason have been unearthed (due to tides or winds). So it is relevant to bear in mind that beach surveys do not give a full representation of the marine litter (Thiel *et al*., 2013), being important to relate this study's findings with others, such as the one made by Mordecai *et al*., 2011, in submarine canyons.

As UNEP (2009) referred, there has been a lack of political commitment regarding this problem. Therefore, more political efforts must be done, as well as a more involvement of the population in this matter is very important, in order to raise awareness to the fact that marine litter is a global problem, and not just a regional one, and that the sea is a valuable natural and economic resource that needs to be protected.

With this study, despite the lack of a clear relation between the characteristics of the beaches and the amount of litter collected, it was possible to identify some of the origins for the litter present in the coastline. It is important, in future studies, to relate the litter distribution with the different types of marine litter transports vectors (such as winds and currents). It is also important to understand how atmospheric conditions influence the amount and distribution of litter in the coastline.

Chapter 3: Final Remarks

The purpose of this work was to relate the different characteristics of coastal areas with the occurrence of marine litter and to learn the implications for the design of monitoring plans. Plastic, paper and sanitary waste were the predominant types of debris found in the study area. In general, the main items were plastic (0-2.5cm), polystyrene (0- 2.5cm) and cigarette butts, also considering the high number of cotton bud sticks collected. The high amount of the last items, demonstrates that it is necessary to educate the population and evaluate the flaw in the water waste treatment, in order to find a practical way of stopping the cotton bud sticks to enter the sea.

Regarding the sources of the marine debris collected, the majority was considered as having a mixed origin. However, the litter identified as having a land origin was mainly due to the beachgoers and the litter identified as having a marine origin was mainly due to the item pellets, which can originate from spillage of cargo in oceanic waters, during transportation.

Maçãs was the beach with the highest quantity of marine litter, contrary to Sesimbra where the lowest values were observed. The analysis of the quantity of litter along the beach showed that the highest number of debris was found in the high tide line, followed by the vegetation line. This suggests that if the monitoring studies focus on this part of the beach, the survey would catch an important amount of litter and it would reduce the costs and effort to survey the entire beach. Autumn was the season with the highest amount of litter. Despite considered in the OSPAR Guideline, monitoring beaches during summer in Portugal proved to be a difficult task. It was not possible to conduct the summer survey due to the strong and constant presence of beachgoers and to the fact that the beaches are cleaned every day. Thus, monitoring marine litter in Portugal, in this season, would be strongly affected by both aspects influencing the data obtained.

The baseline is that there is a need for more relevant information, considering the objectives of Marine Strategy Framework Directive, that faces the challenge to achieve good environmental status by 2020 (Galgani *et al*., 2013). To do so, it is necessary to evaluate the main problems of each European Union Member State, which can only be achieved with the recognition of the seriousness of the marine litter problem. In Portugal, within the framework of the implementation of MSFD, an effort to put into practice projects as BDLixList and LiMar, that have the purpose of quantifying the marine litter on the coast (creating a national database), and to determining bioindicators for the

Descriptor 10 to be applied to Portuguese marine waters (Programa de Monitorizaç aõ e Programa de Medidas - Annex IV (2014).

It is important to complement the present study in order to understand the dynamics of marine litter in Portugal. Similar monitoring studies should be done encompassing a higher time period, as done by Ribic *et al* 2010, and considering others factors, such as the weather and current information at the time of the survey, considered a week or two before and as done by Cunnigham & Wilson (2003). Further studies could also apply different methodologies, in order to understand how effective a type of survey for the site particular characteristics is. Relate the different types of litter transport with the amount of litter, establishing a relationship of cause and effect could be an interesting study, as well as to assess how the oceanic currents influence the coastline litter, identifying the nationality of the litter. As most marine debris are land-source it is important to dedicate studies to estuaries and rivers in order to quantify how much litter (and what type) is transported down the river to reach the sea, as done in Moore *et al.*, (2011).

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