Universidade de Aveiro Departamento de Biologia
Ano 2013

Sara Maria Fardilha Alves de Sá

Floating Debris in the Portuguese Continental Offshore Waters

Detritos Flutuantes nas Águas Oceânicas Portuguesas

Declaração

Declaro que este relatório é integralmente da minha autoria, estando devidamente referenciadas as fontes e obras consultadas, bem como identificadas de modo claro as citações dessas obras. Não contém, por isso, qualquer tipo de plágio quer de textos publicados, qualquer que seja o meio dessa publicação, incluindo meios eletrónicos, quer de trabalhos académicos.

Universidade de Aveiro Departamento de Biologia
Ano 2013

Sara Maria Fardilha Alves de Sá

Floating Debris in the Portuguese Continental Offshore Waters

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestrado em Biologia Aplicada – Ramo de Biologia Marinha, realizada sob a orientação científica do Doutor José Vingada, Professor Auxiliar do Departamento de Biologia da Escola de Ciências da Universidade do Minho e co-orientação do Prof. Doutor Amadeu Mortágua Velho da Maia Soares, Professor Catedrático do Departamento de Biologia da Universidade de Aveiro.

Este trabalho contou com o apoio financeiro do projecto MarPro (Life 09/NAT/PT/0038) – Conservação de espécies marinhas protegidas em Portugal Continental, financiado pelo programa LIFE+ da Comissão Europeia.

Dedico este trabalho à minha família, pelo apoio incondicional.

o júri

presidente

Prof. Doutor João António de Almeida Serôdio
professor auxiliar do Departamento de Biologia da Universidade de Aveiro

Doutor Alfredo López Fernández
Investigador de Pós-Doutoramento do Centro de Estudos de Ambiente e Mar e da Coordinadora para o Estudo de Mamíferos Marinos

Prof. Doutor José Vítor de Sousa Vingada
professor auxilar da Escola de Ciências da Universidade do Minho

agradecimentos

Agradeço em primeiro lugar à minha família por toda a paciência, dedicação e apoio incondicional que demonstraram ao longo destes meses e ao longo de toda a minha vida. Sem vocês não teria conseguido chegar até aqui. Agradeço ainda aos meus pais por tudo o que investiram em mim, pois permitiu-me concretizar mais esta etapa da minha vida.

Agradeço também aos meus orientadores Doutor José Vingada e Doutor Amadeu Soares, por se terem disponibilizado a ajudar e assim tornar possível a realização deste trabalho. Ao Doutor José Vingada agradeço por me ter integrado na sua equipa e possibilitado a experiência de participar na campanha a bordo do Santa Maria Manuela assim como a participação em cursos de formação que me foram úteis na realização deste trabalho e por toda a ajuda ao longo destes meses.

Ao Jorge Santos e Hélder Araújo pela paciência, por estarem sempre disponíveis para me esclarecer, e pela grande ajuda que me deram na análise dos dados recolhidos. A vossa ajuda foi fundamental para a concretização deste trabalho. Obrigada por tudo.

A toda a equipa da Sociedade Portuguesa de Vida Selvagem por me terem recebido tão bem e por toda a ajuda. Obrigado à Flávia Alves, Bruno Ferreira, ao Prof. Pedro Gomes, à Ana Cláudia e ao Nuno Pinto por se terem disponibilizado a fazer turnos na recolha de dados de lixo a bordo do navio.

A todas as pessoas que participaram e estiveram presentes na campanha a bordo do Santa Maria Manuela, desde a equipa à tripulação, pelo bom ambiente e boa disposição ao longo daquelas semanas, assim como pela ajuda e participação na recolha dos dados de lixo. Obrigado a todos pelo apoio!

Ao Rúben, por todo o carinho e apoio nos momentos mais difíceis.

A todos os colegas de mestrado, pelos bons momentos passados na vossa companhia.

palavras-chave Detritos flutuantes, densidade, distribuição, impactos, cetáceos

resumo

Os detritos flutuantes estão presentes em todos os oceanos do mundo, podendo ter impactos negativos na fauna marinha, tais como o enredamento, ingestão e o transporte de espécies exóticas. O presente trabalho tem como objectivos obter estimativas de abundância e densidade de detritos flutuantes e navios, assim como as suas distribuições espaciais ao longo da área de estudo e tentar identificar áreas de sobreposição espacial entre os detritos, a cetáceos e os navios. A pesquisa foi realizada durante o verão de 2011, a bordo do veleiro Santa Maria Manuela. Esta campanha faz parte do projecto LIFE+ MARPRO – Conservação de espécies marinhas protegidas em Portugal continental, e a região abrangida desde as 50 às 220 milhas náuticas totalizou uma área de 252833 Km^2. A pesquisa foi realizada ao longo de transectos lineares, seguindo uma metodologia que permitiu usar métodos convencionais de distance sampling para estimar a abundância e densidade dos detritos flutuantes e navios. A densidade média dos detritos em toda a área de estudo foi 2.96 objectos por km^2 e a abundância total foi 747720 objectos flutuantes. O plástico flutuante foi o tipo de detrito mais comum. No que diz respeito aos navios, a densidade média obtida foi 0.0013434 embarcações por km^2 e a abundância total foi 340 embarcações.

keywords

Debris, density, distribution, impacts, entanglement, ingestion, cetaceans

abstract

Floating marine debris are present throughout the oceans and may have negative impacts on marine fauna, such as entanglement, ingestion and transport of exotic species. The present work aims at obtaining estimates of abundance and density of floating marine debris and vessels, as well as their spatial distributions along the entire study area. It also aims at identifying areas of spatial overlap between marine debris, cetaceans and vessels. The sighting surveys were performed during the summer of 2011, aboard the sailing vessel Santa Maria Manuela. This campaign was part of the project LIFE+ MARPRO - Conservation of marine protected species in Mainland Portugal, and the study area ranged between the 50 and the 220 nautical miles west of Portugal mainland, covering an area of about 252833 Km^2. The survey was conducted along line transects, following a methodology that allowed to using conventional distance sampling methods to estimate the abundance and density of floating marine debris and vessels. Mean density (objects per km_2) of debris in the study area overall was 2.96 objects per km^2 and the total abundance was 747720 floating pieces. Floating plastic was the most common type of debris. In respect of vessels, mean density was 0.0013434 vessels per km_2 and the estimated total abundance was 340 vessels.

Table of contents

List of Figures

List of Tables

Chapter I: Introduction

Marine debris

Human activity adversely affects biodiversity and natural environments all over the world in many ways, and these negative impacts led to 1.000 to 10.000-times higher extinction rates, mainly in the last 75 years (Lovejoy, 1997). A wide range of Human actions threaten marine life including overexploitation of fishery resources, dumping of waste, pollution, introduction of exotic species, dredging, land reclamation, and global climate change (National Research Council, 1995; Irish & Norse, 1996; Ormond *et al.*, 1997; Tickell, 1997; Snelgrove, 1999). This study will address a particular anthropogenic impact: pollution by floating marine debris.

Marine debris, defined as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes" by the NOAA Marine Debris Program (http://marinedebris.noaa.gov/). This definition obviously refers to nondegradable persistent synthetic materials, excluding natural flotsam, such as trees washed out to sea (National Research Council, 2009). Pollution by marine debris only recently was recognized as a worldwide problem, being presently considered a major threat to the marine ecosystem (Pruter, 1987; Stefatos *et al.*, 1999). This threat became more serious mainly with the enlargement of coastal populations and the replacement of degradable natural materials by non-degradable synthetic ones (Aliani *et al.*, 2003).

In general, the accumulation of debris in the marine environment is a consequence of improper disposal, accidental loss and natural disasters (Watters *et al.*, 2010). Globally, it is estimated that approximately 6.4 million tons of debris reach the ocean each year and that around 8 million items are discarded into the sea every day (UNEP, 2005). The sources of this type of pollution can be inserted in two main groups: land-based sources, such as rivers and estuaries, storm-water discharges, drainage systems (domestic and industrial), litter left behind by beachgoers and material lost from coastal landfill sites; and ocean-based sources such as litter from ships, commercial fishing, recreational boats, military vessels and the oil industry (Pruter, 1987; Gregory, 1991; Ribic *et al.*, 1992; Derraik, 2002; Williams *et al.*, 2005; Allsopp *et al.*, 2006). Internationally, 80% of the marine debris in the ocean comes from land-based sources (Sheavly, 2005; UNEP, 2005).

Floating marine debris

Solid marine debris can either immediately sink and accumulate on the seafloor or remain afloat for long periods (weeks to several months). However, floating marine debris (FMD) is usually transported over long distances by currents and winds before stranding on a beach, or it may also lose floatability and sink (Thiel *et al.*, 2003; Hinojosa & Thiel, 2009). Therefore, it is only possible to infer about their origins due to some specific characteristics, such as fisheries articles, brand names or material types (Ribic, 1998; Sheavly & Register, 2007).

Floating marine debris and particularly plastic materials, are present in all oceans and coastal waters and higher abundances are frequently found in principal shipping routes and coastal waters adjacent to major urban regions (Thiel *et al.*, 2003; Hinojosa & Thiel, 2009) and/or in the principal ocean current systems (Kubota, 1994; Shiomoto & Kameda, 2005). Several factors affect the abundance and spatial distribution of floating marine debris, including the source type (terrestrial or maritime), ocean currents, wind patterns and physiographic characteristics (Galgani *et al.*, 2000; Donohue *et al.*, 2001). Large gyres accumulating floating marine debris occur in open oceans, such as the North Pacific Subtropical Gyre, a great high-pressure system that extends between East Asia and North America. Large amounts of marine debris with an area of several thousand miles become trapped in a clockwise circuit of currents (Moore, 2003; Harse, 2011). This concentration of marine debris, known as the Great Pacific Garbage Patch was first discovered by Charles Moore in 1997 and consists mainly of plastic debris (Moore, 2003; Sesini, 2011).

Benthonic debris

Although the emphasis here is on floating marine debris, sinking debris that accumulate on the sea floor also represent a threat to the marine ecosystem (Derraik, 2002), which is largely neglected (Hess *et al.*, 1999). Research on the abundance and composition of marine benthic debris are scarce, being limited to the Mediterranean Sea (Galgani *et al.*, 1995b), Bering Sea (June, 1990), Gulf of Alaska (Hess *et al.*, 1999), the Oregon coast (June, 1990), and the Bay of Biscay and the Seine Bay (Galgani *et al.*, 1995a). There are innumerous potential impacts to benthic biota: entanglement and ingestion hazards (Hess *et al.*, 1999); the impairment of gas exchange between the overlying waters and the sediment pore waters, which causes hypoxia or anoxia in the benthos (Derraik, 2002); and "ghost-fishing", i.e., the continuous fish and invertebrate capture by derelict fishing gear, such as monofilament nets and traps (Hess *et al.*, 1999). For example, live coral reefs are often subject to scouring, abrading or breakage when entangled by marine debris (National Research Council, 2009). Benthic marine debris can also be harmful to fishing, since it increases the risk of damage to the operational gear (Hess *et al.*, 1999).

Marine debris impacts

Pollution by marine debris has a largely negative impact on the marine environment (Lazar & Gracan, 2011). Significant marine debris impacts can be traced back to the 1940s, when the new synthetic materials started to be used in the manufacture of fishing nets, line, and all sorts of everyday items (Laist & Liffmann, 2000). However, the impacts on marine life were recognized only in 1984 at the Workshop on the Fate and Impact of Marine Debris, hosted by the National Marine Fisheries Service (NMFS) in Honolulu, Hawaii (Shomura & Yoshida, 1985).

Besides being aesthetically displeasing, debris can be prejudicial to boaters and to the shipping industry: they can snare boat propellers or clog cooling water intakes, damaging the boat motors (Derraik, 2002; Aliani *et al.*, 2003). Some debris (e.g. glass or metal) can wound beachgoers and marine animals, while others (e.g. sewage and medical waste) can contaminate the water and ocean-users along with all living organisms that live in the contaminated area. In fact, marine fauna is also subject to impacts such as entanglement (Boren *et al.*, 2006) and ingestion (Bjorndal *et al.*, 1994; Tomás *et al.*, 2002; Ryan, 2008), which may cause significant mortality and sub lethal effects (National Research Council, 1995). Ingestion of, or entanglement in, debris has been reported in more than 265 species of birds, fish, turtles, and whales (Derraik, 2002).

Entanglement

Entanglement of marine animals in floating marine debris is a frequently documented ecological impact (Derraik, 2002; UNEP, 2005; Boren *et al.*, 2006; Bockstiegel, 2010). They can become entangled in plastic packing straps, discarded fishing gear (e.g. rope, nets, lines and trawls) and other floating debris (Derraik, 2002) particularly seabirds (Blight & Burger, 1997), sea turtles (Carr, 1987; Casale *et al.*, 2010; Vélez-Rubio *et al.*, 2013) and marine mammals (Hanni & Pyle, 2000). The consequences to marine animals include restriction of movements, drowning or exhaustion, inability to catch food and to avoid predators, amputation, wounds resulting from cutting or abrasive action of debris, that may lead to infection, emaciation, reduced fitness, since the energetic costs of travel significantly increase and mortality of the individuals (Jones, 1995; Marine Mammal Commission, 2001; Derraik, 2002; National Research Council, 2009).

In addition to the possible impacts at the individual level, there may also be potential effects of entanglement on animal populations (National Research Council, 2009). For example, in the populations of Hawaiian monk seal (*Monachus schauinslandi*), the most endangered seal in the United States, entanglement is the main obstacle to the species' recovery (Derraik, 2002; Boland & Donohue, 2003). The survival of the species, of which only 1,250 individuals remain (Carretta *et al.*, 2007), depends on the success of juvenile recruitment. However, juvenile Hawaiian monk seals are more frequently entangled than adults (Henderson, 2001), thus impairing the species' recovery. Likewise, entanglement-caused mortality contributed significantly to the decline of the northern fur seals (*Callorhinus ursinus*) population on the Pribiloff Islands, Alaska (Fowler, 1987). Young northern fur seals (newborns to 2-3 year old individuals) were also more susceptible to entanglement due to their curious and playful nature. Juvenile seals frequently insert their heads through plastic loops and holes, and many times even grow into them. Over time, the plastic loops constrict the neck, which may sever the seal's arteries or strangle it (Fowler, 1987; Derraik, 2002). Furthermore, after the entangled animal decomposes, the plastic loop remains free in the ocean and may cause entanglement in other marine animals (Derraik, 2002). Entanglement in marine debris was also reported for the northern sea lion (*Eumetopias jubatus*) (Henderson, 1990; 2001), Antarctic fur seals (*Arctocephalus gazella*) (Waluda & Staniland, 2013) and Australian fur seals (*Arctocephalus pusillus doriferus*) (Jones, 1995). Hanni & Pyle (2000) conducted a survey at south-east Farallon Island, Northern California, where they observed 914 pinnipeds entangled in synthetic materials. As in juvenile seals, young pinnipeds are also more affected then adults (Marine Mammal Commission, 2001). Sperm whales affected by gill net entanglements were reported in the Mediterranean Sea (Pace *et al.*, 2008). In the case of cetaceans injuries in fins (pectoral or caudal) or mouth are usual (Moore *et al.*, 2009; Neilson *et al.*, 2009).

Ingestion

Some marine animals mistake marine debris for prey species (Tomás *et al.*, 2002). Sea turtles, for example, ingest floating trash bags and balloons, likely mistaking them for jellyfish (Plotkin *et al.*, 1993; Derraik, 2002). In fact, several types of marine debris were found in intestinal tracts of sea turtles, in Florida. Of the 24 autopsied turtles 71% had ingested plastic debris, another 38% contained monofilament fishing lines, 4% had ingested fish hooks, and also rubber, aluminum foil and tar were found. (Bjorndal *et al.*, 1994). In the Tuscany coasts of the Pelagos Sanctuary for Mediterranean Marine Mammals were also reported plastic debris ingestion by loggerhead turtles (*Caretta caretta*) (Campani *et al.*, 2013).

Plastic ingestion has been reported for lancetfish *Alepisaurus* spp. (Jantz *et al.*, 2013), opah *Lampris immaculatus* (Jackson *et al.*, 2000) marine catfish *Cathorops* spp. (Possatto *et al.*, 2011), estuarine drums *Stellifer* spp. (Dantas *et al.*, 2012), and mojarras in the family Gerreidae (Ramos *et al.*, 2012). Blight and Burger (1997) reported plastic particles in the stomachs of 8 out of 11 seabird species bycaught in the North Pacific. Plastic ingestion was also reported for several marine-associated bird species, such as Common Murre (*Uria aalge*), Rhinocerous Auklet (*Cerohinca monocerata*), Pigeon Guillemot (*Cepphus columba*), Marbled Murrelets (Brachyramphus *marmoratus*) and Ancient Murrelets (*Synthliboramphus antiquus*), in the eastern North Pacific (Avery-Gomm *et al.*, 2013). Seabirds that accumulate large loads of plastic in their stomachs are useful indicators of changes in the amount and composition of plastic debris at sea, especially petrels (Ryan, 2008) and northern fulmars (van Franeker *et al.*, 2011; Kuhn & van Franeker, 2012). In the Great Barrier Reef (Australia) was documented ingestion of marine plastic debris by late-stage chicks of wedge-tailed shearwater (*Ardenna pacifica*) (Verlis *et al.*, 2013).

Ingestion of floating marine debris by marine animals can cause several problems. For example, it can cause a physical blockage in the digestive system, to the point of starvation or injuries in the digestive system (Carpenter & Smith, 1972; Rothstein, 1973; Derraik, 2002). Ingestion of FMD can also reduce the absorption of nutrients in the gut (National Research Council, 2009) and a decrease in the animals' foraging effort. In fact, when stomachs contain large amounts of debris, a satiety sensation is transmitted to the hypothalamus and, consequently, the animals may die of starvation (Azzarello & Vleet, 1987; Derraik, 2002).

Ingestion of FMD by animals may also enhance the uptake of toxic substances that either comprises the debris or that have been adsorbed onto the debris (Azzarello & Vleet, 1987; Derraik, 2002). For example, plastic resin pellets may serve as a carrier of toxic chemicals, such as polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene (DDE), and nonylphenols (NP) in the marine environment (Mato *et al.*, 2001). PCBs and other toxic chemicals have been found in adult Laysan Albatrosses from Midway Atoll, Hawaiian Leeward Islands (Jones *et al.*, 1995). Therefore, marine organisms that ingest contaminated plastic particles may suffer adverse effects such as reproductive disorders, carcinogenesis, immunotoxic responses and alteration of hormone levels (Azzarello & Vleet, 1987; Lee *et al.*, 2001; Auman *et al.*, 2004).

Marine mammals may ingest marine debris like styrofoam or plastic bags by mistake (Baird & Hooker, 2000; Marine Mammal Commission, 2001), as in the case of the deep-diving and rarely observed species such as beaked whales (Simmonds & Nunny, 2002; Gomerči *et al.*, 2006) and pygmy sperm whales (Stamper *et al.*, 2006). Jacobsen *et al.* (2010) reported the mortality of two sperm whales (*Physeter macrocephalus*) in Northern California caused by the ingestion of large amounts of marine debris. A similar case was recently reported for Mediterranean Sea (De Stephanis *et al.*, 2013). Bottlenose dolphins (*Tursiops truncatus*) asphyxiated by laryngeal entrapment due to ingestion of fishing lines have also been documented (Gorzelany, 1998; Gomerčić *et al.*, 2009). Other affected species include Blainville's beaked whales (*Mesoplodon densirostris*) (Secchi & Zarzur, 1999), killer whales (*Orcinus orca*) (Baird & Hooker, 2000), and the endangered West Indian manatee (*Trichechus manatus*) and Florida manatee (*Trichechus manatus latirostris*) (Derraik, 2002). However, only very experienced researchers or well-trained pathologists following meticulous necropsy protocols are able to identify entanglement and ingestion as the cause of death of stranded marine animals (Raverty & Gaydos, 2004).

Transport of exotic species

Wide dispersal of marine invertebrates by floating marine debris is another important ecological impact (Minchin, 1996; Barnes, 2002; Aliani & Molcard, 2003; Barnes & Milner, 2004). Encrusting organisms such as bacteria, diatoms, algae, bryozoans, hydroids, tunicates, barnacles, polychaete worms and molluscs may settle and grow in these floating objects, being transported over large distances allowing them to colonize new habitats (Carpenter & Smith, 1972; Minchin, 1996; Barnes, 2002). The introduction of non-native animals to new environments is considered one of the greatest causes of loss of species (Carlton & Geller, 1993). Recently, several microorganisms, such as bacillus bacteria, pennate diatoms, coccoid bacteria, centric diatoms, dinoflagellates, coccolithophores, and radiolarians, were found attached to examined (using SEM) items collected in eastern North Pacific Gyre (Carson *et al.*, 2013) and North Atlantic Subtropical Gyre (Zettler *et al.*, 2013).

Potential vector for dispersing HAB species

Drifting plastic debris can also be a potential vector for dispersing Harmful Algal Bloom (HAB) species (Masó *et al.*, 2003). Besides benthic diatoms and small flagellates, potential harmful dinoflagellates, such as *Ostreopsis sp.* and *Coolia sp.*, were also identified in plastic debris collected along the Costa Brava (the northern part of the Catalan coast). Vegetative cells and temporary cysts of the potential harmful dinoflagellate *Alexandrium taylori* Balech, 1994 were also present in plastic debris collected in La Fosca beach, during a bloom of this species (Masó *et al.*, 2003).

Economic impacts

Marine debris can also be responsible for significant economic impacts (Interagency Marine Debris Coordinating Committee, 2008) and can negatively affect coastal communities and sectors such as tourism, fisheries, shipping, aquaculture, coastal agriculture, power generation and industrial use (blocked filters), and local authorities (UNEP, 2009; Galgani *et al.*, 2010).

The decrease of tourism and recreational potential in coastal areas that have debris on their beaches and in the water is a major cause of economic losses (Aliani *et al.*, 2003). These losses can be particularly serious to coastal communities and national economies that depend upon tourism (Interagency Marine Debris Coordinating Committee, 2008; Thompson *et al.,* 2011). Furthermore, there are also the costs of cleaning beach areas, piers, harbors, marinas, docks, and other waterfront areas, along with the costs of at-sea cleanups, of proper debris disposal and of restoration actions at the impacted habitat (Interagency Marine Debris Coordinating Committee, 2008).

In the fishing and shipping industry, impacts include accidents, collisions with larger debris at sea (such as cargo containers and oil drums), blocking of water intake pipes by plastic sheeting and entanglement of floating objects such as ropes and plastics in propeller blades (leading to engine damage) (Jones, 1995; Aliani *et al.,* 2003; McIlgorm *et al.,* 2009). Costs result mainly from damage repairs, loss of operational time, litter removal, and waste management in harbors (Williams *et al.*, 2005; UNEP, 2009). In the fishing industry, other impacts include fouling of trawl nets by bottom debris (Jones, 1995), loss of fishing gear, losses in catch revenues (Interagency Marine Debris Coordinating Committee, 2008; UNEP, 2009), loss of commercial fish caught in ghost-nets (Pichel *et al.*, 2007), the contamination of catch (Galgani et al., 2010) and loss of fishing opportunities, since fishermen are forced to stop operations to remove the litter from propellers, nets and other fishing gear (Interagency Marine Debris Coordinating Committee, 2008). In the communities that rely on fishing revenues, the loss of fishing opportunities is of concern, because it can lead to the lack of basic resources for fishermen (Williams *et al.*, 2005). Economic impacts of marine debris are recently gaining more attention (Hastings & Potts, 2013).

The economic impacts of marine debris was addressed in very few papers, being thus necessary more research in this area in order to improve policies, legislation and mitigation measures (UNEP, 2009; McIlgorm *et al.,* 2011).

Plastics

Plastics are predominant amongst marine litter worldwide (Derraik, 2002; UNEP, 2009). Plastics are lightweight, strong, durable and cheap, characteristics that make them suitable for the manufacture of a very wide range of products (Derraik, 2002). Furthermore, the high persistence of plastic material, poor lifecycle management, high production (Andrady & Neal, 2009), consume and discard habits (Hopewell *et al.*, 2009), concentration of population on coastal areas, and consequent disposal of high volumes of plastic that may enter the water streams if poorly handled, accumulating in oceans and coastline, make this issue a serious hazard to the environment (Bowmer & Kershaw, 2010). Annual plastic production has increased exponentially 1.5 million tonnes in the 1950s to approximately 280 million tonnes in 2011 (PlasticsEurope, 2012).

This threat has been ignored for a long time, and its seriousness has been only recently recognised (Stefatos *et al.*, 1999), as the statement of Fergusson (1974) demonstrates: "plastics litter is a very small proportion of all litter and causes no harm to the environment except as an eyesore". Despite the great boom in the production and use of plastics of the past three decades, in the marine environment the perceived abundance of marine life and the vastness of the oceans have led to the dismissal of the proliferation of plastic debris as a potential hazard (Laist, 1987). However, until now, over 660 marine species worldwide are known to be affected in by plastic waste one way or another (Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel, 2012).

Plastic pollution is a problem even in remote areas of the world previously thought to be unaffected such as the Arctic (Provencher *et al.*, 2010) and the Antarctic (Auman *et al.*, 2004). For example, about 80% of the floating marine debris in the Mediterranean Sea and in the SE Pacific Coast off the Chilean coast is composed of plastics. Also in the Kuroshio Current in the NW Pacific Ocean, over 55% of the stations surveyed presented fragments of plastic products and plastic sheets (Hinojosa & Thiel, 2009). Recently, it was demonstrated that the concentration (items per hectare) of litter on the sea floor of the Adriatic Sea is among the highest along European coasts, after the NW Mediterranean and the Celtic Sea, and if only plastic debris is considered, this sea floor represents the most polluted sea floor in Europe with 2.63 items/ha (Lazar & Gracan, 2011). Also, in the Tokyo Bay plastics debris represented 80-85 % of the debris on the sea floor (Derraik, 2002).

Most plastics degrade slowly through a combination of photodegradation, oxidation and mechanical abrasion (Andrady, 2003). Plastic degradation is even slower in open ocean due to their polymeric nature and intended durability and because UV radiation absorption by seawater and lower temperatures found in aquatics habitats slow deterioration (Ryan *et al.,* 2009; Bowmer and Kershaw, 2010). Plastics will become smaller and smaller, reaching unknown sizes and posing a long-term threat to the marine food chains (Andrady, 2011; Cole *et al.*, 2011; Martins & Sobral, 2011), since they can persist in the marine environment for centuries (Derraik, 2002).

Microplastics

Microplastics are defined by some authors as plastic smaller than 5 mm in diameter (Arthur *et al.*, 2009) while others have set the upper size limit at 1 mm (Claessens *et al.*, 2011). However the first definition is the most commonly used, despite the 1 mm limit be more intuitive (i.e. 'micro' refers to the micrometre range) (Van Cauwenberghe *et al.*, 2013). Their potential impacts on the marine ecosystem have received increasing attention (Gorycka, 2009), despite many of these impacts and consequences have yet to be studied (Moore, 2008). Animals of lower trophic levels, commonly not affected by larger debris, such as polychaetes, bivalves, echinoderms and copepods, may ingest these particles, due to their small dimension (Thompson *et al.*, 2004; Ward & Shumway, 2004; Graham & Thompson, 2009). Microplastics may adsorb hydrophobic substances such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), which may affect even more severely the marine organisms (Frias *et al.*, 2010). Organic pollutants, such as PAHs, PCBs and DDTs, associated to microplastics were found in several Portuguese beaches (Frias *et al.*, 2010; Antunes *et al.*, 2013). In the same way, a wide range of organic micropollutants (PCBs, DDTs, HCHs, PAHs, and hopanes) associated to plastic pellets were reported from nine locations on the Portuguese Atlantic coast (Mizukawa *et al.*, 2013).

Microplastics are globally dispersed in the oceans, due to their persistence nature (Martins & Sobral, 2011; Mizukawa *et al.*, 2013). Their presence has been reported in the water column and marine environment worldwide (Moore *et al.*, 2001; Thompson *et al.*, 2004; Law *et al.*, 2010; Claessens *et al.*, 2011). Microplastic particles were found even in pristine marine environments as the deep sea. Van Cauwenberghe *et al.* (2013) demonstrated for the first time ever, the presence of microplastics in the top sediment layer of the Nile Deep Sea Fan (at 1176 m), the Southern Ocean (at 2749 m), and Porcupine Abyssal Plain (at 4842 m). The evidence of trophic level transfer of microplastics from blue mussels (*Mytilus edulis*) to shore crabs (*Carcinus maenas*) reported by Farrell & Nelson (2013) constitutes another concerning fact.

Prevent and reduce marine debris

Prevention is the most efficient and cost-effective solution to mitigate pollution by marine debris (Interagency Marine Debris Coordinating Committee, 2008; Ryan *et al.,* 2009). This environmental problem can be prevented and controlled through an effective collaboration of education, legislation, and innovation (Sheavly & Register, 2007).

Legislation

At a global level, there are several conventions and agreements aimed at the prevention and management of marine debris both on land and sea (Sheavly & Register, 2007; UNEP, 2009; Thompson *et al.,* 2011). All the world’s oceans are governed by the United Nations Convention on the Law of the Sea (UNCLOS), adopted in 1982 (Miller, 1996; National Research Council, 2009). The convention, which came into force in 1994, establishes a legal framework for all uses of oceans and seas and their resources, defining the rights and responsibilities of the signatory states and providing enforcement mechanisms (Miller, 1996). In relation to the global marine debris problem, nations have the obligation to adopt all measures necessary to prevent, reduce, and control pollution of the marine environment from any source, including prevention of land- and ocean-based discharges of marine debris (National Research Council, 2009).

The major international conventions relevant to the marine debris issue include the 1972 Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter (the London Dumping Convention) and the 1996 Protocol to the Convention, which updates the Convention; and the 1973 International Convention for the Prevention of Pollution from Ships, modified by the Protocol of 1978 MARPOL Annex V. The 1996 Protocol prohibits any deliberate disposal into the sea of wastes or other matter from vessels, aircrafts, platforms or other man-made structures at sea, as well as their storage in the seabed and the subsoil. However, it is important to note that the wastes generated during “normal operations” of vessels, such as ballasting, generation of dry garbage onboard, sewage treatment, and intentional and accidental discharge of noxious substances that were subject to transport are exceptions, not being considered dumping (National Research Council, 2009; Center for International Environmental Law, 2012).

The International Convention for the Prevention of Pollution from Ships was an initiative of the International Maritime Organization, a specialized agency of the United Nations (National Research Council, 2009). Due to significant pollution events resulting from vessel accidents, the agency decided to include prevention and management of pollution associated with accidents and normal operations in their initiatives. Annex V of MARPOL is the primary international authority for controlling ship sources of marine debris, and came into effect in 1989 (Henderson, 2001; Williams *et al.,* 2011). It aims at eliminating or reducing solid waste pollution from ships, specifying the conditions under which different types of garbage may be discharged. Thus, Annex V prohibits at sea disposal of plastics of any kind and tightly restricts other discharges in coastal waters and “special areas”, based on a "distance from land" framework for permissible dumping of garbage (National Research Council, 2009). The distances (3, 12, and 25 nautical miles) are primarily based on historical definitions of state, territorial seas, and international waters rather than on an ecosystem perspective of the problem (National Research Council, 2009). Despite all this, ships are responsible for only a relatively small fraction of marine debris, so this agreement only partially addresses this problem (Williams *et al.*, 2011).

There are also regional agreements, such as the 1983 Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (known as the Cartagena Convention), which entered into force in 1986 (Miller, 1996; Sheavly & Register, 2007). The Convention requires contracting parties to adopt measures to prevent, reduce and control pollution from shipping, dumping, land- and ocean-based sources and atmospheric discharges, and to ensure sound environmental management (Miller, 1996; Sheavly & Register, 2007). A recent integrated policy for the protection of the marine environment is the EU Marine Strategy Framework Directive (MSFD), which requires all European marine waters to be in Good Environmental Status (GES) by 2020. GES is reached when 11 Descriptors (biodiversity, alien species, fish stocks, food-webs, eutrophication, sea-bed integrity, hydromorphology, contaminants in the sea, contaminants in seafood, litter and energy) do not deviate significantly from the undisturbed state (Galgani *et al.*, 2013; Zampoukas *et al.*, 2013).

The legislation implemented has been widely ignored. Jones (1995) reported that, in the Australian waters, at least one-third of the vessels did not comply with the MARPOL Annex V. Also, in the Northwestern Hawaiian Islands, there was no decrease in the accumulation of marine debris or in the entanglement rate of Hawaiian monk seals after the implementation of Annex V of MARPOL (Henderson, 2001). However, some authors recognize some efficiency of this law in reducing pollution by marine debris (Amos, 1993; Arnould & J.P.Croxall, 1995; Derraik, 2002). For example, since MARPOL Annex V entered into force there was a decrease in the entanglement rates of northern fur seals in the Pribilof Islands (Sinclair & Robson, 1999).

Education

Educational campaigns aim at raising public awareness and change behaviors and attitudes related to solid waste management, being therefore considered an essential tool to solve or reduce this environmental threat (Derraik, 2002; National Research Council, 2009; UNEP, 2009). The target audience of these campaigns may include people of all ages, from school children to seniors, with motivations ranging from recreational to professional objectives (Interagency Marine Debris Coordinating Committee, 2008). However, as different user groups (producers, transporters and users of products) and sectors of the population (fishermen, students, politicians) have different perceptions about marine debris, requiring different approaches, most educational programs have focused on a specific target audience (Interagency Marine Debris Coordinating Committee, 2008). In addition, the changes are particularly evident when education is performed in schools, since the youngsters have greater ease in changing their habits, and often act as catalysts for change, alerting their families and the surrounding community to this problem (Derraik, 2002). Given the fact that the majority of debris in the ocean comes from land-based sources, a community with enhanced ecological awareness and willing to adopt behaviors beneficial to the environment can make a significant difference (Derraik, 2002).

Innovation

It is estimated that 60% to 80% of all marine debris is plastic polymer-based (Derraik, 2002). Innovative technologies, such as increasing the biodegradability and photodegradability of plastics may also - together with community education and a stricter legislation - contribute to mitigate this type of pollution. Nowadays, there are alternatives to the typically used materials and products that are less harmful to the environment. However, these would require different waste management strategies (Sheavly & Register, 2007). Biodegradable plastics - made from materials such as starch or cellulose – with functionalities and processabilities comparable to traditional petrochemical-based plastic have been developed for packaging applications (e.g. www.europeanbioplastics.org). Müller *et al.* (2012) investigated the decomposition rates of three different bag types (standard polymer bags, degradable polymer bags and biodegradable polymer bags) in the gastrointestinal fluids (GIF) of the stomach, small and large intestines of an herbivorous Green turtle (*Chelonia mydas*) and a carnivorous Loggerhead turtle (*Caretta caretta*). The study showed that the degradation in salt water of biodegradable polymer bags was much slower than that referred by the manufacturer (ca. 3 years instead of 49 days). This is an area that needs further investigation in order to adequately assess the environmental decomposition of biodegradable polymers (Muller *et al.*, 2012).

Monitorization

Monitoring can be defined as "the systematic measurement of biotic and abiotic parameters of the marine environment, with predefined spatial and temporal schedule, having the purpose to produce datasets that can be used for application of assessment methods and derive credible conclusions on whether the desired state is achieved or not and on the trend of changes for the marine area concerned" (Zampoukas *et al.*, 2013).

Marine debris monitoring programs are crucial and necessary to provide useful information that allows the formulation of management solutions to prevent and reduce marine debris (UNEP, 2009; Zhou *et al.*, 2011). However, successful management strategies require a good understanding of the marine debris problem and human behavior (Sheavly, 2005; 2007). Monitoring programs can clarify and assess several aspects of marine debris, including types and amounts found in particular geographic locations, oceanographic and meteorological conditions, potential sources and the proximity to them, distribution, and ultimately, the human behaviors and activities producing them (Sheavly, 2005, 2007; Zhou *et al.,* 2011). In this way, research and data obtained on marine debris can also be used to assess the efficacy of management strategies, legislation and other activities designed to prevent and control this environmental threat, as well as to provide insight into when strategies need to be modified according to changing conditions (Sheavly, 2007; Ryan *et al.*, 2009; UNEP, 2009; Ribic *et al.*, 2010). The obstacles related to marine debris monitoring derive, in part, from the insufficiency of data and public awareness, and mostly from the lack of standardization and compatibility between the different assessment methods used and results obtained (UNEP, 2009). However, Regional Seas Conventions, such as HELCOM and OSPAR have made an important effort to develop common monitoring approaches, under the Marine Strategy Framework Directive (MSFD) (Zampoukas *et al.*, 2013). The methods used to estimate abundance of floating marine debris are the direct observation of large debris items, net trawls for smaller items or aerial surveys (Ryan *et al.*, 2009; Galgani *et al.*, 2013).

Marine fauna

The MarPro offshore campaign, in which floating marine debris data were collected, constituted the first large effort to increment the knowledge about cetaceans in Portuguese waters, since it was the first time that distant offshore waters (beyond 50 nautical miles) were surveyed in order to obtain data on the distribution, abundance and population structure of cetaceans (Santos *et al.,* 2012). Marine mammal species sighted along the Portuguese offshore waters include striped dolphin (*Stenella coeruleoalba*), spotted dolphin (*Stenella frontalis*), bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), Cuvier's beaked whale (*Ziphius cavirostris*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), risso's dolphin (*Grampus griseus*) and unidentified Balaenoptera and *Mesoplodon* spp. (Santos *et al.,* 2012).

The objectives of the present study were to obtain estimates of abundance and density of floating marine debris and vessels, as well as their spatial distribution along the entire study area, and attempt to identify areas of spatial overlap between marine debris and marine animals, as well as areas where marine debris pose a major threat to wildlife.

Chapter II: Methods

Study area

The Portuguese continental waters (excluding Madeira and Azores) are confined between the 36,5°N and the 41,5°N. The country EEZ has an area of 327667 km^2 of which 23728 km^2 can be considered a part of the continental shelf. The continental shelf has a narrow profile apart from a small region between the river Minho and the Nazaré Canyon. The offshore area is used by fisheries and as a navigation corridor. Additionally, there has been some evaluation of the possibility to use it also to explore different kinds of natural resources (gas, oil, other marine energy sources and minerals) (Santos *et al.,* 2012).

Field methods

The sighting surveys of floating marine debris in the Portuguese Continental Offshore Waters were performed during the summer of 2011 (22 July-4 August, 8-11 August and 7-15 September), aboard the Santa Maria Manuela, a sailing vessel with 68,64 m in length overall, 11 fore-and-aft sails and a total area of 1,130 m^2. This campaign was part of the project LIFE+ MARPRO - Conservation of marine protected species in Mainland Portugal (http://marprolife.org/index.php/en/home). The region comprised in this project ranged from 50 to 220 nautical miles west off Portugal mainland, covering an area of about 252833 Km^2.

The survey was conducted along line transects, following a methodology that would allow to use conventional distance sampling methods to estimate the abundance and density of floating marine debris and vessels (Thomas *et al.*, 2010). A total of 14 samplers, with equal angle design at a random starting point, were obtained in Distance ver.6 to allow for a homogeneous coverage probability of the whole offshore area. However, only 13 samplers were surveyed because of weather conditions (Santos *et al.,* 2012). The team recorded the distances from the line to each object detected. All objects and respective distances from the line, no matter how far they were from the transect line were recorded. In order to obtain unbiased estimates of density and abundance, during the field procedures, the three following assumptions of the method were satisfied: objects directly on the line are always detected, which means that probability of detection is 1 (g(0)=1); objects are detected at their initial location, prior to any movement in response to the observer; distances and angles are measured accurately (Buckland *et al.*, 2001).

Clearly, the responsive movement is not a problem with marine debris. The mean velocity of the vessel along the survey was 10 knots. The team was composed of three people that rotated between positions every hour in order to prevent fatigue and loss of concentration of the observer. In fact, while one person performed the observations, another person was recording data whereas the third element was resting, thus allowing each person to have a 1-hour resting period after two-hour shifts. Data were collected from the deck, where the observer at port or starboard (according to the best visibility conditions) scanned the quadrants between 0° and 90° or between 270° and 0°, with 7x50 reticular binoculars. When marine debris or a ship was sighted, the data recorder wrote down the number of the object, time (indicated by the GPS), radial angle (in degrees), distance (in meters), size of the object, codes of the different types of debris, life associated to debris (if any), codes of the different types of vessels, activity of vessel and comments, if necessary, in a data form (Annex I). The distances were estimated accurately, using personalized measuring sticks and reticular binoculars (7x50). Measuring sticks were personalized because the scale was dependent on the height of the eyes of each observer above sea level. For a correct measurement, the observer held the measuring stick at arm's length, aligned the top of the stick with the horizon and measured the distance to the object through the scale. The radial angle from the track line to the sighting was measured with an angle board mounted on the deck. As for the size, debris were categorized according to the following size classes: **S** (Small): <2.5 cm; **M** (Medium): ≥2.5 cm and ≤10 cm; **L** (Large): >10 cm and ≤1m; **XL** (Extra Large): >1m (Table 1).

Table 1. Marine debris size categories, based on longest dimension.

Size classes	Item length
Small	< 2.5 cm
Medium	≥ 2.5 cm and ≤ 10 cm
Large	> 10 cm and ≤ 1m
Extra Large	> 1m

The described classes, taken from Ribic *et al.* (1992), are based on the size distribution of items found on beaches. The 2.5 cm limit, specifically, is related to the MARPOL Annex V regulations, who claim that materials released from ships have to be smaller than 2.5 cm. This type of classification is important because size influences the type of distribution of marine debris, the possible impacts on wildlife and the type of survey used (Ribic *et al.*, 1992).

The codes used to distinguish between types of debris were taken from Ribic *et al.* (1992) and are divided in ten general categories: Organic; Plastic; Wood; Monofilament; Glass; Rubber; Metal; Styrofoam; Paper or cloth and Other. These categories are divided into sub-categories in order to obtain more specific information about the debris (Table 2). In turn, the codes of the different types of vessels are divided in four general categories: Fishing, Recreational, Transport e Warship. They are also divided into more specific sub-categories (Table 3). The activity of the sighted vessels was also registered using codes to distinguish between three types of activity: In Transit, Fishing and Anchored (Table 4). The data form included a field for comments to record any important distinguishing feature of the objects, detailed descriptions when the detected object was not categorized and other observations that might be necessary.

In order to save searching time, sighting data were collected on passing mode. Objects sighted while off effort were not considered in the density and abundance analyses. Geographical positions were registered with a Global Positioning System (GPS) connected to the computer, and on synchronized handheld GPSs. All the GPS devices were set to register the position at 1-minute intervals (Santos *et al.,* 2012)

Table 2. Codes of marine debris categories and subcategories (adapted from Ribic *et al.*, 1992).

1) Organic (OR – general code)	
ORFI	Fish
ORBI	Bird
ORMA	Mammal
OROT	Other (excluding kelp, jellyfish, or *Velella*; describe in comments)
2) Plastic (PL – general code)	
PLFL	Float
PLBO	Bottle
PLSH	Sheet (including tarp)
PLST	Strap (including cargo straps)
PLBA	Bag
PLCL	Cigarette lighter
PLOT	Other (describe in comments)
3) Wood (WO – general code)	
WOLO	Log or branch
WOVE	Vegetation (land-based including eel grass, etc)
WOLU	Lumber or board
WOPA	Pallet or crate
WOOT	Other (describe in comments)
4) Monofilament (MO – general code)	
MONE	Net (include all netting)
MOLI	Line (include all ropes or tangles of ropes or fishing gear)
MOFF	Lost fishing floats
MOOT	Other (describe in comments)
5) Glass (GL – general code)	
GLBO	Bottle or jar
GLBU	Light bulb or fluorescent tube

GLFL	Fishing float (e.g., glass ball)
GLOT	Other (describe in comments)
6) Rubber (RU – general code)	
RUBA	Balloon (includes all balloons)
RUME	Medical or health item (including gloves, condoms)
RUTI	Tire
RUOT	Other (describe in comments)
7) Metal (ME – general code)	
MECA	Can
MEDR	Drum (e.g., 55-gallon drum)
MEOT	Other (describe in comments)
8) Styrofoam (ST – general code)	
STCO	Food or beverage containers including cups
STFL	Styrofoam float
STPO	Styrofoam popcorn
STOT	Other (describe in comments)
9) Paper or cloth (PA – general code)	
PASH	Sheet (including paper plate)
PACA	Cardboard or plasterboard
PAOT	Other (describe in comments)
10) Other, unidentifiable, or multiple items of different categories	
DEOT	Other debris (describe in comments)

Table 3. Codes of the different types of vessels.

1) Fishery (FI – general code)	
FIL	Longliner
FIT	Trawler
FIN	Nets
FIS	Seining
2) Recreational (RE– general code)	
REY	Yacht
RES	Sailboat
3) Transport (TP – general code)	
TPC	Container
TPB	Bulk cargo
TPF	Ferry-boat
TPT	Oil tanker
4) Warship (WS – general code)	

Table 4. Codes of the different types of vessel activities.

1) In transit **(TR – general code)**
2) Fishing **(FI – general code)**
3) Anchored **(AN – general code)**

Analysis in Distance software

Conventional distance sampling (CDS) methods, described by Buckland *et al.* (2001) were used to analyze the data. Distance sampling comprises a set of methods in which distances from a line or point to detections are recorded, from which the density and/or abundance of objects is estimated (Buckland *et al.*, 2001; Thomas *et al.*, 2010). Analyses were performed using the free software Distance 6.1 Beta 1 (Thomas *et al.*, 2010). Initially, a general analysis was performed to estimate the density and abundance of marine debris in the study area. In that analysis, data were post-stratified by type of debris to obtain estimates of density and abundance for each type of debris. Later, in order to obtain estimates of abundance and density of the different size classes, an analysis was performed for each of the most common types of debris (PLFL – Plastic float, STPO – Styrofoam popcorn, PLBA – Plastic Bag, PLOT – Other plastic item, PLBO – Plastic bottle, PLOT - Plastic, MOLI – Monofilament Line, PASH – Paper Sheet, WOLU – Wood lumber or board and DEOT – Other debris) with a post-stratification by size. It was also performed an analysis to estimate the density and total abundance of marine debris that may pose greatest threat to cetaceans. This risk group for cetaceans, which was designated DDFC - Dangerous debris for cetaceans - includes the following types: PLBA - Plastic Bag, PLOT - Other Plastic Item, PLST – Plastic Strap, MONE - Monofilament net, MOLI - Monofilament line, MOFF – Lost fishing floats, RUME - Rubber medical or health item. The abundance and density of vessels in the study area was estimated, as well as the abundance and density of each type of vessel, carrying out a general analysis with post-stratification by type of vessel (FI - Fishing, RE - Recreational, TP - Transport, WS - Warship).

In all these analysis, including vessels analyses, model and adjustment combinations tested were: uniform key with cosine adjustments; half-normal key with cosine adjustments; half-normal key Hermite polynomial adjustments; hazard-rate key with simple polynomial adjustments (Thomas *et al.*, 2010). The model selection was guided by AIC (the detection function with the best fit – lower Akaike's Information

Criterium, AIC), and to better fit the detection functions, 5% of the longest perpendicular distances were discarded (Buckland *et al.*, 2001; Thomas *et al.*, 2010).

The software Arc Map 10.0 was used to visualize the survey transects, the effort made, and to project the geographic positions of the sighted objects, and to obtain the global distribution of floating marine debris and vessels on the entire study area. Kernel density maps were also used to visualize geographic areas associated with a high probability of occurrence of floating marine debris, vessel and cetaceans. The obtained probability contours, contain the desired percentage of total probability within the smallest area. Kernel densities are often described using percent probability contours, which are the contours that contain the desired percentage of total probability of use within the smallest area. For example, the 10% probability contour contains 10% of the probability of use within the smallest area on the surface of the kernel density. This definition results in an inverse relationship between the probability of finding an item location (marine debris, vessel or cetacean) and the value of the contour; i.e., a 10% probability contour contains only areas with a high probability of use, while a 90% probability contour contains areas with both high and low probabilities of use. If visualized in three dimensions, with the height of the kernel density surface representing probability of use, a 10% probability contour would surround the peak of the surface, whereas a 90% probability contour would be located lower on the surface and include the area within the contours above it (Quakenbush *et al.*, 2009). The area between the coast and the 50nm was not considered in the analysis, because no effort was performed in that area.

The cetaceans data (sighting locations) obtained in this campaign were also used following the results and analysis presented by Santos *et al*. (2012) thus allowing for comparisons between the spatial distribution of cetaceans, floating marine debris and vessels.

PCA and Mann-Whitney test

To investigate whether it is possible to distinguish the debris distribution between transects and detect which type of debris could be responsible for that separation, a multivariate (Principal Component Analysis, PCA) and an univariate analysis (Mann-Whitney test) were applied, since even with variable transformation, the assumptions of normality and homogeneity needed for parametric statistical tests were not accomplished (only 12 of the 36 debris categories were normally distributed according to the D'Agostino & Pearson omnibus normality test). Since transects had different lengths, raw data on observations was transformed into item/10 km.

The dataset used in PCA included 36 categories of debris distributed along the 13 surveyed transects. The goals of a PCA are: to extract the most important information from the data table; to compress the size of the data set by keeping only the important information; to simplify the description of the data set; and to analyse the structure of the observations and the variables, thus associating similar transects in term of debris occurrence. In terms of units, we want to keep the same unit of measurement for the complete space (plastic debris/10 km, metal can debris/10 km), so we performed a covariance PCA, rather than a correlation PCA. PCA summarises all explanatory variables into a few orthogonal principal components (PC). Each PC has an associated eigenvalue that represents the amount of variation explained by that axis (Zuur *et al.,* 2007). For the present study, the selection of the most important PCs to be presented was based on the "Kaiser-Guttman criterion", whereby PCs whose eigenvalues are larger than the mean of all eigenvalues are analysed (Legendre & Legendre, 2012). So, it was assumed that the components that are above the mean value are meaningful and retained for interpretation and those below the mean value are assumed to be unimportant. All calculations were performed using the package JMP9.

The PCA analysis leads to the association of several transects that in terms of marine debris were more similar between themselves. At the same, this analysis allowed to identify the debris types that contribute to the detected associations. In order to confirm possible geographical differences, the PCA analysis was completed with a univariate analysis (Mann-Whitney test) assuming a division of the surveyed area in two sectors, namely north (Transect 1 on till Transect 7) and south (Transect 8 till transect 13). These tests were performed for main debris categories only (19 categories plus an extra category that aggregates all types of debris with low occurrence).

Chapter III: Results

Transects

Line transects designed for the survey as well as the search effort are shown in figure 1. Some small segments of trackline were not surveyed due to poor sea and weather conditions. The characteristics of each transect are given in Table 5.

Table 5. Transect characteristics. H - hours, start longitude and latitude, stop longitude and latitude, Lt - length in km, nt - number of sightings, and rt=Lt/nt, corresponding to the number of sightings per km.

Transect	*Date*	*Time(h)*	*Start long*	*Start lat*	*Stop long*	*Stop lat*	*L_t (km)*	*n_t sight*	*r_t*
1	July 24	10:11:04-18:14:00	-12.08159	41.92374	013.68206	41.63921	73.96	9	8.22
2	July 24 July 25	18:54:00-21:00:00 8:12:36-19:56:07	-13.72770	41.62022	-10.82601	41.28826	149.57	13	11.51
3	Sept. 7	7:33:00-20:16:04	-11,04169	40,95397	-13,24054	40,58653	140.04	59	2.37
4	Sept. 8 Sept. 9	7:35:02-20:10:12 7:43:55-11:19:10	-13,02308	40,44406	-10,09726	40,10391	106.43	87	1.22
5	Sept. 9 Sept. 10	12:38:11-20:20:30 7:32:30-17:48:24	-10,22299	39,95906	-13,57778	39,39505	130.09	87	1.50
6	Sept. 10 Sept. 11	18:21:35-20:20:00 7:31:40-20:21:53	-13,57344	39,39411	-10,50798	39,0504	143.37	81	1.77
7	Sept. 12 Sept. 13	7:30:46-20:12:27 7:30:30-12:09:18	-10,53873	38,77189	-13,50669	38,27777	143.51	105	1.37
8	Sept. 13 Sept. 14	12:30:00-18:50:00 14:03:04-18:39:17	-13,4538	38,26926	-10,15147	37,89838	158.90	25	6.36
9	Aug. 3	7:31:00-18:32:12	-11,99054	37,39198	-9,9698	37,72128	99.03	20	4.95
10	Aug. 2	16:30:30-21:00:13	-10,10038	36,78111	-10,931	36,87718	45.02	6	7.50
11	July 31 Aug. 2	8:30:12-19:30:15 7:31:26-14:43:18	-13,37334	36,04077	-9,94421	36,58912	168.31	47	3.58
12	July 28 July 29	9:00:42-21:00:00 7:40:08-18:23:00	-13,32644	36,06502	-9,23801	35,55801	203.24	53	3.83
13	July 29 July 30	19:54:10-20:53:34 7:33:20-21:00:00	-9,24435	35,55636	-12,1303	35,10866	132.56	16	8.29

As shown in the table above, the highest number of sightings (n. sight. = 105), occurred in transect 7, and the lowest number (n. sight. = 9), in transect 1. The average density values, r_t, vary from 1,22 to 11,51 debris sightings/km, indicating a high variability in the sighting distribution. However, r_t values are only presented as a simple indicator of the number of debris found, because these values cannot be quantitatively compared, given the high variability in transect lengths (Aliani *et al.*, 2003).

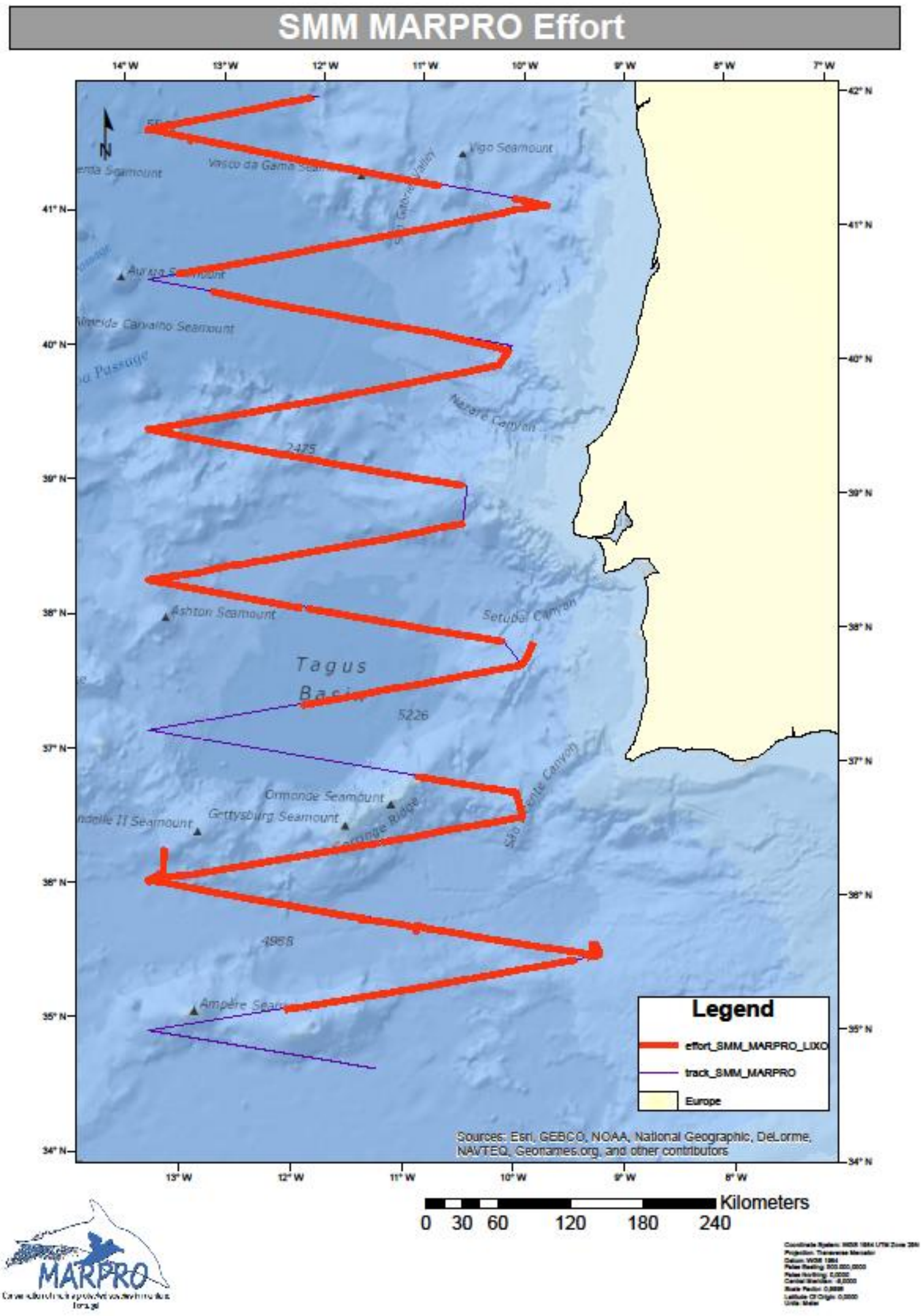

Figure 1. Line transects (in blue) and search effort (in red) of the survey.

The data introduced in distance program related to a total of 608 sightings. After the right-truncation at a strip width of 300 meters, the number of sightings decreased to 586. Mean density of debris (objects per km^2) in the study area overall was 2.96 (95% confidence intervals: 2.32-3.77) and marine debris total abundance was 747720 (95% confidence intervals: 586800-952800) pieces.

The selected model was hazard-rate with simple polynomial adjustments. Figure 2 shows the detection function that best described the data.

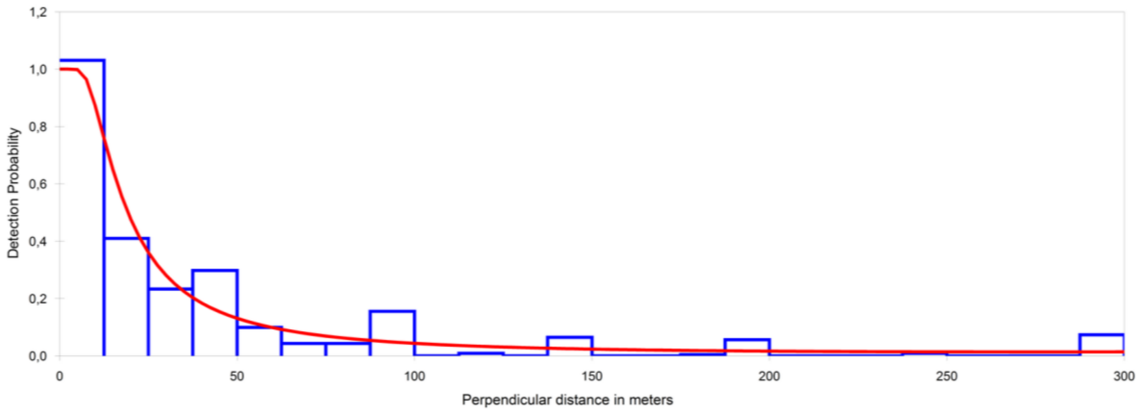

Figure 2. The selected detection function, showing probability of debris detection as a function of perpendicular distance from the trackline.

Floating marine debris were found in all transects. Debris sightings from the survey are shown in figure 3, where each color represents a different type of debris. Plastic was the more frequently sighted type of debris. In the marine debris kernel density map (figure 4) it is possible to see that the highest densities of sightings, including the maximum density, are found in the central zone of the study area. In the north part, the probability of occurrence of FMD – Floating Marine Debris is 60%, while the density of sightings is lower (40%) in the south zone.

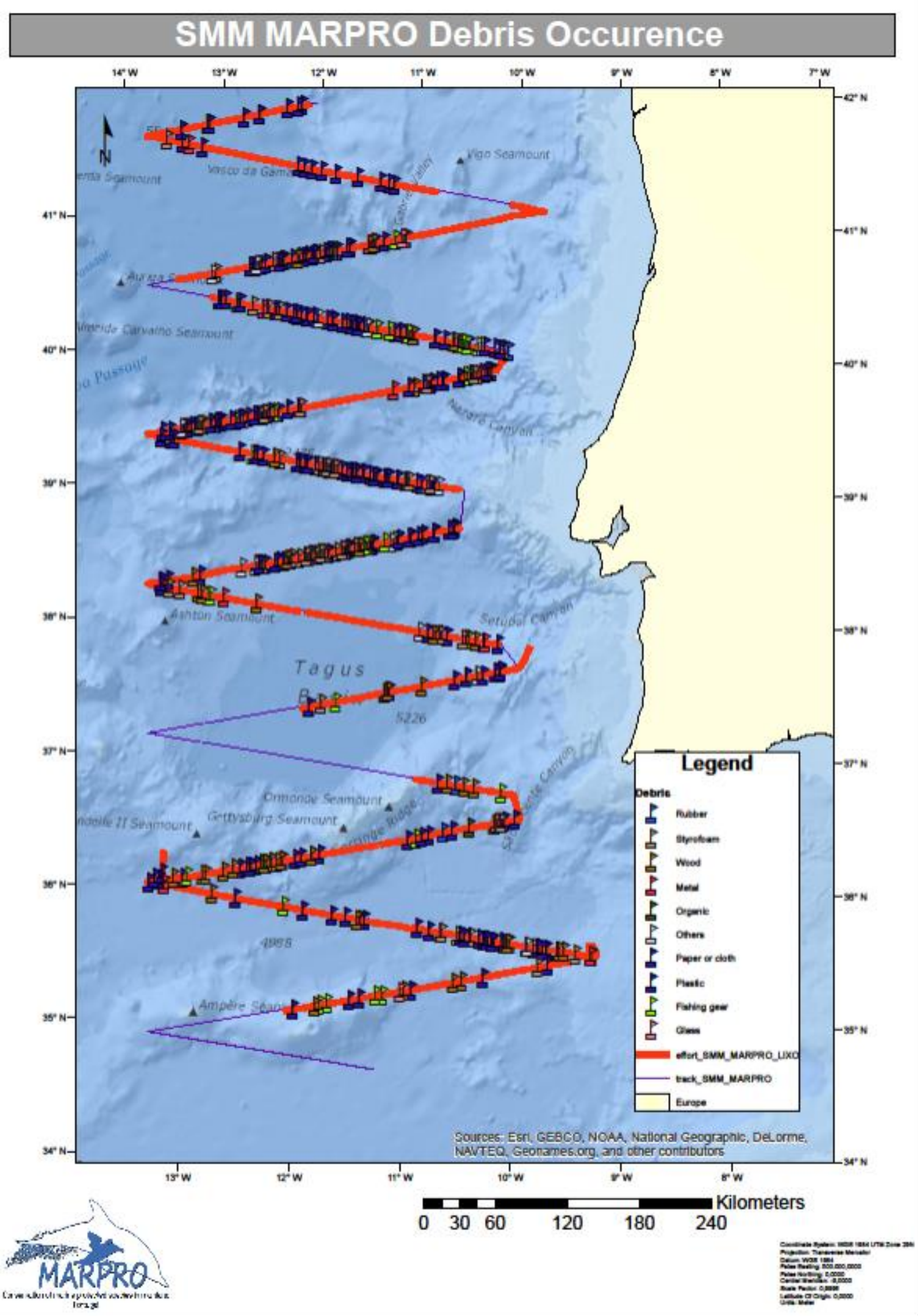

Figure 3. Locations of observed marine debris in the survey transects. The different colors represent different types of debris.

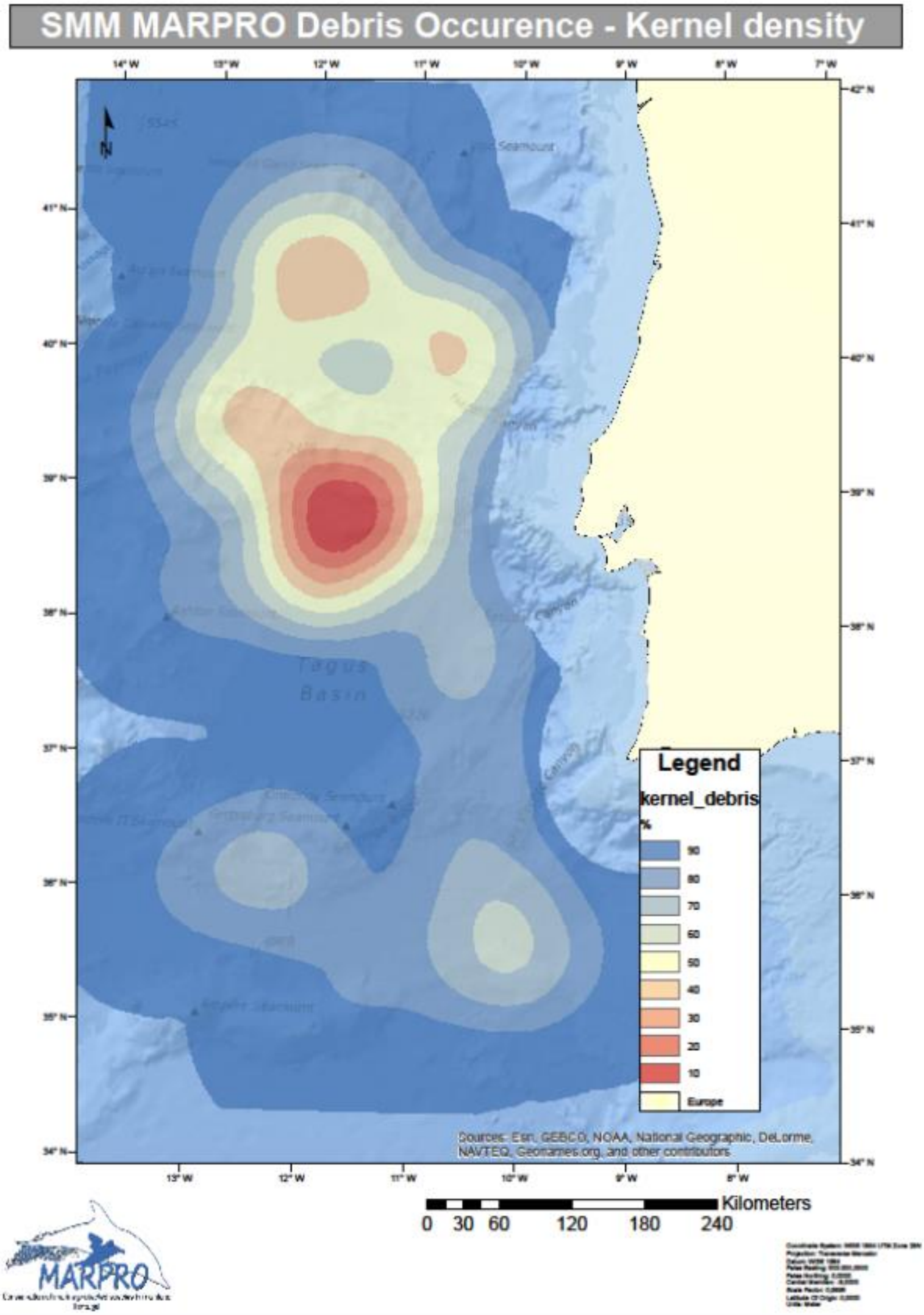

Figure 4. Floating marine debris kernel density map for all sightings (the lower the percentage, the higher the density of sightings).

The most common type of debris was PLFL – plastic float with a density of 0.46 objects per Km^2, and a total abundance for the entire surveyed areas of 117390 pieces (Table 6 and 7). This was followed by STPO – Styrofoam popcorn, with 0.36 objects per km^2 and a total abundance of 90594 objects; PLBA – plastic bags with 0.30 objects per km^2 and a total abundance of 75283 objects; PLOT - other plastic items with 0.26 objects per km^2 and a total abundance of 65075 objects; and plastic bottles (PLBO) with 0.24 objects per km^2 and a total abundance of 59971 objects.

Rubber (RU), other rubber items (RUOT), styrofoam floats (STFL), other wood items (WOOT), metal drums (MEDR), organic dead bird (ORBI), glass (GL) and glass light bulb or fluorescent tube (GLBU) were the less common categories. They all have the same density of 0.0050457 objects per km^2 and the same total abundance, 1276 objects in the entire surveyed area (Table 6 and 7).

Table 6. Density (objects per Km2), coefficient of variation (%CV) and 95% Confidence Interval (95% CI) of each type of debris observed during the survey.

Debris Type	Density (items km^2)	% CV	95% CI
PLFL – Plastic float	0.46421	39.15	0.2051 - 1.0507
STPO - Styrofoam popcorn	0.35825	44.89	0.1416 - 0.9066
PLBA - Plastic Bag	0.29770	25.98	0.1721 - 0.5150
PLOT - Other Plastic Item	0.25733	26.01	0.1487 - 0.4455
PLBO - Plastic Bottle	0.23715	21.20	0.1518 - 0.3706
PASH - Paper sheet	0.16651	54.75	0.0548 - 0.5060
MOLI - Monofilament line	0.15137	27.19	0.0853 - 0.2686
DEOT – Other debris	0.13119	37.89	0.0594 - 0.2897
PL – Plastic	0.12614	32.97	0.0631 - 0.2523
WOLU – Wood lumber or board	0.12110	24.52	0.0722 - 0.2032
MOFF – Lost fishing floats	0.085777	32.67	0.0432 - 0.1705
WOPA – Wood pallet or crate	0.075686	23.64	0.0459 - 0.1246
MECA – Metal can	0.055503	25.83	0.0322 - 0.0957
PACA – Cardboard or plasterboard	0.055503	31.83	0.0284 - 0.1084

PLST – Plastic Strap	0.055503	42.01	0.0232 - 0.1329
STOT - Other Styrofoam Item	0.050457	57.05	0.0159 - 0.1598
WOLO - Wood log or branch	0.035320	32.14	0.0180- 0.0694
PAOT - Other paper or cardboard item	0.030274	39.86	0.0132 - 0.0695
GLBO - Glass bottle or jar	0.030274	40.52	0.0130 - 0.0704
RUME - Rubber medical or health item	0.020183	60.17	0.0060 - 0.0675
ST - Styrofoam	0.020183	73.03	0.0049 - 0.0836
STCO - Styrofoam food or beverage containers	0.020183	77.77	0.0045 - 0.9007
MONE - Monofilament net	0.020183	48.22	0.0075 - 0.5440
WO – Wood	0.015137	68.39	0.0039 - 0.0582
MEOT – Other metal	0.015137	73.89	0.0036 - 0.0636
OROT - Other organic matter	0.010091	66.37	0.0027 - 0.0375
PA – Paper or cloth	0.010091	66.31	0.0027 - 0.0375
RU – Rubber	0.0050457	102.14	0.0008 - 0.0318
RUOT - Other rubber item	0.0050457	98.19	0.0008 - 0.0302
STFL - Styrofoam float	0.0050457	100.01	0.0008 - 0.0309
WOOT - Other Wood item	0.0050457	95.89	0.0009 - 0.0293
MEDR - Metal drum	0.0050457	102.14	0.0008 - 0.0318
ORBI - Organic dead bird	0.0050457	100.01	0.0008 - 0.0310
GL - Glass	0.0050457	100.01	0.0008 - 0.0309
GLBU - Glass light bulb or fluorescent tube	0.0050457	99.79	0.0008 - 0.0309

Table 7. Abundance (number of objects), coefficient of variation (%CV) and 95% Confidence Interval (95% CI) of each type of debris observed during the survey.

Debris Type	Abundance	% CV	95% CI
PLFL – Plastic float	117390	39.15	51862 - 265710
STPO - Styrofoam popcorn	90594	44.89	35800 - 229260
PLBA - Plastic Bag	75283	25.98	43517 - 130240
PLOT - Other Plastic Item	65075	26.01	37592 - 112650
PLBO - Plastic Bottle	59971	21.20	38376 - 93717
PASH - Paper sheet	42107	54.75	13856 - 127960

MOLI – Monofilament line	38279	27.19	21572 - 67928
DEOT – Other debris	33175	37.89	15025 - 73251
PL – Plastic	31899	32.97	15952 - 63791
WOLU – Wood lumber or board	30623	24.52	18255 - 51372
MOFF – Lost fishing floats	21692	32.67	10913 - 43116
WOPA – Wood pallet or crate	19140	23.64	11623 - 31516
MECA – Metal can	14036	25.83	8138 - 24207
PACA – Cardboard or plasterboard	14036	31.83	7185 - 27420
PLST – Plastic Strap	14036	42.01	5863 - 33601
STOT - Other Styrofoam Item	12760	57.05	4030 - 40404
WOLO - Wood log or branch	8932	32.14	4543 - 17561
PAOT - Other paper or cardboard item	7656	39.86	3335 - 17574
GLBO - Glass bottle or jar	7656	40.52	3292 - 17805
RUME - Rubber medical or health item	5104	60.17	1526 - 17073
ST - Styrofoam	5104	73.03	1232 - 21149
STCO - Styrofoam food or beverage containers	5104	77.77	1144 - 22776
MONE - Monofilament net	5104	48.22	1894 - 13757
WO - Wood	3828	68.39	996 - 14714
MEOT – Other metal	3828	73.89	911 - 16080
OROT - Other organic matter	2552	66.37	686 – 9487
PA – Paper or cloth	2552	66.31	687 – 9477
RU - Rubber	1276	102.14	203 – 8033
RUOT - Other rubber item	1276	98.19	213 – 7628
STFL - Styrofoam float	1276	100.01	208 – 7814
WOOT - Other Wood item	1276	95.89	220 – 7396
MEDR - Metal drum	1276	102.14	203 – 8033
ORBI - Organic dead bird	1276	100.01	208 – 7814
GL - Glass	1276	100.01	208 - 7814
GLBU - Glass light bulb or fluorescent tube	1276	99.79	209 - 7791

As already mentioned, the density and abundance of each size of the most abundant debris types were estimated: PLFL – Plastic float, STPO - Styrofoam popcorn, PLBA - Plastic Bag, PLOT - Other Plastic Item, PLBO - Plastic Bottle, PASH - Paper sheet, MOLI - Monofilament line, DEOT – Other debris, PL - Plastic, WOLU – Wood lumber or board (Table 8). The L size was the most abundant in the PLFL – Plastic float, PLOT - Other Plastic Item, PLBO - Plastic Bottle, PL - Plastic, MOLI - Monofilament line and PLBA - Plastic Bag debris types. As for the types STPO - Styrofoam popcorn, PASH - Paper sheet and DEOT – Other debris, M was the most common size, while in type WOLU – Wood lumber or board, XL was the most common size.

Table 8. Density (objects per km2), Abundance (number of objects) and respective coefficients of variation (%CV) and 95% Confidence Intervals (95% CI) of each size (S, M, L, XL) of each type of debris. PLFL – Plastic float, STPO - Styrofoam popcorn, PLBA - Plastic Bag, PLOT - Other Plastic Item, PLBO - Plastic Bottle, PASH - Paper sheet, MOLI - Monofilament line, DEOT – Other debris, PL - Plastic, WOLU – Wood lumber or board. In bold and grey shadow the most frequent size for each debris type.

Debris Type		Density	%CV	95% CI	Abundance	% CV	95% CI
PLFL	S	0.0059303	101.56	0.00095591 - 0.036791	1500	101.56	242 - 9304
	M	0.10082	47.55	0.038494 - 0.26404	25495	47.55	9734 – 66771
	L	**0.40919**	**41.71**	**0.17504 - 0.95657**	**103480**	**41.71**	**44265 - 241900**
	XL	0.017791	73.77	0.0042874 - 0.073825	4499	73.77	1084 – 18669
STPO	S	0.21591	55.27	0.070970 - 0.65686	54600	55.27	17947 – 166110
	M	**0.25743**	**47.73**	**0.097334 - 0.68087**	**65100**	**47.73**	**24614 - 0.172180**
	L	0.083043	53.08	0.028412 - 0.24272	21000	53.08	7185 – 61379
	XL	----------------	----------	--------------------------------	---------------	--------	---------------------------
PLBA	S	------------	---------	--------------------------------	---------------	--------	---------------------------
	M	0.011666	63.90	0.0034627 - 0.039303	2950	63.90	876 – 9939
	L	**0.19443**	**42.38**	**0.085971 - 0.43973**	**49169**	**42.38**	**21741 - 111200**
	XL	0.019443	55.43	0.0067216 - 0.056243	4917	55.43	1700 – 14223

PLOT	S	0.0047389	100.44	0.00079535 - 0.028235	1198	100.44	201 – 7140
	M	0.085300	46.50	0.034667 - 0.20989	21571	46.50	8767 – 53077
	L	**0.13743**	**42.51**	**0.060320 - 0.31310**	**34753**	**42.51**	**15254 - 79177**
	XL	0.0094777	72.79	0.0024026 - 0.037388	2397	72.79	608 – 9455
PLBO	S	--------------	----------	--------------------------------	---------------	-------	---------------------------
	M	0.0025830	104.05	0.00041395 - 0.016117	653	104.05	105 – 4076
	L	**0.11882**	**37.65**	**0.057269 - 0.24651**	**30047**	**37.65**	**14482 – 62339**
	XL	-------------	----------	-------------------------------	---------------	--------	--------------------------
PASH	S	0.015321	103.07	0.0024222 - 0.096916	3875	103.07	613 – 24508
	M	**0.13789**	**53.76**	**0.046875 - 0.40564**	**34871**	**53.76**	**11854 - 102580**
	L	0.099589	77.99	0.022466 - 0.44146	25184	77.99	5681 – 111640
	XL	---------------	-----------	---------------------------------	----------------	-------	---------------------
MOLI	S	-----------------	----------	---------------------------------	----------------	-------	------------------------
	M	0.034879	78.12	0.0082361 - 0.14771	8820	78.12	2083 - 37353
	L	**0.17439**	**47.88**	**0.069494 - 0.43764**	**44101**	**47.88**	**17574 – 110670**
	XL	0.043599	66.13	0.012554 - 0.15141	11025	66.13	3175 - 38289
DEOT	S	0.029916	80.51	0.0067603 - 0.13239	7565	80.51	1710 - 33479
	M	**0.11967**	**54.01**	**0.042443 - 0.33739**	**30261**	**54.01**	**10733 - 85320**
	L	0.10969	57.64	0.036430 - 0.33029	27739	57.64	9213 - 83525
	XL	---------------	---------	----------------------------------	--------------	--------	-------------------------
PL	S	0.0027593	105.41	0.00042446 - 0.017938	698	105.41	107 - 4536
	M	0.019315	49.37	0.0071636 - 0.052081	4885	49.37	1812 - 13170.
	L	**0.038631**	**47.72**	**0.014783 - 0.10095**	**9769**	**47.72**	**3738 – 25529**
	XL	0.0082780	72.40	0.0020479 - 0.033462	2093	72.40	518 - 8462
WOLU	S	--------------	-----------	----------------------------------	----------------	--------	---------------------------
	M	-------------	----------	----------------------------------	-------------	--------	---------------------------
	L	0.018431	34.13	0.0092498 - 0.036724	4661	34.13	2339 – 9287
	XL	**0.023960**	**49.69**	**0.0088398 - 0.064943**	**6059**	**49.69**	**2235.0 - 16423**

Dangerous debris for cetaceans (DDFC)

Density estimated for the group of debris dangerous for cetaceans (DDFC) was 0.81 objects per Km^2 (95% CI: 0.52 - 1.26), and the total abundance was 204020 objects (95% CI: 130630 – 318650) (Table 9). The selected detection function was hazard rate with simple polynomial adjustments (figure 5). The kernel density map for the sightings of marine debris that can endanger cetaceans (figure 6) reveals two areas of higher density, one in the north part of the study area and other in the south. However, the probability of dangerous debris occurrence in these two areas is only 30% for the northern area and 20% for the southern area.

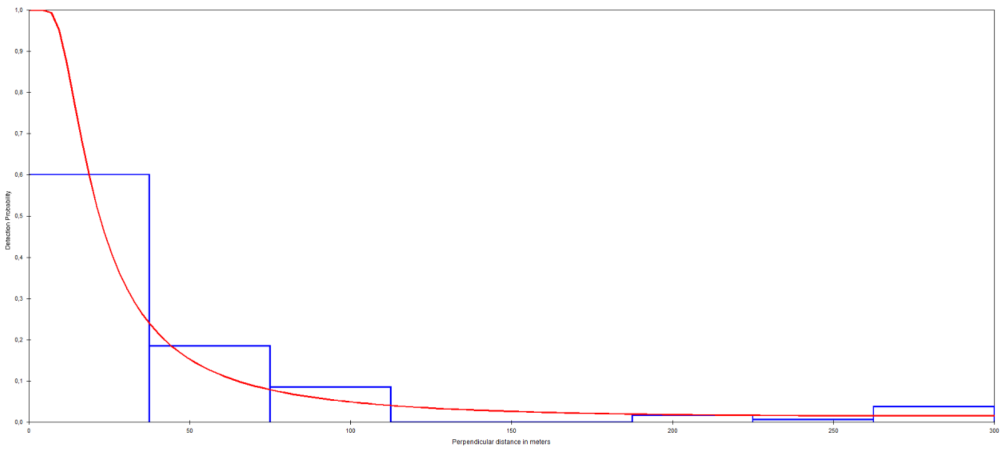

Figure 5. The selected detection function, showing probability of detection of debris dangerous for cetaceans (DDFC) as a function of perpendicular distance from the trackline.

Table 9. Density (objects per km2), Abundance (number of objects) and respective coefficients of variation (%CV) and 95% Confidence Intervals (95% CI) of the group of dangerous debris for cetaceans (DDFC).

	Density	%CV	95% CI	Abundance	%CV	95% CI
DDFC	0.80680	21.87	0.51658 - 1.2601	204020	21.87	130630 - 318650

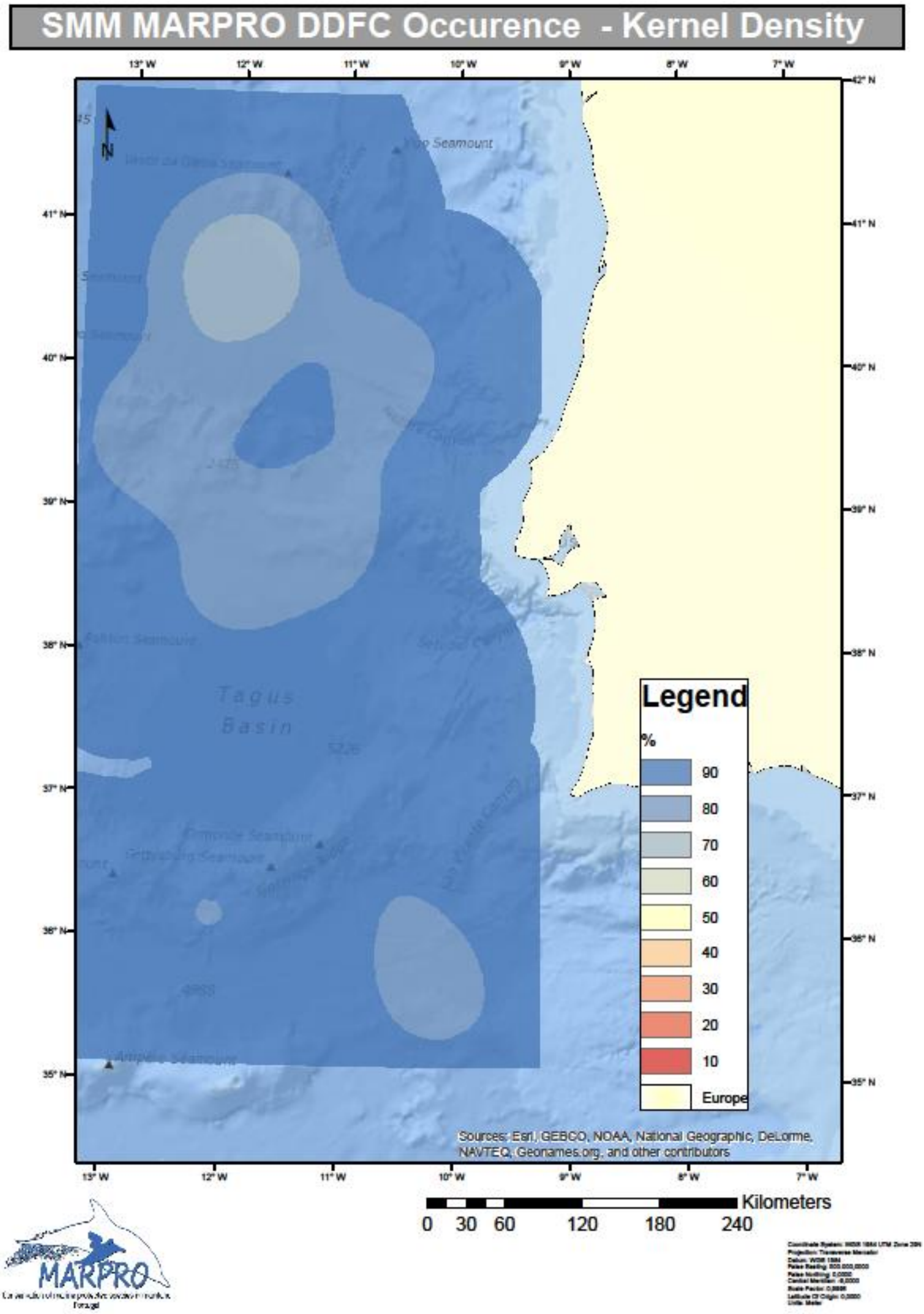

Figure 6. Kernel density map for all sightings of dangerous floating marine debris for cetaceans.

Geographical distribution of marine debris

In what concerns a possible similarity between transects in terms of marine debris occurrence, the results from the PCA (Table 10 and 11) explained 80,75% of the total variation, with PC1 and PC2 accounting for 70,64% and 10,11% respectively. All other components were considered irrelevant to the analysis.

Table 10. PCA on the amount of debris/10 km in the surveyed transects (T1 till T13) correspond to the number of surveyed transects). Eigenvalues, percentage of variability and cumulative percentage of variability.

	Eigenvalue	Variability(%)	Cumulative (%)
PC1	0,486	70,64	70,64
PC2	0,07	10,11	80,75

Table 11. PCA on the amount of debris/10 km in the surveyed transects (T1 till T13 correspond to the number of surveyed transects). Coefficients for each transect for the first two principal components and factor scores, contributions to the components (in percentage), and squared cosines of the transects on principal components 1 and 2. The positive important contributions are highlighted in dark grey shadow and the negative important contributions are highlighted in light grey shadow.

	Northern Sector							Southern Sector					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**
PC1	-0,008	0,020	0,112	0,520	0,441	0,474	0,540	0,058	0,004	-0,010	0,009	0,047	-0,006
PC2	0,179	0,049	0,576	0,378	-0,039	-0,223	-0,286	-0,068	0,246	0,020	0,366	0,372	0,145
F1	-0,006	0,014	0,078	0,362	0,308	0,331	0,376	0,040	0,003	-0,007	0,007	0,033	-0,004
F2	0,047	0,013	0,152	0,100	-0,010	-0,059	-0,075	-0,018	0,065	0,005	0,096	0,098	0,038
ctr1 %	0,0	0,0	1,3	27,0	19,5	22,5	29,1	0,3	0,0	0,0	0,0	0,2	0,0
ctr2 %	3,2	0,2	33,1	14,3	0,1	5,0	8,2	0,5	6,1	0,0	13,4	13,8	2,1
sqrcos1	0,00	0,07	0,13	0,81	0,81	0,94	0,86	0,23	0,00	0,00	0,00	0,08	0,00
sqrcos2	0,16	0,06	0,50	0,06	0,00	0,03	0,03	0,05	0,35	0,00	0,53	0,70	0,28

Based on the coefficients, factor scores and contributions to the components for each Transect, the PC1 reflects a greater similarity between transects 4 to 7 (as also verified with the Kernel map in Figure 4). With lesser importance it is possible to join Transect 3 to this group. All these transects were geographically in the same region (Figure 1) and occurred in the northern part (north of Lisbon) of the surveyed area. In Table 12 it is possible to verify that the debris categories that more contribute to the similarity between transects 4 to 7 are: PLFL (Plastic float), PLBO (Plastic bottle), PLBA (Plastic bag) and STPO (Styrofoam popcorn).

Table 12. PCA on the amount of debris/ 10 km in the surveyed transects. Factor scores, contributions to the components (in percentage), and squared cosines of the debris type observations on principal components 1 and 2. The positive important contributions are highlighted in dark grey shadow and the negative important contributions are highlighted in light grey shadow.

	F1	*F2*	*ctr1 %*	*ctr2 %*	*sqrcos1*	*sqrcos2*
ORBI - Organic dead bird	-0,396	-0,091	0,9	0,3	0,90	0,05
OROT – Other organic matter	-0,395	-0,069	0,9	0,2	0,92	0,03
PL - Plastic	-0,387	0,324	0,9	5,2	0,17	0,12
PLFL – Plastic float	2,910	0,094	48,4	0,4	0,95	0,00
PLBO – Plastic bottle	0,623	0,115	2,2	0,5	0,51	0,02
PLST – Plastic strap	-0,062	-0,101	0,0	0,4	0,05	0,14
PLBA – Plastic bag	0,890	0,661	5,5	17,4	0,48	0,26
PLOT – Other plastic item	0,293	0,994	0,5	39,5	0,08	0,87
WO - Wood	-0,400	-0,070	0,9	0,2	0,90	0,03
WOLO – Wood log or branch	-0,217	-0,121	0,3	0,6	0,50	0,15
WOLU – Wood lumber or board	-0,272	0,142	0,4	0,8	0,17	0,05
WOPA – Wood pallet or crate	-0,201	0,067	0,2	0,2	0,32	0,04
WOOT – Other wood item	-0,402	-0,113	0,9	0,5	0,89	0,07

MONE – Monofilament net	-0,368	-0,111	0,8	0,5	0,70	0,06
MOLI – Monofilament line	0,320	0,173	0,6	1,2	0,31	0,09
MOFF – Lost fishing floats	0,316	0,086	0,6	0,3	0,52	0,04
GL - Glass	-0,396	-0,091	0,9	0,3	0,90	0,05
GLBO – Glass bottle or jar	-0,239	-0,100	0,3	0,4	0,66	0,11
GLBU – Glass light bulb or fluorescent tube	-0,366	-0,152	0,8	0,9	0,82	0,14
RU - Rubber	-0,355	-0,096	0,7	0,4	0,83	0,06
RUBA – Rubber balloon	-0,396	-0,091	0,9	0,3	0,90	0,05
RUME – Rubber medical or health item	-0,282	-0,132	0,5	0,7	0,54	0,12
RUOT – Other rubber item	-0,354	-0,074	0,7	0,2	0,86	0,04
MECA – Metal can	-0,244	0,078	0,3	0,2	0,63	0,06
MEDR – Metal drum	-0,315	-0,098	0,6	0,4	0,80	0,08
MEOT – Other metal item	-0,273	-0,076	0,4	0,2	0,63	0,05
ST - Styrofoam	-0,389	-0,036	0,9	0,1	0,86	0,01
STCO – Styrofoam food or beverage containers	-0,282	0,063	0,5	0,2	0,60	0,03
STFL – Styrofoam float	-0,358	-0,110	0,7	0,5	0,85	0,08
STPO – Styrofoam popcorn	1,950	-0,820	21,7	26,9	0,76	0,13
STOT – Other styrofoam item	-0,397	0,056	0,9	0,1	0,62	0,01
PA – Paper or cloth	-0,353	-0,078	0,7	0,2	0,84	0,04
PASH – Paper sheet	0,784	-0,072	3,5	0,2	0,41	0,00
PACA – Cardboard or plasterboard	-0,167	-0,111	0,2	0,5	0,36	0,16
PAOT – Other paper or cardboard item	-0,303	0,008	0,5	0,0	0,82	0,00
DEOT – Other debris	0,484	-0,048	1,3	0,1	0,72	0,01

The PC2 contributes less to the analysis, but it associates 3 transects in the Southern part of the surveyed area (Transect 9, 11 and 12). These 3 Southern transects have some similarity with Transects 3 and 4 of the Northern region, but they are different in terms of debris in what concerns Transects 6 and 7. Based on Table 12, it is possible to verify that the debris categories that positively contribute to the association between transects 3, 4, 9, 11 and 12 are: PL (Plastic), PLBA (Plastic bag) and PLOT (Other plastic item). At the same time STPO (Styrofoam popcorn) is the only debris category that separates this large group from Transects 6 and 7. In these last two Transects STPO (Styrofoam popcorn) is the dominant debris category, while in the first 5 transects this debris category is almost absent.

Because both Kernel maps and PCA analysis revealed that floating marine debris seem to show geographical differences, comparisons between two geographical regions were made (Table 13) using a non-parametric t-test. This analysis was used in order to check for possible differences not only in the major debris categories (the ones that were identified in the PCA), but also for other debris types. The results from the comparison of 19 debris categories (plus another category with all other low occurrence categories) showed that there are significant geographical differences for 10 debris categories. The analysis also pointed out that 8 categories were more frequent in the Northern sector (PLFL – Plastic float; PLBO – Plastic bottle; PLST – Plastic strap; PLBA – Plastic Bag; MOLI – Monofilament line; STOT - Other styrofoam item; PAOT - Other paper or cardboard item and PASH - Plastic sheet). Only two categories of debris were significantly more detected in the Southern sector: WOLU (Wood lumber or board) and MONE (Monofilament net).

Table 13. Mann-Whitney results for the comparison of main debris types (19 of the 36 detected categories) in the 2 surveyed sectors (North and South). (ns: non-significant, * p-value<0,05, ** p-value<0,01).

	Mann-Whitney U	p-value	Sector with higher occurrence
PL – Plastic	10,50	ns	
PLFL – Plastic float	5,00	*	North
PLBO – Plastic bottle	2,00	**	North
PLST – Plastic strap	3,00	**	North
PLBA – Plastic bag	5,00	*	North
PLOT – Other plastic item	20,00	ns	
WOLO – Wood log or branch	12,00	ns	
WOLU – Wood lumber or board	0,50	**	South
WOPA – Wood pallet or crate	12,00	ns	
MONE – Monofilament net	6,00	*	South
MOLI – Monofilament line	19,50	ns	
MOFF – Lost fishing float	4,00	*	North
GLBO – Glass bottle or jar	12,50	ns	
MECA – Metal can	19,00	ns	
STOT - Other styrofoam item	5,00	*	North
PASH – Paper sheet	6,00	*	North
PACA – Cardboard or plasterboard	20,00	ns	
PAOT - Other paper or cardboard item	7,00	*	North
DEOT – Other debris	9.00	ns	
Other small debris (17 debris categories)	16,50	ns	

Vessels

Mean density of vessels (vessels per km^2) in the study area was 0.00134 (95% CI: 0.00029 - 0.00628) and the estimated abundance was 340 (95% CI: 73 - 1587). The selected detection function was hazard rate with simple polynomial adjustments, represented in figure 7. Vessel sightings from the survey are shown in figure 8, where each color represents a different type of vessel. The vessel kernel density map, represented in figure 9, shows three areas, two in the central zone and one in the south, with higher densities. These areas have a probability of vessel occurrence of 90%.

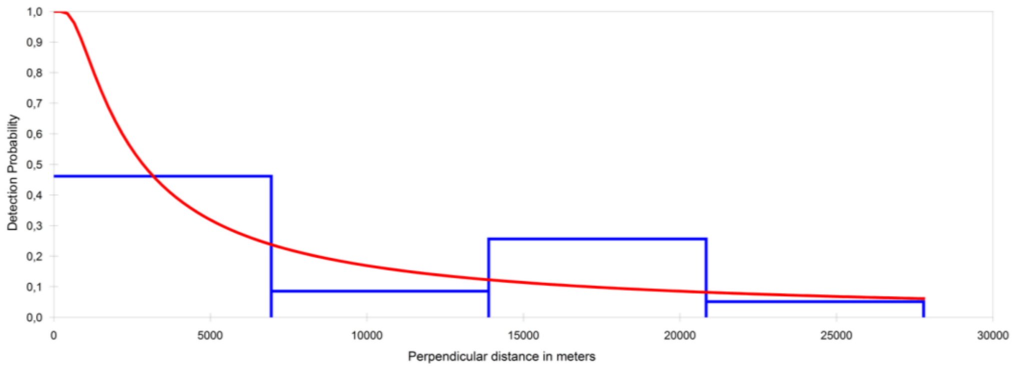

Figure 7. The selected detection function, showing probability of vessel detection as a function of perpendicular distance from the trackline.

Density and abundance of each type of vessel was estimated (table 14). The type of vessel with the highest abundance, 109 vessels, and density, 0.00043 vessels per km^2 was TPC - Container (represented in dark blue), followed by TP - Transport, with an abundance of 95 vessels, and density of 0.00038 vessels per km^2. The less common types were FI - fishery and TPF – Ferry-boat, both with a total of 7 vessels, and a density of 0.00003 vessels per km^2.

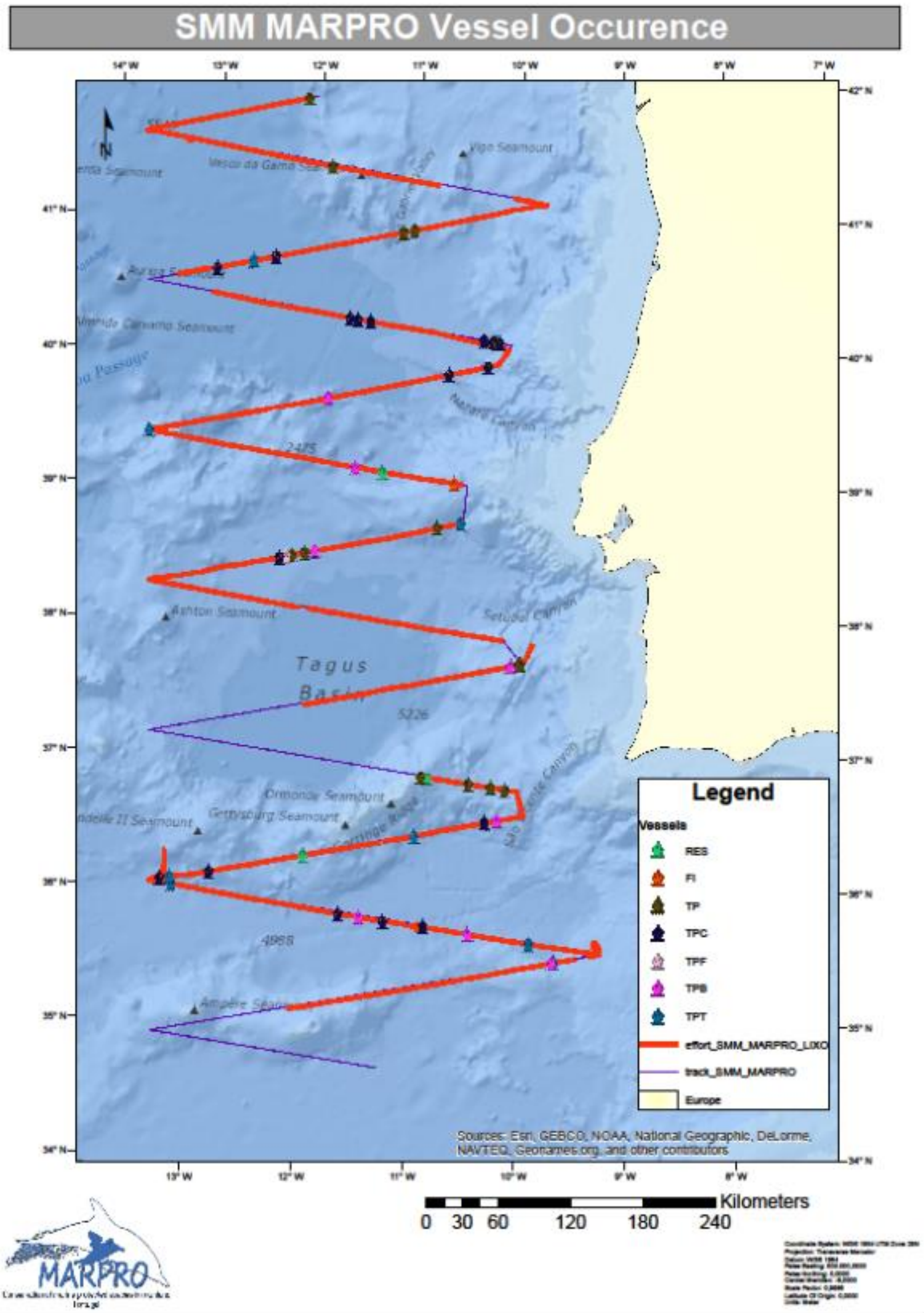

Figure 8. Locations of observed vessels in the survey transects. The different colors represent different types of vessels.

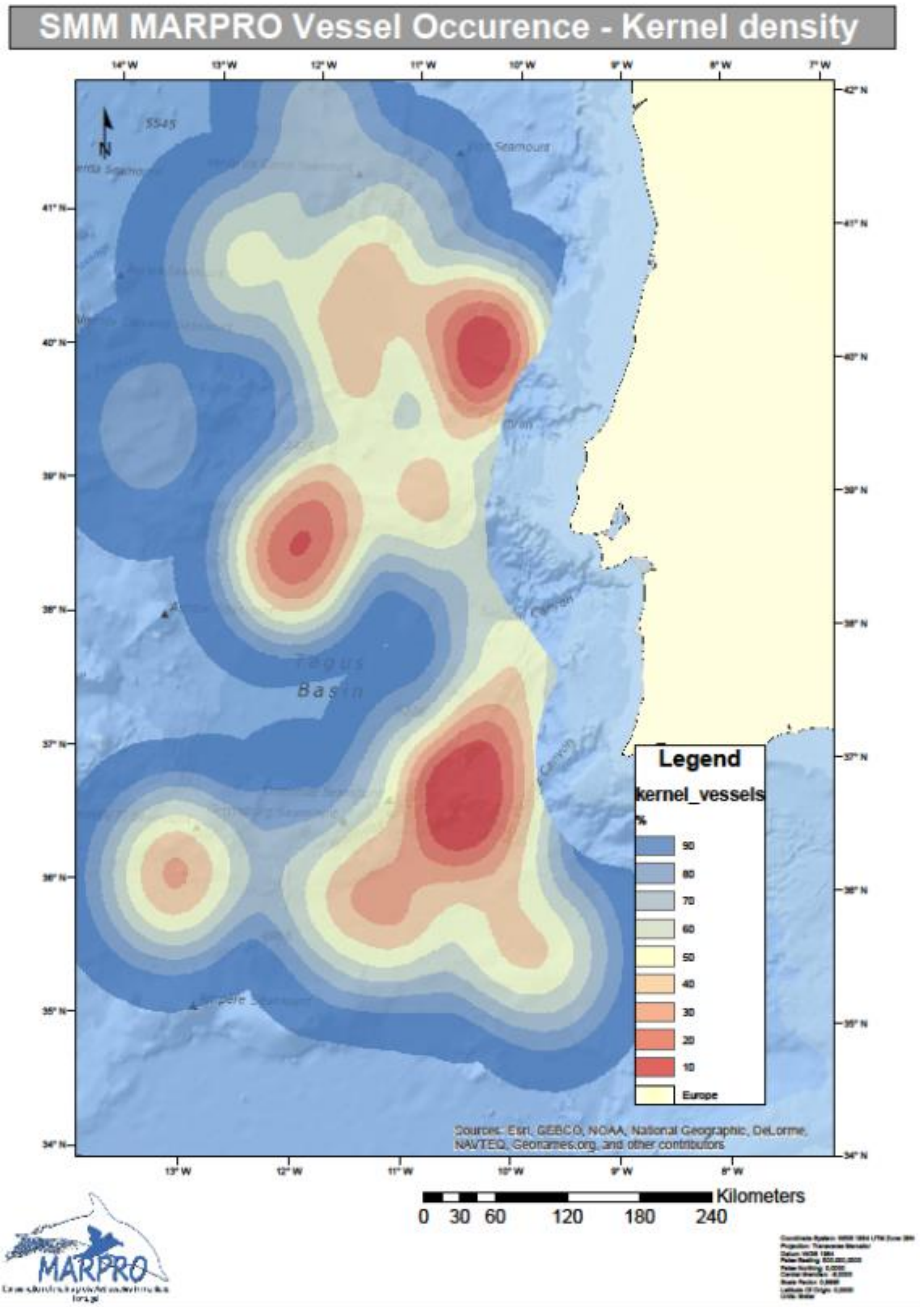

Figure 9. Vessel kernel density map for all vessel sightings from the survey (the lower the percentage, the higher the density of sightings).

Table 14. Density (objects per km2), Abundance (number of objects) and respective coefficients of variation (%CV and 95% Confidence Intervals (95% CI) of each type of vessel.

Vessel Type	Density	%CV	95% CI	Abundance	%CV	95% CI
RES - Sailboat	0.000081	103.59	0.000015 - 0.000445	20	103.59	4 - 113
FI - Fishery	0.000027	132.81	0.000003 - 0.000209	7	132.81	1 - 53
TP - Transport	0.000376	96.61	0.000074 - 0.001909	95	96.61	19 - 483
TPC - Container	0.000430	94.75	0.000087 - 0.002133	109	94.75	22 - 539
TPF – Ferry-boat	0.000027	132.81	0.000003 - 0.000209	7	132.81	1 - 53
TPB – Bulk cargo	0.000188	93.04	0.000039 - 0.000914	48	93.04	10 - 231
TPT – Oil tanker	0.000215	92.67	0.000044 - 0.001041	54	92.67	11 - 263

Cetaceans

The Kernel density for all cetaceans species sighted in this campaign is shown in Figure 10. Cetacean species sighted include: striped dolphin (*Stenella coeruleoalba*), common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncatus*), spotted dolphin (*Stenella frontalis*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), minke whale (*Balaenoptera borealis*), long-finned pilot whale (*Globicephala melas*) and Cuvier's beaked whale (*Ziphius cavirostris*) (Santos *et al.,* 2012).

A Kernel transformation of the sightings data revealed three areas of higher occurrence (90%), the largest being the area located farther north (Figure 10).

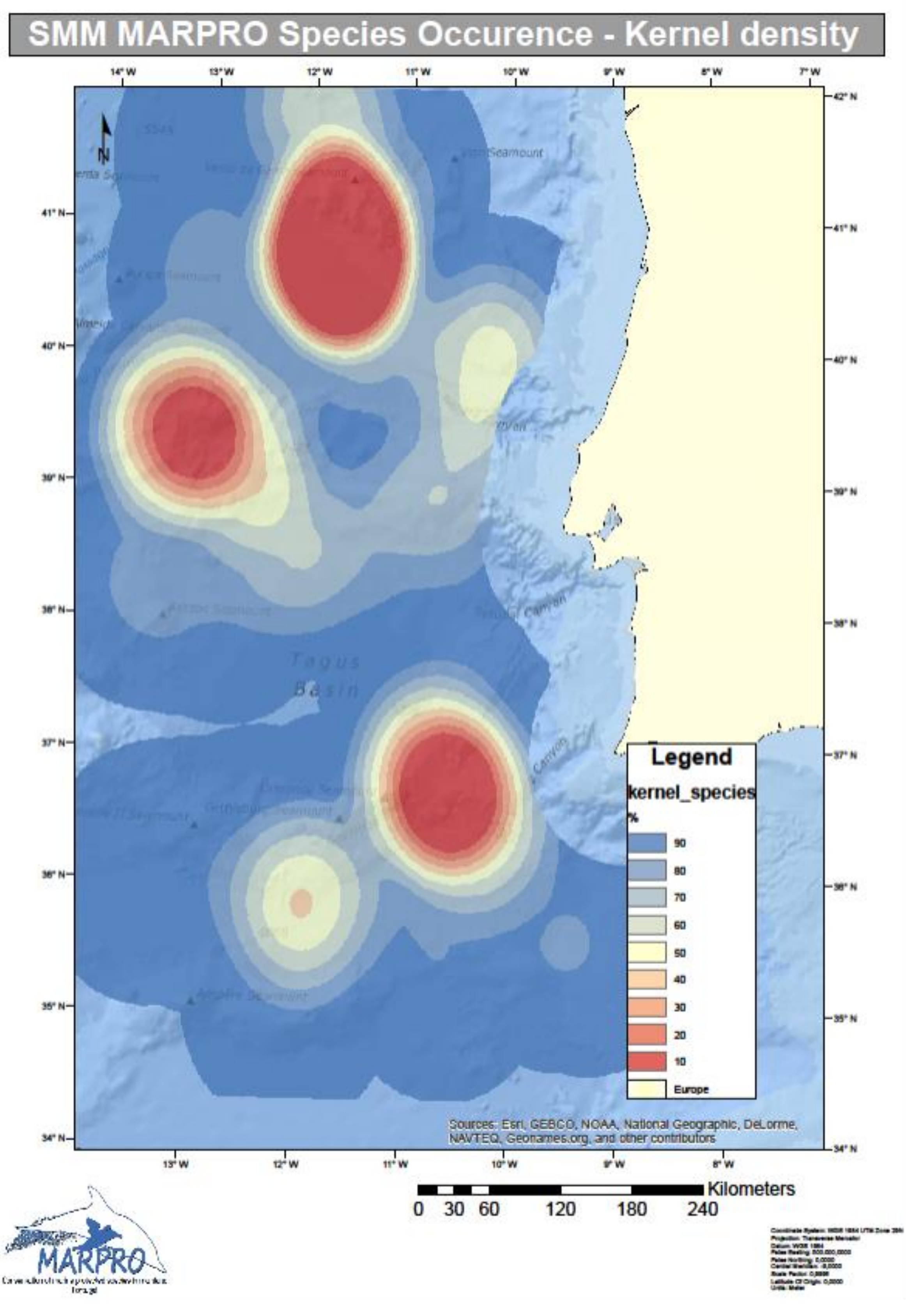

Figure 10. Kernel density map for all cetacean sightings in the MARPRO campaign.

Chapter IV: Discussion

The main objectives of this study – to obtain estimates of abundance and density of marine debris and vessels, as well as their spatial distribution along the study area – were accomplished. Overall abundance of floating marine debris was estimated to be 747720 (95% confidence intervals: 586800-952800) and mean density was 2.96 per Km^2 (95% confidence intervals: 2.32-3.77). With respect to vessels, the mean density (objects per Km^2) was 0.00134 (95% CI: 0.00029 - 0.00628) and the abundance was 340 pieces.

This study represents the first quantitative survey of floating marine debris and vessels in the Portuguese Continental offshore waters, thus no temporal comparisons can be made for this region. Moreover, abundance studies on floating marine debris in other regions of the world, conducted in offshore waters are also not available. Thiel *et al.* (2011) using a similar field methodology (ship surveys), obtained 25.2 items per km^2 for the White Bank sector, 28.0 items per Km^2 for the Helgoland sector and 38.6 items per km^2 for the East Frisia sector (all in the North Sea). So, in the German Bight in the North Sea, marine floating debris densities were higher than those estimated in the present study. In the Coastal System of Coquimbo, located in the northern-central Chile, mean densities of 30 items per km^2 were found for coastal waters also using ship surveys (Thiel *et al.*, 2013). In the Ligurian Sea, in the north-western Mediterranean, densities of floating marine debris ranged from 14.2 items per km^2 in 1997, to 3.4 and 2.9 items per km^2 in 2000 (Aliani *et al.,* 2003). On the other hand, lower densities and abundances of floating marine debris were reported for the coastal waters of British Columbia, Canada. The mean density obtained in this region was 1.48 items per km^2 and the abundance was 36000 objects, approximately half of the values obtained in the present study (Williams *et al.*, 2011).

As expected, plastic items (PLFL – plastic float, PLBA - plastic bags, PLBO - plastic bottles, and PLOT - other items of plastic) and STOP – Styrofoam popcorn (the second most abundant) were the dominant types of marine debris. The main reasons for that might be the high floatability of these materials (Thiel *et al.,* 2003), the extensive use of plastic for a variety of purposes and its long persistence in the marine environment (Derraik, 2002). The proportional dominance of plastic items among marine debris has also been reported for the Great Pacific Garbage Patch (Moore, 2003).

The size Large (L size) was the most common in 6 out of 10 types of debris (PLFL, PLOT, PLBO, PL, MOLI and PLBA). The fact that the marine debris of larger dimensions are more easily sighted may have contributed to this result. Another reason for this dominance may be the higher resistance and lesser degradation of plastic materials and fishing cables, making them more durable and allowing them to float for longer periods (Ryan *et al.,* 2009). Thus, these materials remain with large dimensions while other materials such as wood, cloth and paper are degraded more easily, being detected in smaller sizes.

With regard to potential marine debris sources, it is known that the beaches of the Portuguese coast are affected by plastic accumulation both originating from land sources, as river discharges and population concentration along the coast, and from marine sources, such as fishing and recreational maritime activities. The coast of Portugal is also an important route for commercial vessels and cruise ships, which can also be a source of plastic pollution (Martins & Sobral, 2011).

Comparing the kernel density maps of floating marine debris and cetaceans (figure 11), it is possible to note that in the areas of higher occurrence of marine debris, cetacean occurrence is lower, i.e., the areas of higher occurrence of marine debris and cetaceans do not overlap. Therefore, it can be hypothesized that cetaceans are avoiding the most polluted areas.

Comparing the kernel density map of vessels and cetaceans (figure 12), it is possible to see that in the north region, the areas of higher occurrence of vessels and cetaceans are not overlapped. However, in the south region, the area of higher occurrence of vessels is coincident with the area of higher occurrence of cetaceans. The high occurrence of cetaceans in this area may be related with the location of the Gorringe bank, a group of seamounts, which are considered geographic features with very high productivity that can be used by migratory species or those with a wide area of distribution as places for feeding or spending key periods in their lifecycles, such as mating and reproduction. Therefore, it is possible to understand the relatively high cetacean sightings in this area, despite of the high occurrence of

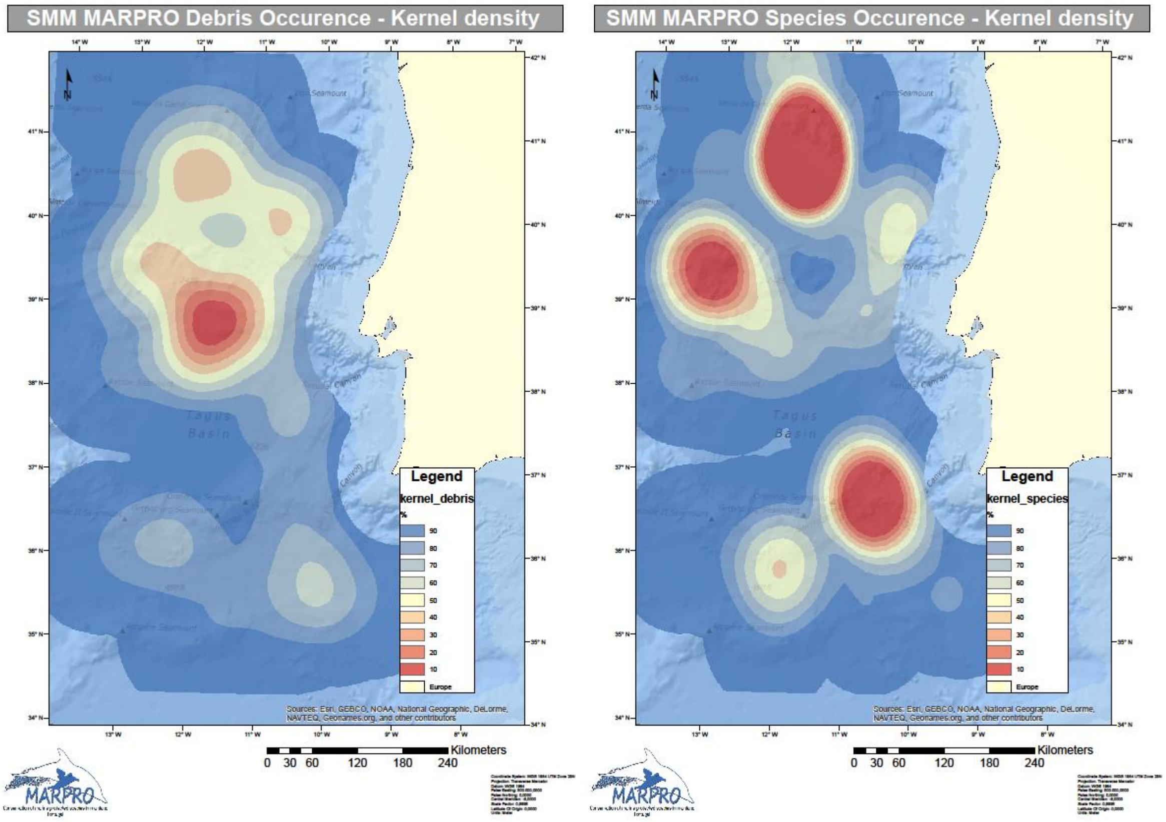

Figure 11. Kernel density maps of floating marine debris and cetaceans.

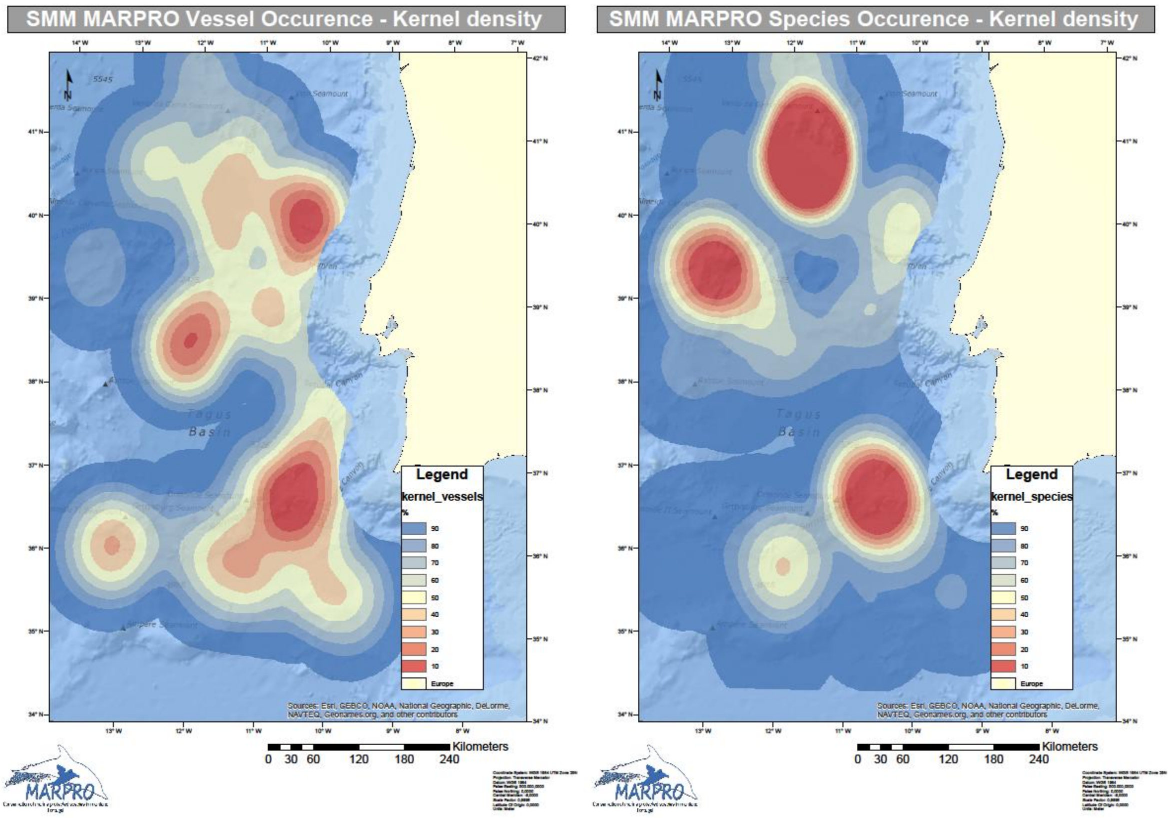

Figure 12. Kernel density maps of vessels and cetaceans.

The high occurrence of vessels in the south region of the surveyed area corresponds to the crossing point of several maritime corridors. Figure 13 shows maritime corridors of transport vessels between the Mediterranean and the North of Europe, between the American continent and the Mediterranean and between Africa and Europe. The overlapping section of these maritime corridors corresponds to the area where the highest occurrence of vessels was detected.

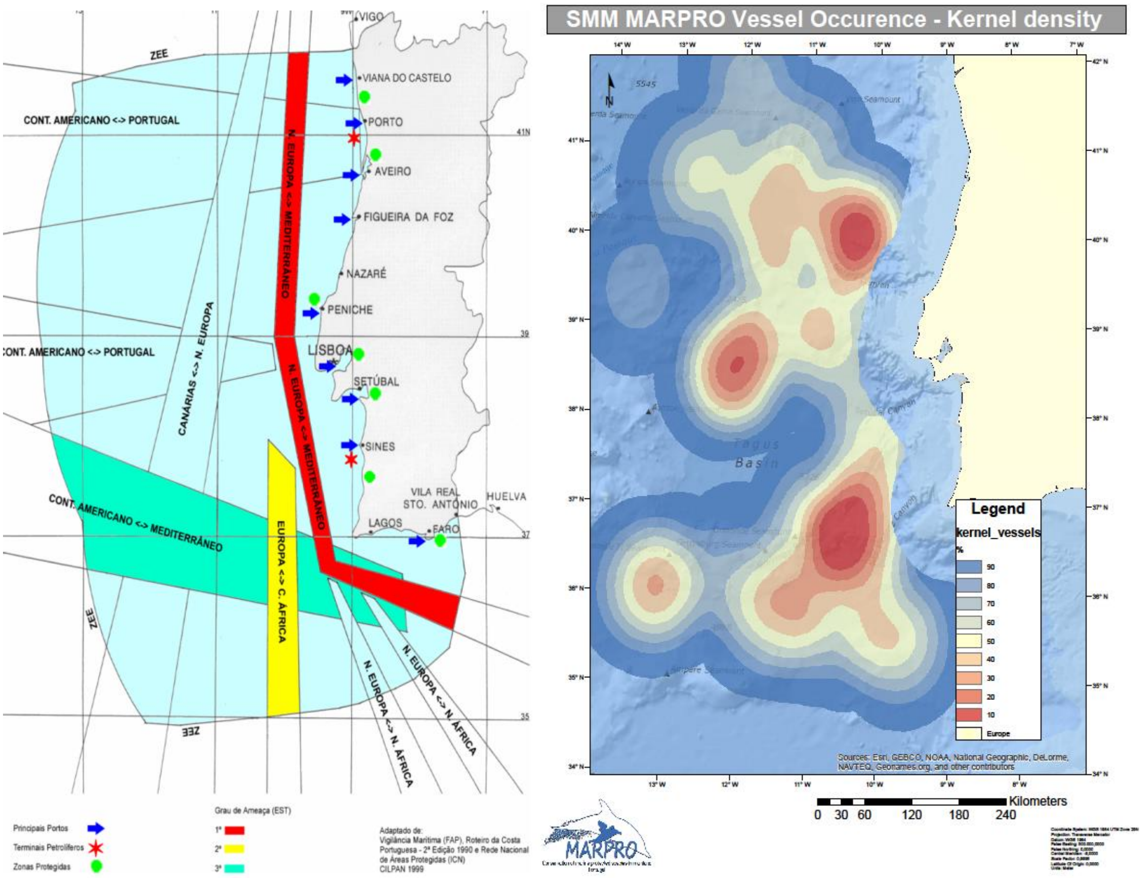

Figure 13. Map of maritime corridors for the Portuguese ZEE and the kernel density map of vessels.

Comparing the kernel density map of floating marine debris and vessels (figure 14), it can be seen that the area with higher occurrence of marine debris (in the north zone of the study area) is coincident with an area of high occurrence of vessels due to the overlap of several corridors leaving from the main harbor in Portugal. However, in the other areas of high occurrence of vessels, the occurrence of marine debris is reduced. This result may be related with ocean currents, a factor that was not addressed in detail in this study. The currents may contribute to the spatial distribution of floating marine debris and may be also responsible for the transport of debris to other areas or directions (the preliminary results may show a tendency for floating debris to be transported in a south – northward direction).

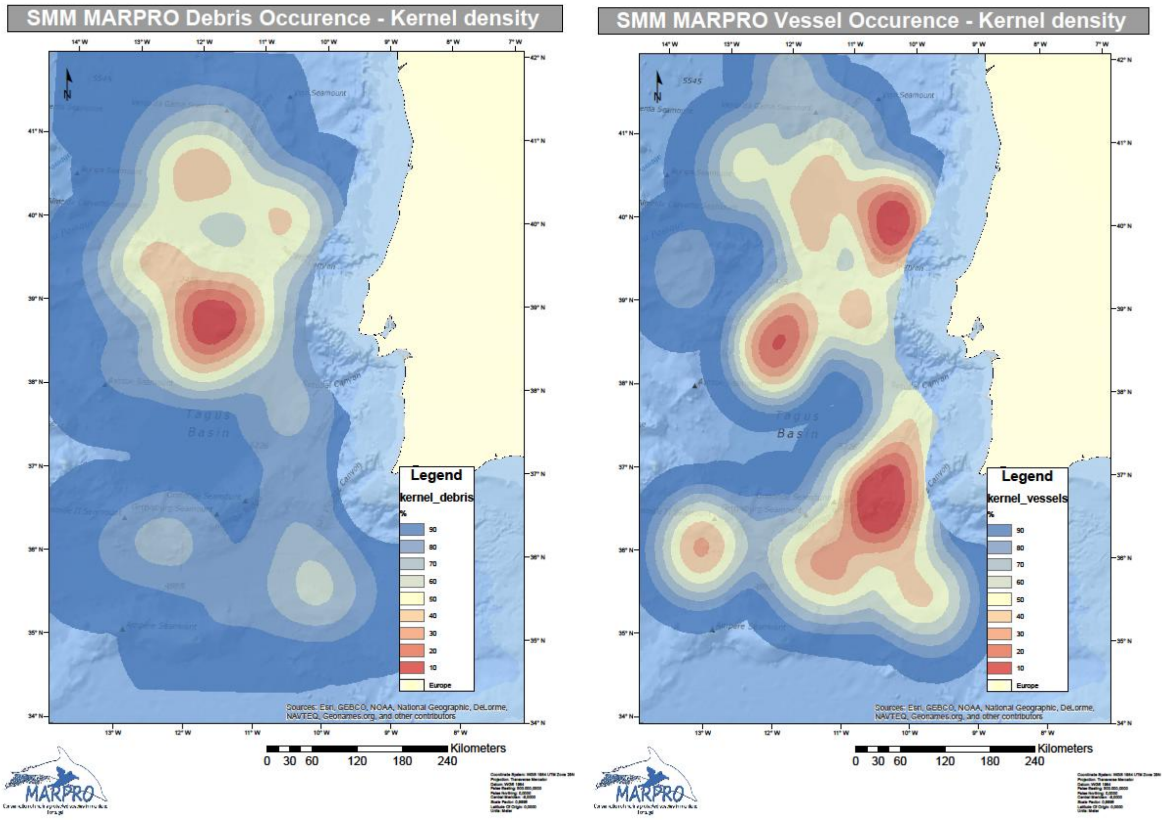

Figure 14. Kernel density maps of floating marine debris and vessels.

Observing and comparing the kernel density maps of dangerous debris for cetaceans (DDFC) and of cetaceans (figure 15), it is possible to verify that, despite the lower occurrence of dangerous debris for cetaceans (always below 60% kernel density) in comparison with all floating marine debris, the areas of higher occurrence of dangerous debris for cetaceans (DDFC) overlaps the areas of higher occurrence of cetaceans. This fact might be a cause for concern, because in the identified areas the interaction between marine mammals and marine debris, such as entanglement or ingestion, is more likely to occur.

The spatial overlap between marine debris and cetaceans does not mean that entanglement or ingestion actually occur, however it is obviously required for the occurrence of entanglement and ingestion. The likelihood of ingesting debris or becoming entangled is not solely a function of proximity, and not all interactions will result in fatalities. Our results do not provide evidence for problems, but instead they identify where to look for potential problems (Williams *et al.*, 2011).

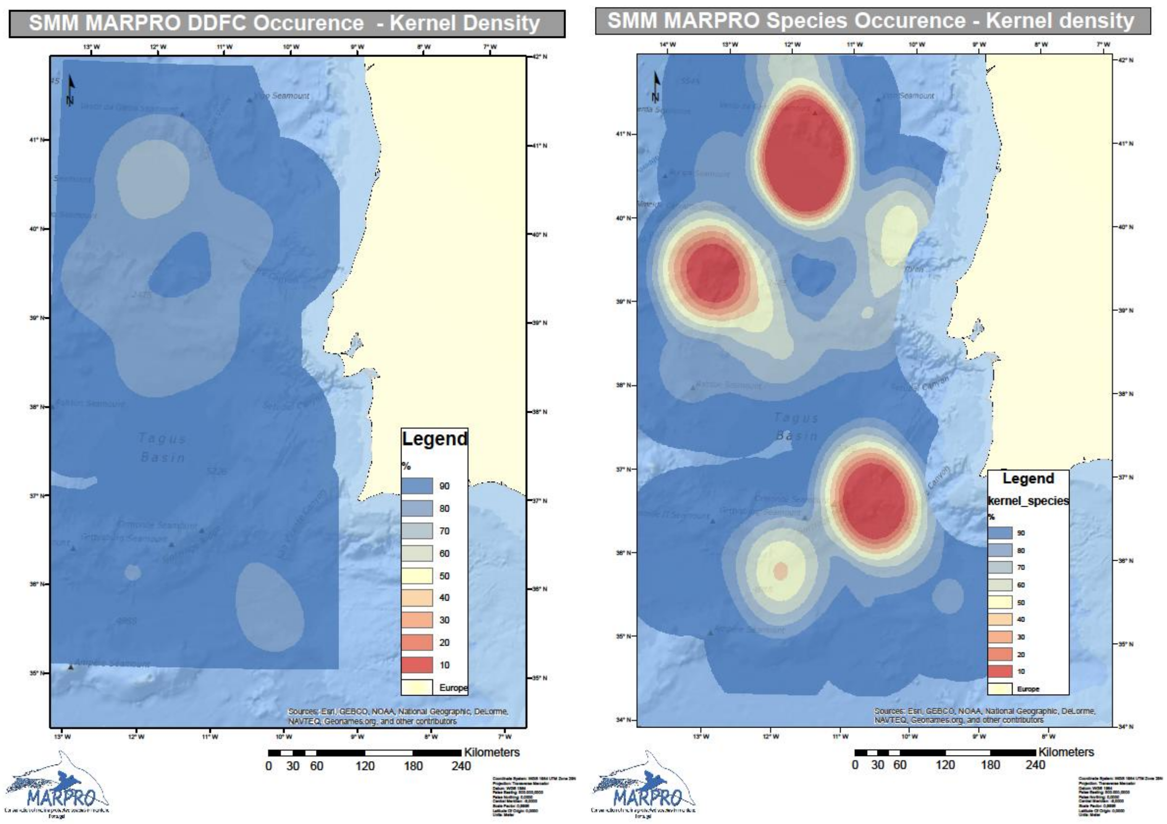

Figure 15. Kernel density maps of the risk group "dangerous debris for cetaceans" and cetacean species.

The PCA results revealed a greater similarity between transects 4 to 7, located in the north sector of the surveyed area. The area where these transects are located is also an area of high occurrence of vessels, which may indicate vessels as the potential source of marine debris in this area. In the same way, the association of transects 9, 11 and 12 located in the south sector could be also related with a high occurrence of vessels in the transects area.

The significant geographical differences between types of marine debris might be due to the location of the sources responsible for this debris. For example, in the north sector the more frequent types of marine debris include plastic items (PLFL – plastic float, PLBO – plastic bottle, PLST – plastic strap and PLBA – plastic bag), which may indicate a land-based source for debris of this region. Instead, in the south sector, the more frequent types (WOLU - Wood lumber or board and MONE - Monofilament net) may indicate ocean-based sources, such as vessels and the fishing industry.

The floatability of materials like plastic, styrofoam, paper or cloth and monofilament lines and their transport by currents may also contribute to the aggregation of these types in the northern region of the surveyed area.

Chapter V: Conclusion

This study is the first contribution to assessing the presence of floating marine debris in Portuguese Continental offshore waters, where 36 types of debris were identified along 13 transects in the surveyed area. The study area has a density of floating marine debris of 2.96 and an abundance of 747720 objects, being plastic float – PLFL the most common type of debris. The obtained density for vessels was 0.00134 and the total abundance was 340 vessels. The distribution and composition of floating marine debris in the offshore environment strongly suggests a mixed source: land-based sources and vessels.

In spite of the effort made in this first campaign, information about biology and ecology of marine fauna existing in offshore waters of mainland Portugal is still scarce due to economic costs and difficulties of distant offshore surveys. A monitoring program, with a regular collection of data on floating marine debris, vessels and marine fauna, with the same methodology would allow for temporal and seasonal comparisons of types and amounts, distribution, areas of overlap between floating marine debris and marine mammals, and potential sources. It would also allow assessing the effectiveness of management strategies, legislation and other activities designed to prevent and mitigate this problem. Educational campaigns aiming at raising public awareness and the utilization of biodegradable materials would also be useful measures to implement in the future.

Future work will include modeling surface currents in order to investigate the pathways of floating marine debris in the study area as well as to help in the prediction of possible areas of main occurrence and aggregation of floating marine debris.

Chapter VI: Bibliography

Aliani, S., Griffa, A. & Molcard, A. 2003. Floating debris in the Ligurian Sea, north-western Mediterranean. *Marine Pollution Bulletin,* 46**,** 1142-1149.

Aliani, S. & Molcard, A. 2003. Hitch-hiking on floating marine debris: macrobenthic species in the Western Mediterranean Sea. *Hydrobiologia,* 503**,** 59–67.

Allsopp, M., Walters, A., Santillo, D. & Johnston, P. 2006. Plastic Debris in the World's Oceans. Amsterdam, Netherlands: Greenpeace.

Amos, A. F. 1993. Solid waste pollution on Texas beaches: a post-MARPOL Annex V study, Volume I: Narrative.

Andrady, A. L. 2003. Plastics and the environment. *In:* Andrady, A. L. (ed.). John Wiley and Sons.

Andrady, A. L. 2011. Microplastics in the marine environment. *Marine Pollution Bulletin,* 62**,** 1596-1605.

Andrady, A. L. & Neal, M. A. 2009. Applications and societal benefits of plastics. *Philosophical Transactions of the Royal Society of London Biological Sciences,* 364**,** 1977-1984.

Antunes, J. C., Frias, J. G. L., Micaelo, A. C. & Sobral, P. 2013. Resin pellets from beaches of the Portuguese coast and adsorbed persistent organic pollutants. *Estuarine, Coastal and Shelf Science,* 130**,** 62-69.

Arnould, J. P. Y. & J.P.Croxall 1995. Trends in entanglement of antarctic fur seals (Arctocephalus gazella) in man-made debris at South Georgia. *Marine Pollution Bulletin,* 30**,** 707-712.

Arthur, C., Baker, J. & Bamford, H. 2009. Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris. National Oceanic and Atmospheric Administration.

Auman, H. J., Woehler, E. J., Riddle, M. J. & Burton, H. 2004. First evidence of ingestion of plastic debris by seabirds at sub-antarctic Heard Island. *Marine Ornithology,* 32**,** 105 -106.

Avery-Gomm, S., Provencher, J. F., Morgan, K. H. & Bertram, D. F. 2013. Plastic ingestion in marine-associated bird species from the eastern North Pacific. *Marine Pollution Bulletin,* 72**,** 257-259.

Azzarello, M. Y. & Vleet, E. S. V. 1987. Marine birds and plastic pollution. *Marine Ecology - Progress Series,* 37**,** 295-303.

Baird, R. W. & Hooker, S. K. 2000. Ingestion of Plastic and unusual prey by a juvenile harbour porpoise. *Marine Pollution Bulletin In Press*.

Barnes, D. K. A. 2002. Invasions by marine life on plastic debris. *Nature,* 416**,** 808-809.

Barnes, D. K. A. & Milner, P. 2004. Drifting plastic and its consequences for sessile organism dispersal in the Atlantic Ocean. *Marine Biology,* 146**,** 815-825.

Bjorndal, K. A., Bolten, A. B. & Lagueux, C. J. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine Pollution Bulletin,* 28**,** 154-158.

Blight, L. K. & Burger, A. E. 1997. Occurrence of plastic particles in seabirds from the eastern North Pacific. *Marine Pollution Bulletin,* 34**,** 323-325.

Bockstiegel, E. 2010. *The North Pacific Garbage Patch problems and potential solutions.* SPEA 499 Honors Thesis, Indiana University, The United States.

Boland, R. C. & Donohue, M. J. 2003. Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, *Monachus schauinslandi* 1999–2001. *Marine Pollution Bulletin,* 46**,** 1385-1394.

Boren, L. J., Morrissey, M., Muller, C. G. & Gemmell, N. J. 2006. Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Marine Pollution Bulletin,* 52**,** 442-446.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. & Thomas, L. 2001. *Introduction to Distance Sampling: estimating abundance of biological populations,* Oxford, Oxford University Press.

Campani, T., Baini, M., Giannetti, M., Cancelli, F., Mancusi, C., Serena, F., Marsili, L., Casini, S. & Fossi, M. C. 2013. Presence of plastic debris in loggerhead turtle stranded along the Tuscany coasts of the Pelagos Sanctuary for Mediterranean Marine Mammals (Italy). *Marine Pollution Bulletin,* 74**,** 225-230.

Carlton, J. T. & Geller, J. B. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science,* 261**,** 78-82.

Carpenter, E. J. & Smith, K. L. 1972. Plastics on the Sargasso sea surface. *Science,* 175**,** 1240-1241.

Carr, A. 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. *Marine Pollution Bulletin,* 18**,** 352-356.

Carretta, J. V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, Brad Hanson, and M. S. Lowry. 2007. U.S. Pacific Marine Mammal Stock Assessments: 2006. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-398. 312p.

Carson, H. S., Nerheim, M. S., Carroll, K. A. & Eriksen, M. 2013. The plastic-associated microorganisms of the North Pacific Gyre. *Marine Pollution Bulletin,* 75**,** 126-132.

Casale, P., Affronte, M., Insacco, G., Freggi, D., Vallini, C., Pino d'Astore, P., Basso, R., Paolillo, G., Abbate, G. & Argano, R. 2010. Sea turtle strandings reveal high anthropogenic mortality in Italian waters. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 20**,** 611-620.

Center for International Environmental Law 2012. Normal operations of a ship in MARPOL: A review of MARPOL's Travaux.

Claessens, M., De Meester, S., Van Landuyt, L., De Clerck, K. & Janssen, C. R. 2011. Occurrence and distribution of microplastics in marine sediments along the Belgian coast. *Marine Pollution Bulletin,* 62**,** 2199-2204.

Cole, M., Lindeque, P., Halsband, C. & Galloway, T. S. 2011. Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin,* 62**,** 2588-2597.

Dantas, D. V., Barletta, M. & da Costa, M. F. 2012. The seasonal and spatial patterns of ingestion of polyfilament nylon fragments by estuarine drums (Sciaenidae). *Environmental Science and Pollution Research International,* 19**,** 600-606.

De Stephanis, R., Gimenez, J., Carpinelli, E., Gutierrez-Exposito, C. & Canadas, A. 2013. As main meal for sperm whales: plastics debris. *Marine Pollution Bulletin,* 69**,** 206-214.

Derraik, J. G. B. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin,* 44**,** 842-852.

Donohue, M. J., Boland, R. C., Sramek, C. M. & Antonelis, G. A. 2001. Derelict fishing gear in the northwestern Hawaiian Islands: diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin,* 42**,** 1301-1312.

Farrell, P. & Nelson, K. 2013. Trophic level transfer of microplastic: *Mytilus edulis* (L.) to *Carcinus maenas* (L.). *Environmental Pollution,* 177**,** 1-3.

Fergusson, W. C. 1974. *In:* Staudinger, J. J. P. (ed.) *Plastic and the environment.* London: Hutchinson and Co.

Fowler, C. W. 1987. Marine debris and northern fur seals: a case study. *Marine Pollution Bulletin,* 18**,** 326-335.

Frias, J. P., Sobral, P. & Ferreira, A. M. 2010. Organic pollutants in microplastics from two beaches of the Portuguese coast. *Marine Pollution Bulletin,* 60**,** 1988-1992.

Galgani, F., Burgeot, T., Bocquéné, G., Vincent, F., Leauté, J. P., Labastie, J., Forest, A. & Guichet, R. 1995a. Distribution and abundance of debris on the continental shelf of the Bay of Biscay and in Seine Bay. *Marine Pollution Bulletin,* 30**,** 58-62.

Galgani, F., Hanke, G., Werner, S. & De Vrees, L. 2013. Marine litter within the European Marine Strategy Framework Directive. *ICES Journal of Marine Science,* 70**,** 1055-1064.

Galgani, F., Jaunet, S., Campillot, A., Guenegen, X. & His, E. 1995b. Distribution and abundance of debris on the continental shelf of the north-western Mediterranean Sea. *Marine Pollution Bulletin,* 30**,** 713-717.

Galgani, F., Leaute, J. P., Moguedet, P., Souplet, A., Verin, Y., Carpentier, A., Goraguer, H., Latrouite, D., Andral, B., Cadiou, Y., Mahe, J. C., Poulard, J. C. & Nerisson, P. 2000. Litter on the sea floor along European coasts. *Marine Pollution Bulletin,* 40**,** 516-527.

Galgani, F., Fleet, D., Franeker, J. V., Katsanevakis, S., Maes, T., Mouat, J., Oosterbaan, L., Poitou, I., Hanke, G., Thompson, R., Amato, E., Birkun, A. & Janssen, C. 2010. Marine Strategy Framework Directive: Task Group 10 Report Marine Litter. *In:* Zampoukas, N. (ed.) *JRC Scientific and Technical Reports.* ICES/JRC/IFREMER Joint Report.

Galil, B. S., Golik, A. & Turkay, M. 1995. Litter at the Bottom of the Sea: A Sea Bed Survey in the Eastern Mediterranean. *Marine Pollution Bulletin,* 30**,** 22-24.

GESAMP. 2010 Proceedings of the GESAMP International Workshop on plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans. In *GESAMP Reports and Studies* (ed. T. Bowmer & P. J. Kershaw): IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP.

Gomerči, H., Đuras Gomerči, M., Gomerči, T., Luci, H., Dalebout, M., Galov, A., Škrti, D., urkovi, S., Vukovi, S. & Huber, Đ. 2006. Biological aspects of Cuvier’s beaked whale (*Ziphius cavirostris*) recorded in the Croatian part of the Adriatic Sea. *European Journal of Wildlife Research,* 52**,** 182-187.

Gomerčić, M. Đ., Galov, A., Gomerčić, T., Škrtić, D., Ćurković, S., Lucić, H., Vuković, S., Arbanasić, H. & Gomerčić, H. 2009. Bottlenose dolphin (*Tursiops truncatus*) depredation resulting in larynx strangulation with gill-net parts. *Marine Mammal Science,* 25**,** 392-401.

Gorycka, M. 2009. *Environmental risks of microplastics.* Masther, VrijeUniversiteit.

Gorzelany, J. F. 1998. Unusual deaths of two free-ranging atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. *Marine Mammal Science,* 14**,** 614-617.

Graham, E. R. & Thompson, J. T. 2009. Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. *Journal of Experimental Marine Biology and Ecology,* 368**,** 22-29.

Gregory, M. R. 1991. The hazards of persistent marine pollution: drift plastics and conservation islands. *Journal of the Royal Society of New Zealand,* 21**,** 83-100.

Hanni, K. D. & Pyle, P. 2000. Entanglement of pinnipeds in synthetic materials at south-east Farallon Island, California, 1976 - 1998. *Marine Pollution Bulletin,* 40**,** 1076-1081.

Harse, G. A. 2011. Plastic, the great pacific garbage patch, and international misfires at a cure. *Journal of Environmental Law,* 29**,** 331-363.

Hastings, E. & Potts, T. 2013. Marine litter: Progress in developing an integrated policy approach in Scotland. *Marine Policy,* 42**,** 49-55.

Henderson, J. R. 1990. Recent entanglements of Hawaiian monk seals in marine debris. *In:* Shomura, R. S. & Godfrey, M. L. (eds.) *Proceedings of the Second International Conference on Marine Debris 2-7 April 1989.* Honolulu, Hawaii: U.S. Department of Commerce, NOAA.

Henderson, J. R. 2001. A Pre- and Post - MARPOL Annex v Summary of Hawaiian monk seal entanglements and marine debris accumulation in the northwestern Hawaiian Islands, 1982-1998. *Marine Pollution Bulletin,* 42**,** 584-589.

Hess, N. A., Ribic, C. A. & Vining, I. 1999. Benthic marine debris, with an emphasis on fishery-related items, surrounding Kodiak Island, Alaska, 1994-1996. *Marine Pollution Bulletin,* 38**,** 885-890.

Hinojosa, I. A. & Thiel, M. 2009. Floating marine debris in fjords, gulfs and channels of southern Chile. *Marine Pollution Bulletin,* 58**,** 341-350.

Hopewell, J., Dvorak, R. & Kosior, E. 2009. Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society of London Biological Sciences,* 364**,** 2115-2126.

Irish, K. E. & Norse, E. A. 1996. Scant emphasis on marine biodiversity. *Conservation Biology,* 10**,** 680.

Jackson, G. D., Buxton, N. G. & George, M. J. A. 2000. Diet of the southern opah *Lampris immaculatus* on the Patagonian Shelf; the significance of the squid *Moroteuthis ingens* and anthropogenic plastic. *Marine Ecology - Progress Series,* 206**,** 261-271.

Jacobsen, J. K., Massey, L. & Gulland, F. 2010. Fatal ingestion of floating net debris by two sperm whales (*Physeter macrocephalus*). *Marine Pollution Bulletin,* 60**,** 765-767.

Jantz, L. A., Morishige, C. L., Bruland, G. L. & Lepczyk, C. A. 2013. Ingestion of plastic marine debris by longnose lancetfish (*Alepisaurus ferox*) in the North Pacific Ocean. *Marine Pollution Bulletin,* 69**,** 97-104.

Jones, M. M. 1995. Fishing debris in the Australian marine environment. *Marine Pollution Bulletin,* 30**,** 25 - 33.

Jones, P. D., Hannah, D. J., Buckland, S. J., Day, P. J., Leathem, S. V., Porter, L. j., Auman, H. J., Sanderson, T., Summer, C., Ludwig, J. P., Colborn, T. L. & Giesy, J. P. 1995. Persistent synthetic chlorinated hydrocarbons in albatross tissue samples from midway atoll. *Environmental Toxicology and Chemistry,* 15**,** 1793 -1800.

June, J. A. 1990. Type, source, and abundance of trawl-caught marine debris off Oregon, in the eastern Bering Sea, and in Norton Sound in 1988. *In:* Shomura, R. S. & Godfrey, M. L. (eds.) *Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii.* Washington D. C.: Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Kubota, M. 1994. A mechanism for the accumulation of floating marine debris north of Hawaii. *American Meteorological Society,* 24**,** 1059 - 1064.

Kuhn, S. & Van Franeker, J. A. 2012. Plastic ingestion by the northern fulmar (*Fulmarus glacialis*) in Iceland. *Marine Pollution Bulletin,* 64**,** 1252-1254.

Laist, D. W. 1987. Overview of the Biological Effects of Lost and Discarded Plastic Debris in the Marine Environment. *Marine Pollution Bulletin,* 18**,** 319-326.

Laist, D. W. & Liffmann, M. 2000. Impacts of marine debris: research and management needs. *Issue Papers of the International Marine Debris Conference.* Honolulu, Hawaii.

Law, K. L., Moret-Ferguson, S., Maximenko, N. A., Proskurowski, G., Peacock, E. E., Hafner, J. & Reddy, C. M. 2010. Plastic accumulation in the North Atlantic subtropical gyre. *Science,* 329**,** 1185-1188.

Lazar, B. & Gracan, R. 2011. Ingestion of marine debris by loggerhead sea turtles, *Caretta caretta*, in the Adriatic Sea. *Marine Pollution Bulletin,* 62**,** 43-47.

Legendre, P. & Legendre, L. 2012. *Numerical Ecology*, Elsevier.

Lee, K.-t., Tanabe, S. & Koh, C.-h. 2001. Contamination of polychlorinated biphenyls (PCBs) in sediments from Kyeonggi Bay and nearby areas, Korea. *Marine Pollution Bulletin,* 42**,** 273 - 279.

Lovejoy, T. E. 1997. Biodiversity: What Is It? *In:* Reaka-Kudla, M. L., Wilson, D. E. & Wilson, E. O. (eds.) *Biodiversity II: understanding and protecting our biological resources.* United States of America: Joseph Henry Press, Washington D. C.

Marine Mammal Commission, 2001. Annual Report to Congress, 2000. Marine Mammal Commission, Bethesda, Maryland.Congress.
Available: http://www.mmc.gov/reports/annual/pdf/2001annualreport.pdf

Martins, J. & Sobral, P. 2011. Plastic marine debris on the Portuguese coastline: a matter of size? *Marine Pollution Bulletin,* 62**,** 2649-2653.

Masó, M., Garcés, E., Pagès, F. & Camp, J. 2003. Drifting plastic debris as a potential vector for dispersing Harmful Algal Bloom (HAB) species. *Scientia Marina,* 67**,** 107 - 111.

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C. & Kaminuma, T. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science & Technology,* 35**,** 318 - 324.

McIlgorm, A., Campbell, H.F.,Rule,M.J., 2009. Understanding the EconomicBenefits and Costs of Controlling Marine Debris in the APEC Region (MRC 02/2007). Publisher APEC. A report to the Asia-Pacific Economic Cooperation Marine Resources ConservationWorking Group by theNational Marine Science Centre (University of New England and Southern Cross University), NSWAustralia, February.

McIlgorm, A., Campbell, H. F. & Rule, M. J. 2011. The economic cost and control of marine debris damage in the Asia-Pacific region. *Ocean & Coastal Management,* 54**,** 643-651.

Miller, M. A. L. 1996. Protecting the marine environment of the Wider Caribbean Region: the challenge of institution-building. Green Globe Yearbook.

Minchin, D. 1996. Tar pellets and plastics as attachment surfaces for lepadid cirripedes in the North Atlantic Ocean. *Marine Pollution Bulletin,* 32**,** 855 - 859.

Mizukawa, K., Takada, H., Ito, M., Geok, Y. B., Hosoda, J., Yamashita, R., Saha, M., Suzuki, S., Miguez, C., Frias, J., Antunes, J. C., Sobral, P., Santos, I., Micaelo, C. & Ferreira, A. M. 2013. Monitoring of a wide range of organic micropollutants on the Portuguese coast using plastic resin pellets. *Marine Pollution Bulletin,* 70**,** 296-302.

Moore, C. 2003. Trashed: Across the pacific ocean, plastics, plastics, everywhere. *Natural History Magazine,* 112**,** 46 - 51.

Moore, C. J. 2008. Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research,* 108**,** 131-139.

Moore, C. J., Moore, S. L., Leecaster, M. K. & Weisberg, S. B. 2001. A comparison of plastic and plankton in the North Pacific Central Gyre. *Marine Pollution Bulletin,* 42**,** 1297-1300.

Moore, E., Lyday, S., Roletto, J., Litle, K., Parrish, J. K., Nevins, H., Harvey, J., Mortenson, J., Greig, D., Piazza, M., Hermance, A., Lee, D., Adams, D., Allen, S. & Kell, S. 2009. Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001-2005. *Marine Pollution Bulletin,* 58**,** 1045-1051.

Muller, C., Townsend, K. & Matschullat, J. 2012. Experimental degradation of polymer shopping bags (standard and degradable plastic, and biodegradable) in the gastrointestinal fluids of sea turtles. *Science of the Total Environment,* 416**,** 464-467.

National Oceanic and Atmospheric Administration. 2008 Interagency Report on Marine Debris Sources, Impacts, Strategies & Recommendations. Silver Spring, MD. 62 pp. Available: http://water.epa.gov/type/oceb/marinedebris/upload/2008_imdcc_marine_debris_rpt.pdf

National Research Council 1995. Understanding marine biodiversity. Washington D.C.

National Research Council 2009. Tackling marine debris in the 21st century. Washington D.C.

Neilson, J. L., Straley, J. M., Gabriele, C. M. & Hills, S. 2009. Non-lethal entanglement of humpback whales (*Megaptera novaeangliae*) in fishing gear in northern Southeast Alaska. *Journal of Biogeography,* 36**,** 452-464.

Ormond, R. F. G., Gage, J. D. & Angel, M. V. 1997. Marine biodiversity: patterns and processes. *Eos,* 79**,** 604.

Pace, D. S., Miragliuolo, A. & Mussi, B. 2008. Behaviour of a social unit of sperm whales (*Physeter macrocephalus*) entangled in a driftnet off Capo Palinuro (Southern Tyrrhenian Sea, Italy). *Journal of Cetacean Research and Management,* 10**,** 131–135.

Pichel, W. G., Churnside, J. H., Veenstra, T. S., Foley, D. G., Friedman, K. S., Brainard, R. E., Nicoll, J. B., Zheng, Q. & Clemente-Colon, P. 2007. Marine debris collects within the North Pacific Subtropical Convergence Zone. *Marine Pollution Bulletin,* 54**,** 1207-1211.

Plasticseurope 2012. Plastics - the Facts 2012: an Analysis of European Plastics Production, Demand and Waste Data for 2011. Available: http://www.plasticseurope.org/documents/document/20121120170458-final_plasticsthefacts_nov2012_en_web_resolution.pdf

Plotkin, P. T., Wieksten, M. K. & Amos, A. E. 1993. Feeding ecology of the loggerhead sea turtle *Caretta caretta* in the Northwestern Gulf of Mexico. *Marine Biology,* 115**,** 1 - 15.

Possatto, F. E., Barletta, M., Costa, M. F., do Sul, J. A. & Dantas, D. V. 2011. Plastic debris ingestion by marine catfish: an unexpected fisheries impact. *Marine Pollution Bulletin,* 62**,** 1098-1102.

Provencher, J. F., Gaston, A. J., Mallory, M. L., O'Hara P, D. & Gilchrist, H. G. 2010. Ingested plastic in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic. *Marine Pollution Bulletin,* 60**,** 1406-1411.

Pruter, A. T. 1987. Sources, quantities and distribution of persistent plastics in the marine environment. *Marine Pollution Bulletin,* 18**,** 305 - 310.

Quakenbush, L. T., Citta, J. J., George, J. C., Small, R. J. & Heide-Jorgensen, M. P. 2009. Fall and winter movements of Bowhead Whales (*Balaena mysticetus*) in the Chukchi Sea and within a potential petroleum development area. *Arctic,* 63**,** 289 - 307.

Ramos, J. A. A., Barletta, M. & Costa, M. F. 2012. Ingestion of nylon threads by Gerreidae while using a tropical estuary as foraging grounds. *Aquatic Biology,* 17**,** 29-34.

Raverty, S. A. & Gaydos, J. K. 2004. Killer whale necropsy protocol and disease testing protocol.

Ribic, C. A. 1998. Use of Indicator Items to Monitor Marine Debris on a New Jersey Beach from 1991 to 1996. *Marine Pollution Bulletin,* 36**,** 887-891.

Ribic, C. A., Dixon, T. R. & Vining, I. 1992. Marine debris survey manual. Seattle, Washington: National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

Ribic, C. A., Sheavly, S. B., Rugg, D. J. & Erdmann, E. S. 2010. Trends and drivers of marine debris on the Atlantic coast of the United States 1997-2007. *Marine Pollution Bulletin,* 60**,** 1231-1242.

Rothstein, S. I. 1973. Plastic particle pollution of the surface of the Atlantic Ocean: evidence from a seabird. *The Condor,* 75**,** 344 - 366.

Ryan, P. G. 2008. Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans. *Marine Pollution Bulletin,* 56**,** 1406-1409.

Ryan, P. G., Moore, C. J., van Franeker, J. A. & Moloney, C. L. 2009. Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society London Biological Sciences* 364**,** 1999-2012.

Santos J., H. Araújo, M. Ferreira, A. Henriques, J. Miodonski, S. Monteiro, I. Oliveira, P. Rodrigues, G. Duro, F. Oliveira, N. Pinto, M. Sequeira, C. Eira & J. Vingada. 2012. Chapter I: Baseline estimates of abundance and distribution of target species. Annex to the Midterm Report of project LIFE MarPro PT/NAT/00038.

Secchi, E. R. & Zarzur, S. 1999. Plastic debris ingested by a Blainville's beaked whale, *Mesoplodon densirostris*, washed ashore in Brazil. *Aquatic Mammals,* 25.1**,** 21-24.

Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel— GEF (2012). *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions*, Montreal, Technical Series No. 67, 61 pages.

Sesini, M. 2011. *The garbage patch in the oceans: the problem and possible solutions.* Columbia University.

Sheavly, S. B. 2005. Sixth meeting of the UN Open-ended informal consultative process on oceans & the law of the sea. The Ocean Conservancy.

Sheavly, S. B. 2007. National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary. Prepared for U.S. Environmental Protection Agency by Ocean Conservancy.

Sheavly, S. B. & Register, K. M. 2007. Marine Debris & Plastics: Environmental Concerns, Sources, Impacts and Solutions. *Journal of Polymers and the Environment,* 15**,** 301-305.

Shiomoto, A. & Kameda, T. 2005. Distribution of manufactured floating marine debris in near-shore areas around Japan. *Marine Pollution Bulletin,* 50**,** 1430-1432.

Shomura, R. S. & Yoshida, H. O. 1985. Proceedings of the workshop on the fate and impact of marine debris. *NOAA Technical Memorandum NMFS.* Honolulu, Hawaii: National Marine Fisheries Service, Nacional Oceanic and Atmospheric Administration.

Simmonds, M. & Nunny, L. 2002. Cetacean Habitat Loss and Degradation in the Mediterranean Sea. *In:* Notabartolo di Sciara, G. (ed.) *Cetaceans of the Mediterranean and Black Seas: State of Knowledge and Conservation strategies.* Monaco.

Sinclair, E. H. & Robson, B. W. 1999. Fur seal investigations, 1997. *NOAA Technical Memorandum NMFS-AFSC-106.* U.S. Department of Commerce.

Snelgrove, P. V. R. 1999. Getting to the bottom of marine biodiversity: sedimentary habitats. *Bioscience,* 49**,** 129 - 138.

Stamper, M. A., Whitaker, B. R. & Schofield, T. D. 2006. Case Study: Morbidity in a Pygmy Sperm Whale *Kogia Breviceps* Due to Ocean-Bourne Plastic. *Marine Mammal Science,* 22**,** 719-722.

Stefatos, A., Charalampakis, M., Papatheodorou, G. & Ferentinos, G. 1999. Marine debris on the seafloor of the Mediterranean Sea: examples from two enclosed gulfs in western Greece. *Marine Pollution Bulletin,* 36**,** 389 - 393.

Thiel, M., Hinojosa, I., Vásquez, N. & Macaya, E. 2003. Floating marine debris in coastal waters of the SE-Pacific (Chile). *Marine Pollution Bulletin,* 46**,** 224 - 231.

Thiel, M., Hinojosa, I. A., Joschko, T. & Gutow, L. 2011. Spatio-temporal distribution of floating objects in the German Bight (North Sea). *Journal of Sea Research,* 65**,** 368-379.

Thiel, M., Hinojosa, I. A., Miranda, L., Pantoja, J. F., Rivadeneira, M. M. & Vasquez, N. 2013. Anthropogenic marine debris in the coastal environment: a multi-year comparison between coastal waters and local shores. *Marine Pollution Bulletin,* 71**,** 307-316.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R., Marques, T. A. & Burnham, K. P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology,* 47**,** 5-14.

Thompson, R. C., Belle, B. E. L., Bouwman, H. & Neretin, L. 2011. Marine debris: defining a global environmental challenge. Washington D. C. : Global Environment Facility.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., McGonigle, D. & Russell, A. E. 2004. Lost at Sea: Where Is All the Plastic? *Science,* 304**,** 838.

Tickell, C. 1997. The value of diversity *In:* Ormond, R. F. G., Gage, J. D. & Angel, M. V. (eds.) *Marine biodiversity: patterns and processes.* United States of America: Cambridge University Press, New York.

Tomás, J., Guitart, R., Mateo, R. & Raga, J. A. 2002. Marine debris ingestion in loggerhead sea turtles, *Caretta caretta*, from the Western Mediterranean. *Marine Pollution Bulletin,* 44**,** 211 - 216.

UNEP, 2005. Marine Litter: An Analytical Overview, Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation, 47 pp. Available: http://www.unep.org/regionalseas/marinelitter/publications/docs/anl_oview.pdf overview.

UNEP, 2009. *Marine Litter: A Global Challenge.* Nairobi: UNEP. 232 pp. Available: http://www.unep.org/regionalseas/marinelitter/publications/docs/Marine_Litter_A_Global_Challenge.pdf

Van Cauwenberghe, L., Vanreusel, A., Mees, J. & Janssen, C. R. 2013. Microplastic pollution in deep-sea sediments. *Environmental Pollution,* 182**,** 495-499.

Van Franeker, J. A., Blaize, C., Danielsen, J., Fairclough, K., Gollan, J., Guse, N., Hansen, P. L., Heubeck, M., Jensen, J. K., Le Guillou, G., Olsen, B., Olsen, K. O., Pedersen, J., Stienen, E. W. &

Turner, D. M. 2011. Monitoring plastic ingestion by the northern fulmar *Fulmarus glacialis* in the North Sea. *Environmental Pollution,* 159**,** 2609-2615.

Vélez-Rubio, G. M., Estrades, A., Fallabrino, A. & Tomás, J. 2013. Marine turtle threats in Uruguayan waters: insights from 12 years of stranding data. *Marine Biology,* 160**,** 2797-2811.

Verlis, K. M., Campbell, M. L. & Wilson, S. P. 2013. Ingestion of marine debris plastic by the wedge-tailed shearwater *Ardenna pacifica* in the Great Barrier Reef, Australia. *Marine Pollution Bulletin,* 72**,** 244-249.

Waluda, C. M. & Staniland, I. J. 2013. Entanglement of Antarctic fur seals at Bird Island, South Georgia. *Marine Pollution Bulletin,* 74**,** 244-252.

Ward, J. E. & Shumway, S. E. 2004. Separating the grain from the chaff: particle selection in suspension- and deposit-feeding bivalves. *Journal of Experimental Marine Biology and Ecology,* 300**,** 83-130.

Watters, D. L., Yoklavich, M. M., Love, M. S. & Schroeder, D. M. 2010. Assessing marine debris in deep seafloor habitats off California. *Marine Pollution Bulletin,* 60**,** 131-138.

Williams, A. T., Tudor, D. T. & Gregory, M. R. 2005. Marine debris: onshore, offshore, seafloor litter. *In:* Schwartz, M. (ed.) *Encyclopedia of coastal processes.* Springer.

Williams, R., Ashe, E. & O'Hara, P. D. 2011. Marine mammals and debris in coastal waters of British Columbia, Canada. *Marine Pollution Bulletin,* 62**,** 1303-1316.

Zampoukas, N., Piha, H., Bigagli, E., Hoepffner, N., Hanke, G. & Cardoso, A. C. 2013. Marine monitoring in the European Union: How to fulfill the requirements for the marine strategy framework directive in an efficient and integrated way. *Marine Policy,* 39**,** 349-351.

Zettler, E. R., Mincer, T. J. & Amaral-Zettler, L. A. 2013. Life in the "plastisphere": microbial communities on plastic marine debris. *Environmental Science & Technology,* 47**,** 7137-7146.

Zhou, P., Huang, C., Fang, H., Cai, W., Li, D., Li, X. & Yu, H. 2011. The abundance, composition and sources of marine debris in coastal seawaters or beaches around the northern South China Sea (China). *Marine Pollution Bulletin,* 62**,** 1998-2007.

Zuur, A. F., Ieno, E. N. & Smith, G. M. 2007. *Analysing Ecological Data*, Springer.

Chapter VII: Annexes

Annex I: The form of floating debris and vessels sightings, in which data were recorded.

FORMULÁRIO DE AVISTAMENTOS – NAVIOS E LIXO

TAMANHO
S < 2,5 cm
M >2,5 cm < 10 cm
L >10 cm <1m
XL >1m

NAVIOS
PE PESCA
DE DESPORTIVO
TP TRANSPORTE
NG NAVIO GUERRA

ACTIVIDADE
TR EM TRÂNSITO
PE PESCA
AN ANCORADO
OU OUTRO

LIXO
OR ORGÂNICO
PL PLÁSTICO
MA MADEIRA
RE REDES
VI VIDRO
BO BORRACHA
MT METAL
ES ESFEROVITE
PA PAPEL OU CARTÃO
OU OUTRO

DATA			FORM Nº	TOTAL FORMS NO DIA
DIA	MÊS	ANO		

NUM	HORA			ÂNGULO	DISTÂNCIA METROS	LIXO			NAVIOS	ACTIVI-DADE	COMENTÁRIOS
	H	M	S			TAMANHO	CODIGO	VIDA ASSOC.			