

Τα Κυριότερα Προβλήματα Περιβαλλοντικής Ρύπανσης στη Μεσόγειο Θάλασσα

Επιστημονικές Έρευνες για την Ρύπανση και τα Είδη Απορριμμάτων
στο Θαλάσσιο Περιβάλλον και τις Μεσογειακές Παραλίες

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Περίληψη. Η Μεσόγειος θάλασσα θεωρείται η κοιτίδα του ανθρώπινου πολιτισμού. Παρά τις προσπάθειες που καταβάλλονται σε διεθνές, περιφερειακό και εθνικό επίπεδο, υπάρχουν σαφείς ενδείξεις ότι η θαλάσσια ρύπανση από τοξικές χημικές ουσίες και τα θαλάσσια απορρίμματα αυξάνονται με αλματώδεις ρυθμούς και με επικίνδυνες επιπτώσεις στην ποιότητα των ακτών, των νερών, των υδρόβιων οργανισμών και των οικοσυστημάτων. Η Μεσόγειος είναι ιδιαίτερα ευαίσθητη στη ρύπανση γιατί ως κλειστή θάλασσα έχει ρυθμό ανανέωσης υδάτων τα 80 έως 90 χρόνια. Η Μεσόγειος θάλασσα αντιπροσωπεύει το 1% των παγκόσμιων θαλάσσιων εκτάσεων και περιέχει το 6% του συνόλου των θαλασσίων ειδών.



Μελέτες από τη δεκαετία του 1970 έδειξαν ότι η ρύπανση από απόβλητα, τοξικές χημικές ουσίες και αστικά απορρίμματα στην περιοχή της Μεσογείου και τις παραλίες έχουν καταστεί σημαντικά περιβαλλοντικά προβλήματα. Τα πλαστικά αποτελούν το μεγαλύτερο ποσοστό απορριμμάτων με ανησυχητικές τάσεις αύξησης τα τελευταία χρόνια. Μέταλλα, υάλινα αντικείμενα, χαρτιά, δίχτυα ψαρέματος, υφάσματα, αποτσίγαρα κλπ αποτελούν τα άλλα είδη απορριμμάτων. Το μεγαλύτερο ποσοστό απορριμμάτων είναι αποτέλεσμα τουριστικών δραστηριοτήτων, απόρριψης στερεών αστικών σκουπιδιών και πλαστικών σκουπιδιών από πλοία.. Στην επισκόπηση αυτή παρουσιάζονται στατιστικά στοιχεία τοξικών και επικίνδυνων χημικών ρύπων που εκλύονται στη Μεσόγειο θάλασσα. Το μεγαλύτερο τμήμα όμως επικεντρώνεται στις κυριότερες έρευνες παρουσίας απορριμμάτων στα επιφανειακά νερά, τις παραλίες και στο βυθό της θαλάσσιας Μεσογειακών περιοχών και επιπτώσεις σε θαλάσσιους οργανισμούς.

Πλήρες κείμενο της εργασίας στα αγγλικά [38 σελίδες]: [αρχείο PDF, 1,43 MB](#)

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The Most Important Problems of Environmental Pollution in the Mediterranean Sea

Scientific Studies on Pollution and the Source and Type of Marine Litter in the Mediterranean Sea and Beaches

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Abstract. The Mediterranean Sea is considered the cradle of the human civilization. Although international and national projects and efforts have been initiated to protect the Mediterranean environment, there are indications that the sea pollution from toxic substances and marine litter is increasing substantially with dangerous consequences for the quality of coastlines, marine water, marine life and ecosystems. The Mediterranean Sea sensitive to pollution because is enclosed by land and the warm waters take more than 80 to 90 years to clean and renew themselves. The Mediterranean Sea represent the 1% of the global marine areas but has 6% of the total of marine species.



Since the 1970s, a number of studies have dealt with the problem of sea pollution by toxic substances and marine litter in the Mediterranean Sea and beaches. Plastics have been the main source of marine litter that increased in recent years exponentially. Sources, types and abundance of marine litter have been investigated and recorded by a variety of environmental studies. Glass pieces, metal objects, as well as fishing nets, cloths, paper, cigarette butts are also found in appreciable quantity in beaches and in the bottom of the Mediterranean marine environment. Thousands of tons of toxic substances and litter in the sea constitute a considerable source of pollution which can affect marine organisms and the quality of sea water. High concentrations of marine litter and floating debris are found near shipping lanes, around fishing areas, near beaches and holiday resorts and in oceanic current convergence zones. In this comprehensive review we present the latest studies on the general pollution problems by industry, urban effluents, shipping and other anthropogenic activities. Also, a substantial part of the review deals with various sources of marine litter of the surface water, in the bottom of the sea, beaches and marine organisms of the Mediterranean Sea.

1. Introduction: The Mediterranean Sea

The Mediterranean Sea is almost an enclosed sea area that covers an approximate area of 2.5 million km², but its connection to the Atlantic (the Strait of Gibraltar) is only 14 km wide. The Mediterranean Sea has an average depth of 1,500 m and the deepest recorded point is 5,267 m in the Calypso Deep in the Ionian Sea. The Mediterranean Region is known as the cradle of civilization and has been subject to human intervention for millennia, so that little remains of indigenous ecosystems. But the region is still an important biological resource of animals and plants and its biodiversity is unique. The coastline extends 46,000km running through 22 countries. The Mediterranean region is known for its particularly mild climate with uniform and moderate temperatures. Around the Mediterranean coasts are lands rich in endemic species. The variety of flora is estimated at over 25,000 species, over half of which are endemic (Briand F, 1993; REMPEC 2002; UNEP, 2004; Abudafia 2011; Goffred and Dubinsky, 2014).



Figure 1. The Mediterranean Sea was the first regional sea to be protected by the Regional Sea Programme of the UNEP because of its environmental significance and the importance of its marine biodiversity.

An environmental Action Plan (MAP) was adopted in 1975, as part of the Regional Sea Programme of UNEP (United Nations Environment Programme), for the protection of the Mediterranean Sea against pollution (**Barcelona Convention**). The convention covered various forms of pollution, such as pollution by dumping from ships and aircraft (in force 1978), pollution for land-based sources and activities (in force 1986), specially protected areas and biodiversity (1986), pollution from exploration of continental shelf and seabed (1994), pollution by transboundary movements of hazardous wastes and their disposal (1996), etc. The basic aims of the convention was to reduce pollution in the Mediterranean Sea, protect the marine environment for a sustainable future and make the marine ecosystems resistant to pollutants. (UNEP, 1976; Jeftic et al, 1989; UNEP/MAP, 2013).

2. Major Problems of Environmental Pollution in the Mediterranean Region

The Mediterranean Sea, according to various technical and environmental reports is probably the most polluted sea on Earth. The UNEP/MAP has estimated that every year in the last decade the Mediterranean Sea received 650.000.000 tons of sewage, 129.000 tons of mineral oil, 60.000 tons of mercury, 3.800 tons of lead and 36.000 tons of phosphates, which are dumped untreated from various industrial operations, urban, domestic and other anthropogenic processes. Because the Mediterranean Sea is enclosed by land, the warm waters take more than 80-90 years to clean and renew themselves. The basic aim of Barcelona Convention was to reduce pollution in the Mediterranean Sea, protect the marine environment for a sustainable future and make the marine ecosystems resistant to pollutants. Also, the Barcelona Convention covers the rich biodiversity of the area as well as the sensitive ecosystems of the region (de Walle et al., 1993; Wainwright and Thornes JB, 2004; Sailiot A, 2005; UNEP/MAP, 2013). Another very urgent problem that emerged in the last years is the “plague” of marine litter (plastic, metals, glass, etc) and big debris

of garbage that accumulated over the years in the coastal areas and the bottom of the sea (Valavanidis and Vlachogianni, 2012; Kershaw et al., 2013)



Figure 2. Pollution hotspots and pollution sensitive areas in the Mediterranean Sea. Most hotspots are in the coastal areas where industrial facilities are operating, large cities dump their waste and around busy shipping routes. [UNEP/MAP. Transboundary Diagnostic Analysis TDA for the Mediterranean Sea, Athens, 2005. (ISBN: 92 867 25785)] [<http://projects.inweh.unu.edu/inweh/display.php?ID=3604>].

The Mediterranean Sea has some of the busiest shipping routes on Earth. Estimates showed that 220,000 merchant vessels (more than 100 tons) travel around the Mediterranean Sea routes every year (1/3 of the total merchant shipping). The majority of these ships carry hazardous and toxic cargo which in case of leaks or accidents can severe damage marine life and pollute marine waters for a long period of time. Despite the conventions and the protective processes to avoid accidents, discharges of chemicals, petroleum and oily wastes are substantial sources of pollution in the Mediterranean Sea. It has been estimated that more than 15% of the global marine pollution every year occurs in the Mediterranean Sea (approximately 100,000 tons of crude oil is released (deliberately or accidentally) in to the sea from shipping activities. This is the result of the extended amounts of 370,000,000 tons of petroleum oil that are transported annually in the Mediterranean Sea (20% of the world total), with around 250-300 oil tankers

crossing the Sea every day. Accidental oil spills average of 10 spills per year in the Mediterranean Sea (([Sailiot , 2005](#); [MIRA 2012](#); [Cinnirella et al. 2013](#)).

The Mediterranean Sea, because of its location between the industrial Europe and the Arab oil producing countries (OPEC, Organization of the Petroleum Exporting Countries) is influenced by the busy shipping routes. The rapid increase of the last decades of the urban population in the Mediterranean region and tourism are also two other important factors for environmental pollution. Environmental threats that influence the long term quality of waters, marine organisms and ecosystems in the Mediterranean Region are increasing in recent years ([Empron, 2012](#); [UNEP/MAP, 2012](#)).

The rich ecosystem of the Mediterranean Region has been altered in many ways throughout its history. Temporal trends indicate that overexploitation and habitat loss are the main human drivers of historical changes. Human population explosion, commercial shipping, industrial and urban development, tourism were the main pressures that have grown exponentially. At present, habitat loss and degradation, as well as, chemical pollution, eutrophication and the introduction of alien species, and recently climate change, are the most important threats that affect the greatest number of taxonomic groups occurring in the Mediterranean Sea ([Coll et al., 2010](#); [Coll et al., 2012](#)).

a. Invasive or alien species (especially after the opening of the Suez Canal in 1869) and replacement of indigenous species by alien marine species. In recent decades, more than 900 new alien marine species, including the poisonous puffer fish, have been encountered in the coastal environments of the eastern Mediterranean Sea. This alien species invasion has wrought changes on the food web of the sea and the ecosystems are at risk dealing with the invaders. ([Streftaris and Zenetos, 2006](#); [Zenetos et al., 2012](#); [Otero et al., 2013](#); [Vlachogianni et al., 2013](#)).

The Mediterranean Region is a place where urbanization of the littoral zone, the most productive part of the sea, is reaching a climax on the northwestern shores. On the southern and eastern shores, runaway population growth is producing an unprecedented anthropic pressure on

marine ecosystems (pollution, overfishing, habitat destruction and new species introductions). These major disturbances, in addition to invasive (or alien) species introductions, severely impact the natural balance of ecosystems and have resulted in the extensive loss of biodiversity.

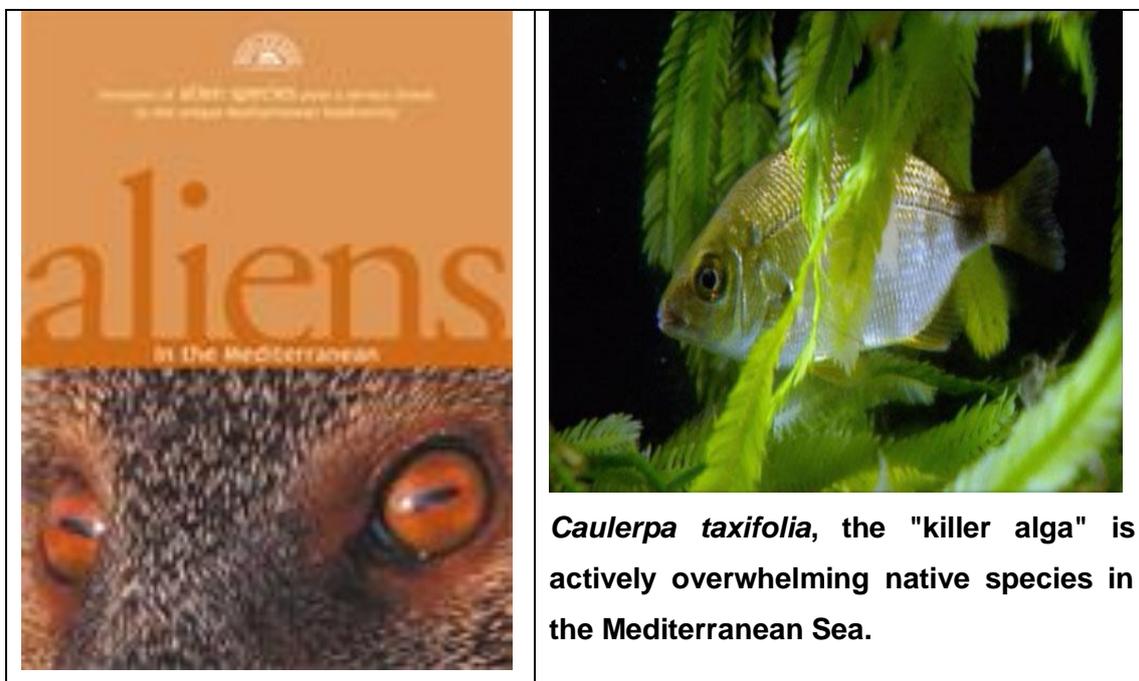


Figure 3. An interesting leaflet with photos on alien species in the Mediterranean Sea. Vlachogianni T, Vogrin M, Scoullou M. *Aliens in the Mediterranean*. MIO-ECSDE publication, Athens, 2013.

b. Eutrophication (water enriched with nutrients). The Mediterranean Sea as a semienclosed basin is a sensitive environment to eutrophication pressures. The main body of water of the Mediterranean is characterized by very low nutrient concentrations, and is classified among the most oligotrophic (very poor waters in nutrients) seas of the world's oceans. Loads of nutrients from sewage effluents, river fluxes, aquaculture farms, fertilizers, and industrial facilities, cause intense eutrophic phenomena with many adverse effects for the marine ecosystem and humans. The problem of coastal eutrophication in the Mediterranean Sea has been studied in connection with public policies of the Mediterranean States based on national and international legislation. (Karydis and Kitsiou, 2012). More than 450 million people live in the drainage basin of the Mediterranean, of whom about one-third inhabit coastal regions. Rapid demographic growth and economic

development since the 1950s has caused a major increase in nutrient supply to the Mediterranean Sea (Van Cappellen et al, 2014).

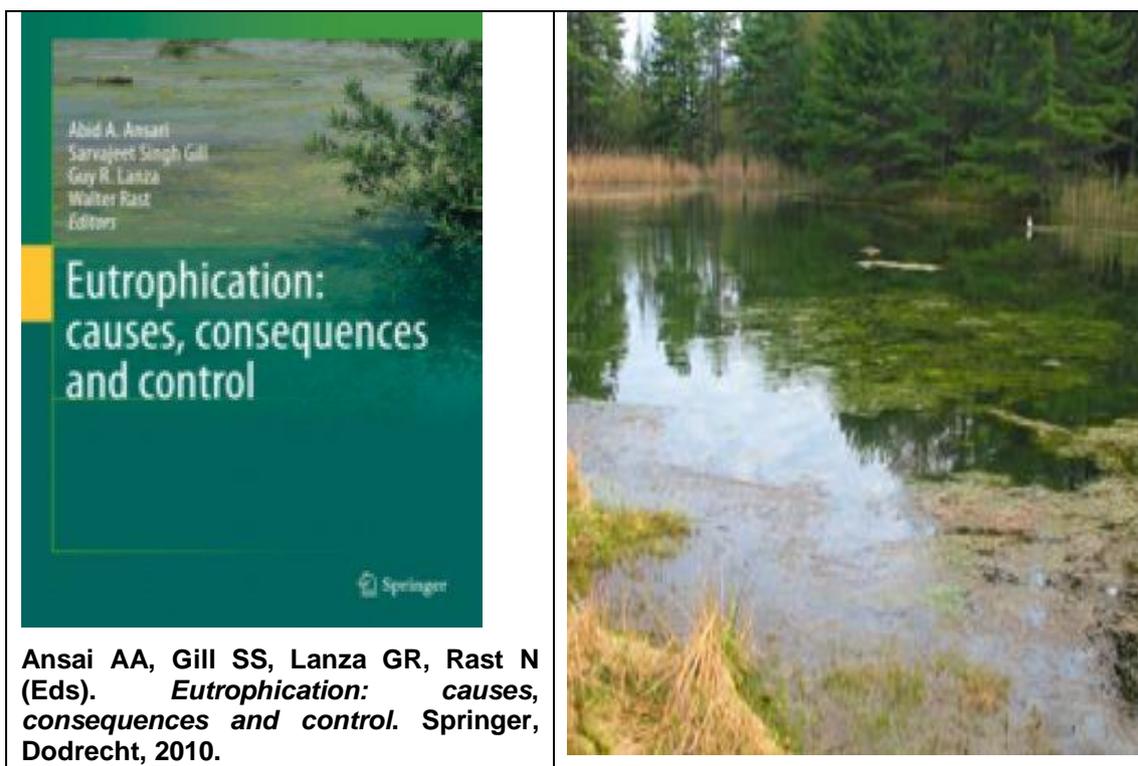


Figure 4. Eutrophication in the Mediterranean Sea has been studied in connection with public environmental policies of the Mediterranean states

c. Shipping routes in the Mediterranean: The Mediterranean Sea is amongst the world's busiest waterways accounting for 15% of global shipping activity and 10% by vessel deadweight tons. Overall vessel activity within the Mediterranean has been rising steadily over the past 10 years and is projected to increase by a further 18% over the next 10 years. Chemical tanker and container vessels will show the highest rates of growth in respect of port callings within the Mediterranean over the next ten years whilst increases in transits will be most pronounced in the product and crude tanker sector. Statistical data showed that 220.00 merchant vessels of more than 100 tons cross the Mediterranean sea waters per year or 1/3 of the total; merchant shipping. These vessels release large amounts of petroleum oil and other chemical substances which are hazardous to marine life and the quality of sea water (Turley 1999; Kingston P, 2002; Alves et al., 2014).

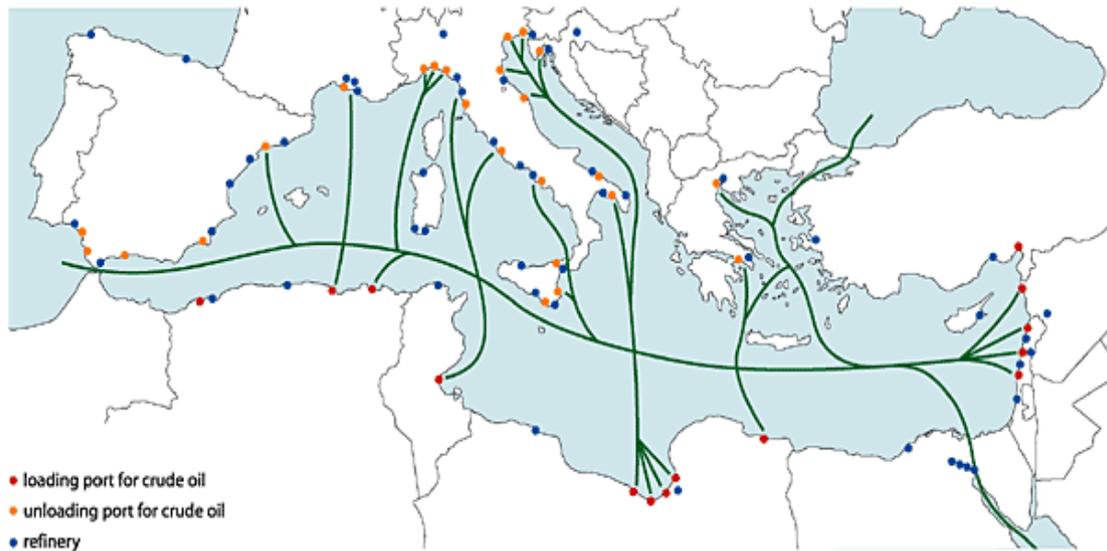


Figure 5. Three continents meet on the Mediterranean basin: Africa, Asia and Europe. Socio-economic and political conditions make this one of the most tense areas around the globe. The Mediterranean is the major shipping route for oil originating in the Middle East [<http://one-europe.info/the-challenges-of-europe-and-the-mediterranean>].

d. Tourism The tourist industry in the Mediterranean region caused serious environmental problems. It produces large amounts of solid and liquid waste in the beaches and the sea causing degradation of coastal and marine environment. Also, the large number of tourists visiting various places increase the long term threats to habitat and endangered Mediterranean species. It is estimated that of the 220 million tourists who visit the Mediterranean Region every year, over 100 million tourists flock to the Mediterranean beaches and other costal sites. Mass tourism has led to degraded landscapes, soil erosion, increased waste discharges into the sea, loss of natural habitats, higher pressure on endangered species and heightened vulnerability to forest fires. Tourism is known to put a strain on water resources (washing, cleaning, drinking water). The Mediterranean Region is estimated to have 31% share in the world tourism. Mediterranean coastal areas account for 20% of international tourist destinations and are considered already seriously damaged (UN World Tourism Organization, 2012) .

At the same time, tourism is one of the most important sources of income for many Mediterranean countries. Studies showed that 82 million people live in coastal cities of the Mediterranean Sea. Also tourism supports small communities in coastal areas and islands by providing alternative sources of income. Rapid development of hotels and tourist facilities has been encouraged by Mediterranean governments to support the large numbers of tourists visiting the region each year. But tourism often concentrates in areas of high natural wealth, causing a serious threat to the habitats of endangered Mediterranean species such as sea turtles and monk seals ([Marris, 2011](#); [Hadjikakou et al., 2013](#); [Languar , 2013](#)).



Figure 6. Mass tourism has put pressure on water sources, led to degraded landscapes, soil erosion and increased waste discharges into the sea.

e. Overfishing in the Mediterranean Sea is another major environmental problem. It is estimated that 20% of marine resources are depleted and 15% are overexploited, such as bluefin tuna, albacore, hake, swordfish, marling, red mullet, sea bream. There are clear indications that catch size and quality have declined dramatically in many fishing sea areas. Also, studies showed that larger and longer-lived species have disappeared entirely from commercial catches of the Mediterranean Sea. Large open water fish like tuna have been a shared fisheries resource for thousands of years but the stocks are now dangerously low. The amount of bluefin tuna in the Mediterranean had decreased by over 80% (over the last 20 years) and

urgent action is considered very important by government scientists. In the Mediterranean Sea, fishing has been historically the greatest ecological stressor, depleting target species and altering entire ecosystems. In addition, the Mediterranean marine ecosystems, especially in coastal areas, have been impacted by the arrival of non-indigenous species and the northward expansion of southern Mediterranean species due to climate changes. Sea temperatures are steadily increasing, extreme climatic events and related disease outbreaks are becoming more frequent, faunas are shifting, and invasive species are spreading (Guidetti et al., 2014; Oceana, 2014).



Figure 7. Incomplete knowledge on the state of the marine environment is a cause of concern. Overfishing in the Mediterranean Sea and climate change are depleting fish stocks and threatened marine ecosystems..

3. An Emerging Threat : Marine Litter in the Mediterranean Sea

Environmental pollution by marine litter is another emerging and threatening prospect for the marine environment. Although marine litter is not highly toxic at first sight the impact on coastal and marine ecosystems was recognized many decades ago. The most important pollutants of the marine environment were presented in various scientific publications (Clark, 2001; Hofer, 2008; Katsanevakis, 2008). Some important scientific papers and reviews on marine litter in the last decade have been published. in the

international scientific journal *Marine Pollution Bulletin*. dedicated to document marine pollution of seas and oceans and inform marine environment scientists and administrators on the emerging environmental problems ([Spengler and Costa, 2008](#); [Cole et al., 2011](#); [Zarfl et al., 2011](#); [Lebreton et al., 2012](#); [Galgani et al., 2014](#)).

Marine studies observed that fertilizers, pesticides and agrochemicals were contributing about 50% of the total pollution source of surface water and by far the greatest volume of waste discharged to the marine environment is sewage. Sewage effluent, industrial waste, municipal wastes, animal remains and slaughterhouse wastes, etc, are also important sources of marine pollution. Oil pollution from petroleum tanker accidents caused major environmental problems. Additionally, heavy metals and trace elements as by-products of many industrial processes and organic synthetic chemicals were contributing vast amounts of pollutants to the seas ([Islam and Tanaka, 2004](#)).

From the 1960s it became obvious to marine scientists and environmentalists that sea pollution from marine litter in the open ocean, along the coastline and on beaches was becoming very serious environmental issue. Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea and on beaches, such as plastics, wood, metals, glass, rubber, clothing, paper etc. The toxic consequences of this pollution are considerable for the quality of seas and the marine biota ([Barnes, 2002](#); [Ivar do Sol and Costa, 2007](#); [Ryan et al., 2009](#)).

The rapid increase in the last decades of polymer production and myriad applications of single use plastics inevitably lead to a large amount of plastic litter by modern societies which was discarded in the marine environment. Microplastics can be classified in micro-(0.2-2 mm), large micro-(2-5 mm) and meso-plastic (5-10 mm). The results of several studies on marine litter found that in the beginning of the 21st century 60-80% of marine litter is comprised of plastic ([Derraik, 2002](#); [Barnes et al., 2009](#); [Koelmans et al., 2014](#)).



Figure 8. Microplastics in the oceans (sizes 0.2 to 2 mm) is the result of discarded plastic items which degrade slowly into smaller size.

Globally, 288 million metric tons (in 2010, Mtons) of polymers are produced every year ([PlasticsEurope, 2013](#)). More than 1/3 of that total is used in disposable packaging which is discarded within one year of production ([Barnes et al., 2009](#); [Thompson et al., 2009](#)). Plastic debris dominates marine litter ([Coe and Rogers, 1997](#); [UNEP, 2005](#)) because plastic products and thousands of plastic items break down slowly into smaller pieces, called microplastics through a combination of photodegradation, oxidation and mechanical abrasion ([Andrady, 2003](#); [Andrady, 2011](#)), whereas thick plastic items can persist for decades, especially when shielded from UV radiation under water or in sediments ([Gregory and Andrady, 2003](#)). The worrying think is that while plastic consumption all over the world is dramatically increasing, waste recycling, and management (i.e. for energy use, etc) and other measures to reduce the amounts of plastic municipal solid waste (MSW) proved inadequate. It is estimated that 4.3 billion urban residents (by 2025) will generate 1.42 kg/capita/day of MSW or 2.2 billion tons per year ([Hoornweg and Bhada-Tata, 2012](#)). According to Environmental Protection Agency (EPA), in 2012 USA produced 32 million tons of plastic waste, representing ~13% of MSW. In 2012, the US generated almost 14 million tons of plastics as containers and packaging, about 11 million tons as

durable goods such as appliances, and almost 7 million tons as nondurable goods, such as plates and cup (EPA, 2014).

The factors that influence littering behavior of the public, especially in tourist destinations, are well studied. (Bator et al., 2011; Slavin et al., 2012, Kin, 2012). Because of the long lifetimes of plastic, prevention strategies are vital to reduce marine litter. Microplastics formation is another serious pollution problem for the marine environment. Marine debris can be prevented by controlling litter and trash at the source, building strong public awareness and fostering behavior change are key components (Keehner, 2012).

4. Why Marine litter in the Mediterranean Sea Has Become Big Issue?

The Mediterranean Sea region is surrounded by 18 highly populated countries and it is the greatest tourist destination in the world. Mediterranean Sea waters include some of the most extreme oligotrophic waters in the world such that it is only capable of supplying 50% of its requirements for fish. The Mediterranean Sea is highly sensitive to climatic changes, it has high evaporation rates, low land runoff from few rivers and seasonal rains resulting in a deficit in its hydrological balance.



Figure 9. Marine Litter in the Mediterranean Beaches has become a big environmental issue in recent years.

This has worsened with the damming of rivers such as the Nile. Changes in river flow and agricultural practice in the Mediterranean region influenced the concentration and ratio of different nutrients flowing into the sea (higher nitrogen and phosphorus flowing into the Adriatic and lagoons of the Nile which has led to eutrophication). Additionally, the Mediterranean Sea in the last decades witnessed some rapid population increases in the surrounding countries, and a large influx of tourists in the coastal areas, especially along the southern shores. All these changes increased the risk of pollution in coastal areas applying substantial pressure on the future of the Mediterranean sensitive ecosystems and protected areas ([Turley, 1999](#)).

Marine litter has been an environmental issue of concern in the Mediterranean area since the 1970s and especially its sensitive ecosystems. The Mediterranean countries adopted the Convention for the Protection of the Mediterranean Sea against Pollution (the **Barcelona Convention**) in 1976 and in 1980 adopted a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources (with emphasis on marine litter). Also, plastic marine litter in the Mediterranean area is considered very important, due to the increasing knowledge about their deleterious impacts of polymer chemicals and additives on marine biota ([Laist, 1987](#); [Coe and Rogers, 1997](#); [Moore, 2008](#)).

5. Actions and Surveys to Identify Sources and of Marine Litter

After the Barcelona Convention, (1975) Mediterranean countries adopted in 1995 the Action Plan for the Protection of the Marine Environment and the Sustainable Development of the Coastal Areas of the Mediterranean (MAP Phase II) ([European Commission, 1995](#)). The UNEP/MAP (United Nations Environment Programme/Mediterranean Action Plan), jointly with IOC (Intergovernmental Oceanographic Commission) and FAO (Food and Agriculture Organization, Rome), commissioned in 1988 a survey with five participating countries (Cyprus, Israel, Italy, Spain and Turkey), considered as a landmark activity for the assessment of coastal and marine litter in the Mediterranean Sea ([IOC/FAO/UNEP, 1989](#); [UNEP/IOC/FAO, 1991](#)). A review

related to the marine litter in the coastal areas of the Mediterranean Sea was presented in 2000 ([IOC/UNESCO, 2000](#)).

From 1999 UNEP/MAP initiated actions on coastal and marine litter in the Mediterranean Sea. Especially solid waste which is considered responsible for the presence of marine litter on the beaches, with most plastic debris floating on the sea water or found on the sea bed. Based on survey facts, MEDPOL built up a strategy and an action plan (SAP MED) to assist coastal local authorities to improve the coastal management of waste, identify priority categories of polluting substances (plastics) and the implementation of specific pollution reduction measures (<http://www.unepmap.org>). In 2003, UNEP/MAP and WHO prepared Guidelines for Management of Coastal Litter for the Mediterranean Region ([MAP, 2003](#)) and in 2006 UNEP/MAP developed a medium-term public awareness and education campaign on the management of marine litter in the Mediterranean area ([UNEP/MAP, 2005](#)). Also, in Greece, UNEP/MAP, opted to work with Non-governmental Organizations (NGOs), such as the well organized MIO-ECSDE (Mediterranean Information Office, for Environment, Culture and Sustainable Development), HELMEPA (Hellenic Marine Environment Protection Association) and Clean Up Greece. The outcome of this partnership was a series of awareness events, brochures and clean-ups in various beaches with the support of schools ([UNEP/MAP, 2011](#)).

International organizations and NGOs have conducted surveys and beach cleanup campaigns yielding data and information on marine and coastal litter. The 2008 report-assessment contained data from 14 Mediterranean countries concluding that mostly comes from land-based activities (tourism and other recreational activities). Marine litter is composed mainly of plastics 50-70% (bottles, bags, caps/lids, etc.), aluminum and other metals ~15-17% (cans, etc) and glass bottles ~10-12%. Also, smoking related activities accounts for a large number of collected items (i.e. cigarette butts discarded on marine beaches). In terms of marine litter floating in the sea (number of items observed), plastics account for about 83 %, while all other major categories (textiles, paper, metal and wood) account for about 17% ([UNEP, 2009](#); [UNEP/MEDPOL, 2011](#)).

On May 12th 2014 in Athens (Greece) a series of activities related to marine litter in the Mediterranean took place within the framework of the Greek Presidency of the European Union and back-to-back with the Union for the Mediterranean (UfM) Ministerial Meeting on Environment and Climate Change. A 3-day regional training took place on Marine Litter in the Mediterranean and the launching of an exhibition on marine litter, organized within the framework of the FP7 project entitled: MARine Litter in European Seas – Social Awareness and CO Responsibility (MARLISCO) (MIO-ECSDE, 2014). Two important reviews on marine litter in European Seas and guidance notes on monitoring were published in 2013 by scientists and NGO members of the Mediterranean countries (Hanke et al., 2013; Kershaw et al., 2013).

Another very interesting project combating marine litter in the Adriatic Sea is the DeFishGear (collecting and recycling fishing nets). The Institute of Water of the Republic of Slovenia (IWRS) and the Mediterranean Information Office for Environment, Culture and Sustainable Development (MIO-ECSDE) worked together within the framework of the IPA Adriatic funded DeFishGear project addressing the wider context of the marine litter issue in order to provide strategic input on a regional level.



Figure 10. The pollution problems of the Mediterranean Sea have been the focus of various environmental actions by Non-governmental organizations (NGOs). [Sweepnet .The Mediterranean Sea is our mutual responsibility. (worldwide movement) (<http://www.sweepnet.org/mediterranean-sea-our-mutual>)].

6. Sources and Composition of Marine Litter in the Mediterranean Beaches and Coastlines

From the 1980s some initial studies and surveys on marine litter in the Mediterranean Sea, were performed in the coastline and touristic beaches but also for floating plastics items along the coastline. In later years scientists examined marine litter in the bottom of the sea (or the so called benthic marine litter) that was collected by trawl nets or oceanographic cruises. In this review we arranged the studies in chronological order and the recovery of marine litter from beaches, surface water and the bottom of the sea.

The first recorded survey of marine litter in the Mediterranean was in 1979 by Shiber ([Shiber, 1979](#)) in the coast of Lebanon. The occurrence of plastic pellets (resin) along the coastline is not a new phenomenon, but their importance as marine litter was recognized from the 1970s. Except for polluting the seas these pellets are eaten by fish or other marine animals causing suffocation or toxic effects. These pellets occurred fairly commonly all over the world beaches ([Gregory, 1977](#)). Most of the plastic pellets were styrofoam, wax, broken plastic-ware and other materials (mainly polyethylene, PE, polymethyl methacrylate, PMMA and polystyrene, PS) and most likely was due to waste disposal by plastic factories or cargo-loss during sea transport ([Shiber, 1979](#)). In 1982, Shiber extended his studies to Spain's 'Costa del Sol' beaches (from Barcelona to Algeciras). The study found great variety of shape and colour pellets covered with tar. Noticeably, more than 100 of Spain's plastic factories are situated on or near Mediterranean coastal areas. Tourism, cargo loading and spillage at sea during transport are the most important sources ([Shiber, 1982](#), [Shiber, 1987](#)). In 1988, Shiber extended his survey with five beaches along the coast of Beirut. Plastic pellets were more abundant than they were in 1977 on three beaches. Megalitter, chiefly plastic but also paper, metal, and glass, had increased greatly compared with that seen 10 years ago (waste disposal practices of the plastic manufacturers and loss of cargo from ships).

These initial studies prompted other scientists to extent their surveys to other beaches of the Mediterranean area. Persistent litter on 13 beaches were

measured in Spain, Italy (Sicily), Turkey, Israel and Cyprus in the 1988-1989 period. Plastic litter items were the most abundant (followed by wood, metal and glass). The quantity of the litter was inversely related to its geographical distance from a population centre and as it was expected related to the number of visitors. The nature of garbage indicated that most coastal litter was land based ([Gabrielides et al., 1991](#)). Hand collection of marine litter in beaches of the Mediterranean region was conducted for many years in various countries. A study from six beaches in Israel found that 70% of the litter was plastic and the remaining wood, metal and glass. Clean-up operations during summer help reduce litter on the beach but only for a few weeks. The nature of the litter (containers of food, beverages and cosmetics, plastic bags, garments, foam rubber mattresses and toys) indicates that most of the litter is left by beach-goers ([Golik and Gertner, 1992](#); [Golik, 1997](#))



Figure 11. Plastics, metal, glass and paper are the most important type of marine litter in many Mediterranean beaches.

International Coastal Cleanup (ICC) campaigns are coordinated globally by the NGO Ocean Conservancy (Washington DC-based, USA) in cooperation with NGOs in over 1000 countries. ICC campaigns in the Mediterranean region were organised in various countries in the period 2002-2006 (volunteers and schools). The results of these campaigns were recorded in a report of UNEP/MAP in a meeting in Rhodes (Greece), 25-27 May 2011

([UNEP/MAP, 2011](#)). The Hellenic Marine Protection Association (HELMEPA) was the national coordinator of the ICC campaign in Greece. Litter data were collected over from 16 Mediterranean countries that participated in the ICC campaigns between 2002-2006. The countries participating were: Bosnia, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, Malta, Palestine, Portugal, Spain, Turkey and Tunisia. The surveys of 2002-2006 founds that the origin of marine litter was predominately: 52%, from shoreline and recreational activities, 40% from smoking related activities, 5% from ocean/waterway activities, 2% dumping activities and 1% from medical and personal hygiene. The percentage of marine litter was: 27% cigarette and cigarette filters, 10% cigar tips, 10% plastic bottles, 8.5% plastic bags, 7.5% aluminium cans, 7.3% caps/lids, etc. ([UNEP/MAP, 2011](#)). A study of marine litter in beaches on the island o Malta (central Mediterranean Sea) focused on the abundance of plastic pellets. The concentration plastic pellets was more than 1,000 pieces per m². The majority of the polymeric material was PE, which is also the predominant plastic material found in other Mediterranean regions ([Turner and Holmes, 2011](#)).

A review on the current state of marine litter (distribution, quantities and types) in various European seas and national surveys and activities have been presented in a thorough study under the MARLISCO project (MARline Litter in Europe Seas: Social Awareness and CO-Responsibility). The report contains details on international and national surveys in the various environmental compartments by MSFD regions ([Kershaw et al., 2013](#)).

7. Marine Litter as Floating Debris in the Mediterranean Sea

Floating marine litter in the Mediterranean Sea can be observed in many areas. The first study for floating litter was carried out by in Malta. It was found that there is a high density of floating debris, at approximately 2.000 items per square Km in a region 64 km SW of Malta and that 60-70% of the floating objects counted were pieces of plastic ([Morris, 1980](#)). Floating megalitter (for sighting by eye or with binoculars) was carried out in the Eastern Mediterranean Sea (small area of 8 km over 22 days). The concentration of floating items was in the order of 0.012 g/m². Most of the

observed marine litter was plastic debris and other man-made items (McCoy, 1988). Another study (1997-2000) with large floating debris on surface water was carried out in the Ligurian Sea (NW Mediterranean Sea). The density order was 15-25 objects per km² (1997) decreasing to 3-1.5 objects per km² in 2000. Authors suggested that the difference is the result of meteorological factors, marine currents and debris input variability (Aliani et al., 2003). Plastic accounted for the major items of debris because of poor degradability. Aluminum cans, fishing nets, glass and polyurethane containers were also found in the area under study. Floating marine litter can become a vehicle for transport (by wind and surface currents) of marine species (rafts for “hitch-hiking” species) like mollusks, polychaetes and bryozoans (Aliani and Molcard, 2003).

A large-scale survey of floating natural and anthropogenic litter debris (for sizes >2 cm) in the central and western part of the Mediterranean Sea took place in the last years and results were published in 2014. Floating debris was found throughout the entire study area with densities ranging from 0 to 194.6 items/km². 78% of all sighted objects were of anthropogenic origin, such as plastic and styrofoam. Researchers estimated that more than 62 million macro-litter items are currently floating on the surface of the whole Mediterranean basin (Suaria and Aliani, 2014).



Figure 12. Discarded fishing nets have become a serious environmental problem in many areas of the Mediterranean Sea. Various efforts were initiated recently to collect and recycle fishing nets.

A study measuring neustonic plastic litter (surface sea water) was carried out in Corsica (August 2011-August 2012, Bay of Calvi) ([Collignon et al. 2014](#)). Plastics were classified in micro-(0.2-2 mm), large micro- (2-5 mm) and meso- plastic (5-10 mm). The average concentration of 6.2 particles/100 m² was observed, whereas the highest abundance values (69 particles/100 m²) were observed during periods of low offshore wind conditions. A high percentage (74%) of samples contained plastic particles, such as filament, polystyrene and thin plastic films. Micro- and meso- plastic pollution in the Western Mediterranean Sea was carried out in 2013. The results revealed that plastic marine items are widely distributed and their concentrations are the same order of magnitude with those in the N Atlantic and N. Pacific subtropical gyres ([Faure et al., 2013](#)).

8. Marine Litter Collected from the Seafloor of the Mediterranean Sea (benthic marine litter)

A number of exploratory studies for marine litter took place in the bottom of the Mediterranean Sea by trawl nets in the period 1987-2014. The first study in the scientific literature was carried out by Bingel and co-workers. Bean trawl nets were employed to sample plastic litter. This type of litter is called also benthic marine litter ([Bingel et al., 1987](#)). The next study (a 30 days survey) was carried out in Eastern Mediterranean regions in 1993 by beam trawl net sampling benthic fauna and marine litter at the same time. The majority of the items collected were plastic bottles, various other plastic items and aluminium cans. The type of marine litter is an indication that vessel-generated waste are discharged in the sea despite the prohibitive regulations and maritime laws ([Galil et al., 1995](#)). In the period 1993-1994 a marine litter investigation was carried out in the continental shelf of the NW Mediterranean region during oceanographic cruises. The majority of the marine litter in the bottom of the sea were plastic and glass bottles, metallic objects and fishing gear with the greatest abundance near metropolitan areas. Concentrations of more than 200 debris pieces per hectare (1 ha=10,000 m², 100 m by 100 m) were found around Marseille. Plastic bags accounted for more than 90% of

total debris. In the Gulf of Lions, most of the debris was found in submarine canyons to a depth of 700 m. (Galgani et al., 1995).



Figure 13. Marine litter, mostly plastic, car tyres, fishing gears, glass bottles and metals are found of the seafloor of the Mediterranean Sea.

Another oceanographic cruise in NW Mediterranean Sea (1994-1996) collected debris from the deep sea floor on the continental slope and bathyal plains at depth of more than 500 m. Litter were mostly plastics (plastic bags accounted from more than 70% of total debris), plastic and glass bottles, metallic objects and fishing gear. Concentrations ranged from 0 to 70 pieces per hectare. In the last cruise a manned submersible Cyana (designed for observation at depths reaching 3,000 metres) was used. The submersible was provided by IFREMER, (Institut Francais de Recherche pour L'Exploitation de la Mer). Sixteen dives were carried out in canyons off Marseilles and Nice ranging from 40 to 1448 m in depth. In the Gulf of Lions, only small amounts of debris were collected on the continental shelf (Galgani et al., 1996).

Seafloor marine debris was collected by trawl nets in two gulfs, the Patras and Echinadhes Gulfs in Greece in 1999 at depths of 80-360 m. The examination of the findings showed that concentrations were 240 pieces per km² and 89 per km² respectively. The most abundant debris were plastic items followed by metal objects. The high percentage of beverage packaging in Echinadhes Gulf was attributed by authors to shipping traffic (Stefatos et

al., 1999). A comprehensive paper described the results from 27 oceanographic cruises that were undertaken in the period 1992 to 1998 for the study of distribution and abundance of marine litter in continental shelves and slopes along European Seas (including Baltic Sea, North Sea, Celtic Sea, the Bay of Biscay the NW basin of the Mediterranean Sea and the Adriatic Sea). From these studies marine debris were enumerated, particularly plastic and glass bottle, metallic objects, diverse material and fishing gear. Results showed considerable geographical variation. Concentrations of marine litter ranged from 0 to 101,000 pieces per km². Plastic bags and bottles accounted for 70% of the total. In these studies the submersibles Cyana and Nautila were used (at depths 50 to 2,700 m). The influence of geomorphological factors, local anthropic activities and river inputs were obvious from the results of abundance of marine litter in various regions. Accumulation areas for marine litter were detected 200 km west of Denmark, in the southern part of the Celtic Sea and along the south-east coast of France (Galgani et al., 2000).

Shallow coastal areas in Greece were the subject of a thorough survey for marine litter. The mean total density of marine debris was 15 items per 1,000 per m². Plastics were the dominant form of litter (55%) with concentration higher in coastal areas (bays) than in the continental shelf and the deep seafloor. In the Saronicos Gulf, surrounded by densely populated and highly industrialized areas, the abundance of marine debris was higher than the rest of the Greek areas surveyed. Artisanal fishing activities contributed significantly to marine pollution of coastal areas. The major categories of marine debris was: plastic (55%), metal (25%), aluminum beverage cans (14%), rubber (5%), paper-cardboard (3%), clothing (2%), glass (2%), anchorage (2%), etc. (Katsanevakis and Katsarou, 2004). Also, benthic marine litter was collected and studied from Greek gulfs by using bottom trawl nets. The types of benthic marine litter collected from the Gulfs of Patras, Corinth, Echinades and Laconikos were plastic (56%), metal (17%) and glass (11%). The most dominant usage category was aluminum and plastic beverage packaging (32%), general packaging (28%) and food packaging (21%). The dominant marine litter source was land-based activities

(69%), followed by vessel-based (26%) and fishery-based (5%) (Koutsodendrīs et al., 2008).

A study established the abundance and composition of solid marine litter in the SW Black Sea collected by trawling (2007-2008), at depths ranging from 25 m to 100 m. Concentration of marine litter on the seabed showed a large variability (with zones ranging from 128–1320 items per km² and 8–217 kg per km²), higher than in the Mediterranean Sea, consisting mainly of plastic materials (Topcu and Öztürk, 2010). A photographic documentation of marine litter in bathyal and abyssal depths (900-3,000 m) in the Mediterranean Sea was presented by the ePIC (electronic Publication Information Center, Germany, Data Archive PANGAEA (<http://epic.awi.de/30126/>)). (Ramirez-Llodra et al., 2012). Similarly, land-based marine litter in the Mediterranean Sea along the Gaza coast of Palestine was presented in a recent study with dominant plastic items (Zaqoot et al., 2012). A Spanish study investigated the distribution of marine litter on soft-bottom marine habitats in trawling grounds. The results of the study showed that density of marine debris ranged from 0-405 pieces/hectare. Plastics being the dominant marine litter items (Sanchez et al., 2013). A conventional bottom trawl was used to study marine litter in Eastern Mediterranean (Bay of Antalya, Turkey). The depth of sampling area varied between 200-800 m. The mass of overall marine debris concentration range from 18.5 to 2,186 kg/km² and the number of debris range from 115 to 2,762 items/km². The type of marine litter was: plastic (81%), glass (3.9%) and metal (2.2%) (Güven et al., 2013). Another Turkish investigation on marine litter in the bottom of the sea in NE Mediterranean Sea used selective grid system deployed on demersal trawls (used to catch fish or prawns that live on the bottom of the sea). Results showed that plastic were the most abundant debris (73% by weight) and metals (10%). (Eryaşar et al., 2014).

9. Impact of Marine Litter on Marine Biota in the Mediterranean Sea

The extent of the toxic and hazardous impacts of marine litter on marine biota is determined by the type and where it settles (on beaches, submerged on the seafloor or floating). A large number of marine species is

known to be harmed and/or killed by various types of debris. The small size of micro- and meso-plastics can jeopardize their survival, especially since many species are already endangered by other forms of anthropogenic activities.



Figure 14. Marine litter degrades slowly into small pieces and toxic constituent chemicals and additives are leached into the seawater.

Marine animals are mostly affected through entanglement in and ingestion of litter, especially microplastic, metal and glass (Derraik, 2002). It has been established that man-made debris in the sea causes harm, poison or kill a substantial number of marine species (Coe and Rogers, 1997). Especially, synthetic polymers and their final plastic products that have been entering the marine environment in quantities paralleling their level of production over the last half century. However, in the last two decades the deposition rate accelerated past the rate of production, and plastics are now one of the most ubiquitous and persistent pollutants in ocean waters and beaches worldwide (Moore, 2008). Polymers degradation products (microplastics), toxic metals which are widely used as plasticizers, catalysts, stabilizing additives, and pigments can poison marine biota. However, only few reports on toxic chemicals leached from plastics and other marine litter are available (Teuten et al., 2009; Rochman et al., 2013). Weathering and photodegradation of plastics on the beaches results in their surface embrittlement and microcracking, yielding meso- and micro-particles that can be ingested by marine biota. Bioavailability and the efficiency of transfer of the ingested synthetic pollutants across trophic levels are not known and the

potential damage posed by these to the marine ecosystem has yet to be quantified and to understand the impact on marine food webs ([Adrady 2011](#); [Cole et al., 2011](#); [Setälä et al., 2014](#)).

Studies of the impact of marine litter and especially plastic litter on marine biota in the Mediterranean Sea are very limited. A study in Malta that examined loggerhead turtles found that over 20% were contaminated with plastic or metal litter and hydrocarbons ([Gramentz, 1988](#)). Heavy metals as contaminants of marine species originating from general pollution sources or from ingested marine litter has been studied in turtles. Concentrations of heavy metals (Hg, Cd and Pb) were determined in internal organs and nest contents of green turtles *Chelonia mydas* and loggerhead turtles *Caretta caretta* from northern Cyprus, eastern Mediterranean Sea. Mercury concentrations in liver tissue were in the range 2.4-0.55 $\mu\text{g g}^{-1}$ dry weight. Cadmium concentrations were highest in kidney tissue (30.5-5.8 $\mu\text{g g}^{-1}$ dry weight). Lead concentrations in internal tissues were below detection limits in both species. Results were consistent with inter-specific differences in diet and trophic status ([Godley et al., 1999](#)). Marine litter and other chemical pollutants are considered as very serious threat to sea turtles and some endangered species in the Mediterranean Sea ([Jones, 1990](#); [Venizelos, 1991](#)). Plastic litter can transport hydrophobic pollutants which are easily absorbed by lipid tissues of marine species, thus increasing their toxic potential ([Teuten et al. 2007](#)). The occurrence of marine debris in the gastrointestinal tract of 54 loggerhead sea turtles (*Caretta caretta*) was investigated (stranded or captured dead) by fisheries in the Adriatic Sea. Marine plastic debris was present in 35.2% of turtles. Marine plastic debris averaged $2.2 \pm 8.0\%$ of dry mass of gut content, with a maximum of 35% found in a juvenile turtle that most likely died due to debris ingestion. The authors suggested that considering the relatively high occurrence of debris intake and possible sub-lethal effects of even small quantities of marine litter, this can be an additional factor of concern for loggerhead sea turtles in the Adriatic Sea ([Lazar and Gračan, 2011](#)). Marine litter, mainly plastics, were detected in 71% of loggerhead turtle of the Pelagos Sanctuary (Italy) ([Campani et al., 2013](#)).

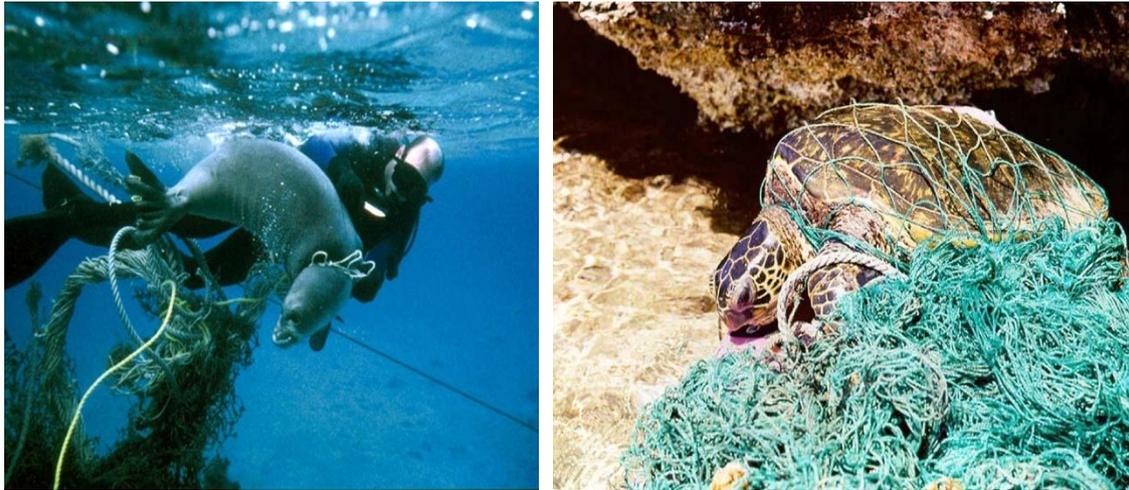


Figure 15. Marine litter can be responsible for damages to marine biota. Fishing nets lost by fishermen –ghost nets– can entangle dolphins, sea turtles, etc, causing starvation, laceration, infection and suffocation.

The Mediterranean basin is a hot spot of biodiversity and sensitive ecosystems with a uniquely high percentage of endemic species. Despite its small dimensions, the basin hosts more than 7.5% of global biodiversity. Most of the data for the variety of marine biota is almost completely confined to coastal ecosystems, and data on deep-sea assemblages are still limited. The study of the impact on marine litter on marine biota and its biodiversity, especially the effects of microplastic pollution, will be very difficult to measure due to lack of the adequate data ([Danovaro et al., 2012](#)).

Baleen whales in the Mediterranean Sea were investigated for micro-litter ingestion as a result of their filter-feeding activity. A study of the Mediterranean fin whale (*Balaenoptera physalus*) and the toxicological effects of microplastics. Initially, the study collected and counted microplastics in the Pelagos Sanctuary (Mediterranean Sea), then measured phthalates in surface neustonic/planktonic samples, and finally detected of phthalates in stranded fin whales. 56% of the surface neustonic/planktonic samples contained microplastic particles. High concentrations of Di-(2-ethylhexyl)phthalate (DEHP) and mono-(2-ethylhehyl) phthalate (MEHP) were detected in the neustonic/planktonic samples. The concentrations of MEHP found in the blubber of stranded fin whales suggested that phthalates could serve as a tracer of the intake of microplastics by marine species ([Fossi et al., 2012](#)).

Also, the presence of plastic debris were investigated in 26 fish species caught in the Eastern Ionian Sea (deep-water long-line surveys). Ingested debris was found in 24 individuals of *Galeus melastomus* (3.2%) and single individuals of *Pteroplatytrygon violacea*, *Squalus blainville*, *Etmopterus spinax*, and *Pagellus bogaraveo*. Ingested debris included mainly plastics (86.5%, fragments of hard plastic, bags, fishing gear and textile fibers)) and to a lesser extent pieces of metal and wood (Anastasopoulou et al., 2013).

Marine litter in the Mediterranean Sea has a major impact on large vertebrates, as animals often become entangled in discarded ropes and nets, or trapped in plastic containers and strapping bands. Turtles have been recorded as ingesting plastic bags in certain Mediterranean areas (Galganic et al., 2014). The impact of microplastics (>5 mm) on large filter feeding marine organisms such as baleen whales and sharks are dangerous. Potentially dangerous because they are ingesting micro-litter by filter feeding activity. These species can be proposed as indicators of microplastics in the pelagic environment in the implementation of Descriptor 8 and 10 of the EU Marine Strategy Framework Directive (MSFD) (Fossi, et al., 2014).

10. Conclusions

Man-made litter has become in the last decades a serious environmental pollution threat, placing a heavy burden to regulators and environmentalists. Accumulation and persistence of litter in the marine environment presents a series of hazards and toxicological concerns to the quality of water and the marine biota. Studies in the Mediterranean regions showed that marine litter has been spread in all marine habitats, from coastal water, to beaches, surface water, seafloor and to the most remote points in the sea. On the seafloor, marine litter, particularly plastic, can accumulate in high densities with deleterious consequences for the marine species. Marine litter is found in all European sea waters and in most remote locations from land, as recorded in 32 sites (Phammail et al., 2014). Studies showed that the Mediterranean Sea has one of highest densities recorded of marine litter. The surveys showed that the highest litter density occurs in submarine canyons, whilst the lowest density can be found on continental shelves and on ocean

ridges. Plastic was the most prevalent litter item found on the seafloor. It is hoped that the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC) will establish direct action to tackle marine litter and to achieve good environmental status of the marine waters by 2020. The Executive summary of the guidance on monitoring of marine litter in European seas was published in 2013 from the MSFD technical subgroup on marine litter ([Galgani et al., 2013](#)).



Figure 16. Marine litter in the Mediterranean Sea has a major impact on large vertebrates, as animals often become entangled in discarded ropes and nets and some find difficulties to explore for food.

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