The Terminology of Marine Pollution by Plastics and Microplastics

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I dedicate this book to my mother

INTRODUCTION

When I started my PhD course in Euro-languages and Specialised Terminologies at the Department of Legal and Economic Studies of the University of Naples Parthenope, I had fuzzy ideas about academic research and little knowledge of terminology as a science. Then, during my first year, I started to appreciate the possibilities offered by terminological research.

Before introducing this book, it could be useful to give some basic notions on terminology to the non-expert reader. Far from being a simple branch of linguistics, terminology is rather a linguistic science fitting perfectly into broader academic contexts. In particular, terminology can be seen as serving technical-scientific subjects, somehow working towards their advancement and development by offering a complementary—linguistic yet scientific—standpoint. It is no coincidence that ISO 1087-1:2000 defines terminology as a “science studying the structure, formation, development, usage and management of terminologies in various subject fields”, where terminology is understood as a “set of designations belonging to one special language”. Terminology operates according to specific methodologies, “tr[ying] to keep stick to the mechanisms of scientific approach” (L. Depecker, 2015 p. 42). Hence, terminology studies arise from these areas of specialised knowledge, where communication responds to precise linguistic codes. Starting a project in terminology is always a challenging enterprise: knowledge of a given subject field, practical and technical expertise, research abilities, linguistic awareness and a clear view on the scope of the whole work are just some of the skills needed by the researcher. As for the subject of a terminological study, it has been noted that “[i]t is the importance of the topic […] that provides the stimulus for the planning and design of any terminology project” (P. Faini, 2014 p. 22).

By the time I had to start conceiving my PhD thesis, I realised that I could choose to investigate the language of a topic which was always very dear to me. As a sea lover and environmental activist, my wish was to talk about the sea as a way of contributing to its protection and conservation. I was no marine scientist nor an expert in marine research, but as a terminologist I could bridge categories and work to raise awareness among non-experts on the language of marine ecology. Indeed before 2018—when the impact of some epochal resolutions on plastic pollution at the EU level hit the media—people were significantly less aware not only of the proportions of global marine pollution by plastics, but also of certain terms and expressions from the field of marine ecology. Getting closer to the international community of marine researchers, moreover, I noticed that there may be room for misunderstanding even among experts, given the lack of coordination in this broad research field.

This book examines the terminology of marine pollution by plastics and microplastics based on a corpus made up of different textual genres. The language of marine ecology, it will be shown, is endowed with the features of a specialized language, although the popularity of some of its contents brings it beyond the simple expert-to-expert usage context and out of the scientific domain proper. To date, there are few known studies exploring the relation between ecology and humanities studies, and even fewer focusing on the linguistic-terminological aspects of ecology. Therefore, this book aims to analyse the nature, characteristics and applications of this terminology by observing its degree of technicity in a terminological corpus. The corpus collected for this purpose was created following specific criteria and was processed with the aid of a software for terminological extraction, with outcomes concerning research operations such as frequency and keyword analysis, concordances and collocations.

From a methodological standpoint, terminological works may be descriptive or prescriptive, depending on the ultimate objective of the project: a descriptive work is usually made to describe the set of established terms and expressions of a given domain, to register new entries and/or to simply observe the evolution of a terminology over time—with questions on whether to choose a synchronic or a diachronic approach. A prescriptive work, on the other hand, can be used in those fields or specific domains where there is no standardised terminology, either because it is too recent or too obsolete, and a terminological review is necessary; to this end, terminological records can be designed, as well as glossaries and databases.

This work has a marked descriptive intent and privileges the synchronic approach, given the dynamicity of the chosen linguistic domain. It is offered to expert and non-expert readers with the sole, though ambitious, aspiration to illustrate a language encompassing both technical terms and words from the general language in English. Ultimately, by spreading information on the language of marine plastic pollution, it will hopefully serve as a humble contribution to the environmental cause.

In particular, Chapter 1 offers an introduction to marine ecology, tracing its origins as a science discipline and illustrating its key concepts and concerns. By providing an overview of the topics subject of research in marine ecology, basic field terminology is presented and explained to the reader. In the second part of the chapter, applied marine ecology and the issue of marine pollution by plastics are introduced. These sub-topics represent the core of this book, whose aim is to observe and analyse the terminology within these research areas. More specifically, I decided to examine research and publications produced within the European Union area and/or dealing with the situation in the Mediterranean Sea. Therefore, a summary of existing regulations on marine litter in Italy and at the European Union level is provided in the conclusive paragraphs of this chapter so as to further complete the discourse on marine ecology.

Chapter 2 introduces the theoretical and methodological framework, with terminology and corpus linguistics as reference disciplines. After an outline of the main theories of terminology studies and a brief literature review, the key concept of domain is explained and considerations on the synchronic approach are made. Speaking of terminology, it is essential to mention specialised languages as the privileged field for terminological research; some definitions on the issues of use and specificity within language for specific purposes (LSP) are also provided. The last part of the chapter is devoted to corpus linguistics, considered both as a methodology and a "methodological practice" necessary for corpus analysis. Finally, notions on textual typology and genre taxonomy are given.

Chapter 3 and 4 represent the core of this work. In Chapter 3, I tried to establish a link between marine ecology and the humanities, two broad disciplines and areas of knowledge traditionally separated also in terms of research subjects. Luckily, the increase of studies in environmental humanities is today helping to narrow the gap between these two fields, with more and more points of contact between scientists and scholars from social sciences, philosophy, ethics, and other fields. Therefore, my idea was and is that also the humanities—especially linguistics and terminology—can contribute to the advancement of marine ecology and environmental protection in general by spreading specialised terms and concepts among non-experts.

In particular, some areas of expertise which make the language of marine ecology an LSP proper are illustrated; at the end of the chapter, some characteristics of my terminological corpus are introduced.

In chapter 4, the MEco (Marine Ecology) corpus is finally presented. This extraction corpus, a collection of texts in the domain of marine ecology focusing on plastic pollution, constitutes the material for my case study. In order to make software analysis less obscure to the reader, the rationale behind the construction of the MEco corpus is given, together with an explanation of the three textual sub-genres composing it (scientific, informative, normative texts).

Chapter 5 shows the results of corpus analysis. After presenting the features of the chosen extraction software (*AntConc*, version 3.4.3 for Windows), chapter sections provide software outcomes concerning different research operations. In particular, frequency analysis and keyword analysis (relative to the whole MEco corpus and the three sub-corpora) will yield significant results concerning the presence and distribution of technical and/or specialised terms within the three sub-genres and in the whole corpus. Moreover, concordance and collocation analysis starting from the MEco frequency list further validate my research hypotheses.

Finally, chapter 6 completes this book by describing the results of an online survey on the language of marine ecology and pollution, and by offering further research perspectives.

The conclusive section, following the standards of terminological works, consists of terminological records relative to the main keywords from the MEco corpus.

CHAPTER 1

MARINE ECOLOGY

1.1 Ecology: Key Concepts

The birth of ecology dates back to the last four decades of the 19th century, when the appearance of Darwin's *On the Origin of Species* (1859) determined an epochal change for European studies on zoology and botany. The work of Ernst Haeckel is to be considered in this context of scientific ferment and natural discoveries. Inspired by Darwin's most influential book, Haeckel wrote to the British naturalist to show his admiration and enthusiasm. In 1866, he published two volumes of *Generelle Morphologie der Organismen*—with volume II dedicated to Darwin himself, as he intended to reorganise zoology along Darwinian principles—where he first coined the term *ecology* (*Ökologie* in German) from the Greek word *οἶκος*, "home". He indeed conceived the environment as "the household of nature" and living organisms as elements in "the economy of nature", while he defined ecology as "the whole science of the relations of organism to the environment including, in the broad sense, all the 'conditions of existence'" (F. N. Egerton, 2013 pp. 227, 286). In 1906, a one-volume abridgement of *Generelle Morphologie* with clearer explanations eventually helped establishing the term *ecology* among other suggestions. Later, the concept of environment would be further implemented to include organic and inorganic settings, other organisms and physical surroundings, as well as relationships and interactions between individuals, populations, and between organisms and their ecological systems, or ecosystems.

Regarded "as little more than a pastiche of natural history and schools of thought" (E. P. Odum, G. W. Barrett, 2005 p.xiii) at the beginning of the 20th century, ecology found its recognition around the 1920s as a distinct field of science. As a matter of fact, the field was at the beginning strictly divided along different taxonomies (such as plant ecology or animal ecology), until eminent studies by the pioneers of modern ecology—such as Elton's *Animal Ecology* (1927), Clements'

Plant Physiology and Ecology (1907), Shelford's *Animal Communities in Temperate America* (1913) or the works by Warming and Forbes, to name but a few—contributed to its unification. Starting from 1893, the common denomination of ecology was adopted to refer to field studies separated from laboratory ones: "[e]cology was to be the study of nature in nature" (G. Van der Valk, 2011 p. 40). In the first decades of the 20th century, ecologists started to see themselves as a community, establishing the first societies—the first ones, the British Ecological Society and the Ecological Society of America founded in 1913 and 1917 respectively—and dedicated journals. Another past misconception about ecology looked upon it as a division of biological sciences, somehow similar to environmental biology; after the 1970s, however, ecology gained its status as an interdisciplinary science where biological, physical, and social sciences were linked together. A more inclusive definition of ecology by the eminent biologist Edward O. Wilson acknowledges that ecology

> was and remains the discipline that addresses the highest and most complex levels of biological organization. It was and remains a study of holism and emergence, of the properties of life taken from the top down. […] To understand ecology thoroughly would be to understand all of biology, and to be a complete biologist is to be an ecologist. (E. P. Odum, G. W. Barrett, 2005 p. xiii)

The holistic approach may indeed be pivotal to understand the real nature of ecology, one in which all elements are interrelated and interdependent, and where no theory can be exhaustive unless it is based on careful consideration of all possible aspects, problems or elements connected to a given topic. This is why ecology is intrinsically multidisciplinary, and why this discipline struggled so much to be recognised as a proper field of research and practice. Speaking of ecology theories and practices, these include an array of methodologies based on different perspectives (and different purposes), all of which are complementary to one another and constitute the very peculiarity of this science.

The contemporary era of ecology opens after the environmentalist "awakening of consciences" of the late 1960s: after some major pollution events and the appearance of breakout books like Rachel Carson's *Silent Spring* (1962), awareness of man-made pollution raised, leading to popular environmental movements first in the US and then in Europe. Carson herself was among the first environmental activists and scientists to grasp and communicate the ecology principle that natural systems are interrelated and interdependent. Carson noticed that, compared to the lifespan of our planet, the human presence and coexistence with the earth's natural environment is incredibly short. In her own words:

> [t]he history of life on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and the habits of the earth's vegetation and its animal life have been molded by the environment. Considering the whole span of earthly time, the opposite effect, in which life actually modifies its surroundings, has been relatively slight. ([1962] 2002 p. 5)

It was in this period that people started to realise the impact of human activities on nature, making ecology popular and coming to understand that human beings are also part of nature's life. Thanks to Carson, it became well-know that the human body was also vulnerable to a toxic environment, hence showing that our bodies are not boundaries (L. Lear introducing R. Carson 2002, pp. xiii-xiv). For the first time, men realised that they were not in a position of dominance over nature, and questioned their relation with the surrounding environment. Eventually, the environmental movements influenced the government's decision to tackle pollution by introducing, in the US, the first major regulations and structured policies (such as the creation of E.P.A. in 1970, the Clean Water Act in 1972, the ban of DDT in 1972), while more and more people became concerned and involved in the protection and conservation of nature. Thanks to this popular shift, today ecology is understood as both a biological and a human science, and contributions to ecological studies range from different perspectives and approaches, all agreeing that "[w]e are, after all, a species in an ecosystem, exactly adapted to the conditions peculiar to the surface of this planet, and subject to the same principles of ecology as all other species" (E. P. Odum, G. W. Barrett, 2005 p. xiii).

Other interesting connections of ecology to human and social disciplines include the relation with economics, already pointed out by Odum and Barrett when they note that the word *ecology* shares the same root with *economics*, both deriving from the Greek word for "house", *οἶκος*. However, the lexical/semantic similarity is but the most obvious contact point between the two fields, both applying to the "material welfare of man", as suggested by Forbes already in 1922. The two scholars also advised against neglecting ecology among the subjects of practical interest to human societies, highlighting how economic systems "value things made by human beings that primarily benefit the individual, but […] place little monetary value on the goods and services of nature that benefit us as a society" (E. P. Odum, G. W. Barrett, 2005 pp. 2-3); the idea that these "life-support services" are considered free implies that natural resources have no value in many economic systems—which was the standard policy framework until two decades ago. Today, the new models of green and circular economy are spreading in many western societies, gaining more and more *momentum* among governments and citizens as the only feasible way towards short and long-term sustainability.

The 20th century has proven an era of unprecedented environmental changes, and only in the last few decades have the world's governments been taking resolutions to keep up with them. A few years ago, Timothy Morton imagined a new ecological society in which the ecological thought would shape the economy, demolishing the "boring, rapacious reality" of capitalism and establishing a more pleasurable, sociable, and reasonable way for our future (2012 p. 19). After all, ecology is more social and humanistic than it appeared at its beginning.

For what concerns the aim of ecology, it can be found in the desire to gain scientific understanding of nature's ecosystems as processes, by explaining or describing them, in order to increase our "knowledge of the living world"; according to Begon *et al.*, "[e]cologists also often try to predict what will happen to an organism, a population, a community or an ecosystem under a particular set of circumstances: and on the basis of these predictions we try to control the situation" (2006, p. xii). However, these circumstances may vary depending on numerous factors, therefore ecology must deal with certain "constraints" and "contingencies" which, as noted by Boero (2009 p. 7), affect the study of an ecosystem's life. Of course, our understanding of the environment comes from our knowledge of certain nature laws (constraints), but it is the specific conditions of each ecosystem (contingencies) that best represent the progression of history, representing nature's changeability. As it has been noted, history (time) is one of the three primary dimensions of an ecology study together with spatial heterogeneity (space) and connectivity; other frameworks include structure or organization as useful pattern-identification criteria. Modern ecology is especially concerned with three hierarchical categories: the individual organism (how an organism is affected by/affects the environment), the population (the presence/absence, abundance/rarity of individuals of the same species), and the community (the composition and organization of species populations). Biodiversity itself—defined as "the variety of life on Earth […] includ[ing] all organisms, species, and populations; the genetic variation among these; and their complex assemblages of communities and ecosystems"[1]—is analysed at the level of genetic, species or ecosystem diversity. Levels are set arbitrarily for convenience, as no measurable divisions exist in the global ecosystem, but each ecosystem stands in a continuum. As regards the level of ecosystem, it should be specified that the term *system* is used in its base meaning of "regularly interacting or interdependent group of items forming a unified whole"[2], or, in the words of Begon *et al.*, "a further category of organization […] comprising the community together with its physical environment"(p. xi). This and other related principles provide an essential theoretical and practical framework for any study in ecology.

1.2 Introduction to Marine Ecology

Among the vast array of existing natural ecosystems, the marine one has a specific relevance in quantitative terms: all major oceans (Atlantic, Pacific, Indian, Arctic, and Antarctic) and their connected water systems cover around 70% of the Earth's surface. The ocean ecosystem is also the most vulnerable of all natural ecosystems, either for its elusive nature, its inconceivable magnitude, or for the partial, surprisingly limited insight man still has into it. In his groundbreaking book *Plastic Ocean*, Captain Charles J. Moore describes the ocean as "the planet's womb", where life mysteriously began. Still, he continues, although we "coexist with the ocean", we do not really know it, "like the planet next door" (pp. 3-4). As a matter of fact, the water element on our planet is so vast and seemingly boundless that man is still divided between feelings of fear for it and faith in its power. This is possibly the reason why, for all human history, man has taken advantage of the sea, eventually forgetting that it also needed protection. Going back to Carson, she brilliantly observed that "[i]n an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of his indifference" (2002 p. 39). Today, the scope of marine ecology is delimited by the specific diversity of the ocean

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[1] http://www.unesco.pl/fileadmin/user_upload/pdf/BIODIVERSITY_FACTSHEET.pdf (last accessed March 7, 2018).
[2] *Ibid.* p. 4.

ecosystem, while other types of marine settings such as estuaries and seashores constitute other different ecosystems. Following the definition from the terminological thesaurus *EcoLexicon*, marine ecology is a "branch of ecology that studies seas and oceans from a physical, chemical, biological, and geological perspective"[3] more directly derived from marine biology. Actually, a controversy about whether marine biology and oceanography constitute two separate disciplines exists, but, to put it in simple terms, it could be stated that oceanography is closer to Earth sciences—focusing mainly on the physical elements of the environment—whereas marine biology studies its living organisms. Again *EcoLexicon* describes oceanography as a "science that studies the oceans and seas, their forms, physical features (water, bottom, flora, and fauna) and dynamics"[4], although its objectives often overlap those of marine biology.

Concerning the birth of modern marine research, Ernst Haeckel and Victor Hensen were among the pioneers of marine biology and oceanography. After the British Challenger expedition of 1873—1876, Haeckel wrote three reports describing some of the collected specimens; being an expert in the field of plankton species, he motivated Hensen—the German biologist who first coined the word *plankton*—to expand testing of sampling methods and to improve quantitative research on marine species[5]. Sample testing remains one of the privileged scientific methodologies used by marine ecology, with experimental procedures, chemical identifications, and physical measurements derived from other sciences adapted so as to be effective for the marine environment. Unlike biology, chemistry or physics—where data and results can be quite precise—research in the field of ecology and marine ecology is always subject to an unpredictable number of variables, which make analysis as well as data gathering and evaluation less simple (although experiments in controlled environments are also used). Neither is the taxonomy used for the classification of living organisms as clearly defined as in other sciences, but its schemes constantly change in the effort to better represent the fluctuating relationships among organisms. Witman *et al.* compared ecological

[3] http://ecolexicon.ugr.es/visual/index_en.html (last accessed March 7, 2018).
[4] http://ecolexicon.ugr.es/visual/index.html (last accessed March 7, 2018).
[5] See Frank N. Egerton, "History of Ecological Sciences, Part 47: Ernst Haeckel's Ecology", *The Bulletin of the Ecological Society of America* 94, no. 3 (2013): 234-236; http://www.encyclopedia.com/science/dictionaries-thesauruses-pictures-and-press-releases/hensen-christian-andreas-victor (last accessed March 7, 2018).

experiments in marine ecology to small black boxes, in which elements are removed or added over certain periods of time and responses of the community or ecosystem are measured with the aim of exploring how more factors in the box can be controlled—and thus, of making the experimental box "transparent to the tools of science" (2015 p. 477). On the other hand, it has been observed that the community of marine scientists would benefit from a better synergy between marine and terrestrial studies, in an effort to overlap the perceived barrier residing in the different scientific approach of the two fields[6].

Among the objectives of applied ecology, the protection and conservation of all ecosystems is definitely a priority. Since hardly any natural environment is, even partially, unaffected by the human presence and activity, the branch of applied ecology concerned with the environmental impact of man has been acquiring more and more relevance in the field of ecology studies. The scientific preoccupation with the protection of nature, arising in the second half of the 20th century, is exemplified in a famous quote by Jacques-Yves Cousteau: "For most of history, man has had to fight nature to survive; in this century he is beginning to realise that, in order to survive, he must protect it". As it has been observed, the role of the ecologist is today key to survival, as only a deep ecological understanding can guarantee a sustainable future for the planet and its creatures, one in which our actions are shaped by our ability to predict outcomes under different scenarios. Nevertheless, the understanding effort was often—in the past, but still today in some cases—directed to the purpose of exploiting natural resources, and not conserving them; the environmentalist turn in marine ecology arrived after the intuition that marine ecology could not exclude the human factor from its work; in the words of Munguia and Ojanguren, "[t]he link of without-humans ecology with with-humans ecology is probably one of the greatest revolutions of the environmental sciences" (2015 p. 1).

Today, applied marine ecology can have great influence in the development of local, national and international regulations aimed at protecting marine ecosystems, thanks to a research focus covering global issues that have negative consequences not only for the marine environment, but also for the world's populations: biodiversity loss (at the level of organisms, populations, or communities), habitat loss and destruction, invasive alien species, contamination, ecosystem alterations,

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[6] See Pablo Munguia, Alfredo Fernandez Ojanguren, "Bridging the Gap in Marine and Terrestrial Studies", *Ecosphere* 6, no. 2 (2015): 1.

global climate change, and pollution are now understood as threats to the whole planet. The picture outlined by Greenpeace presents the problem in its full complexity:

> Every second breath we take comes from the ocean. Billions of people rely on our oceans for their food and for employment. In return, we are plundering the oceans of fish, choking them with pollution and altering them forever with the impacts of human-induced climate change. Once seen as boundless, the world's oceans are finite and the marine life they hold can indeed be exhausted. […] The 3rd United Nations Global Biodiversity Outlook in 2010 warned that unless "radical and creative action" is taken quickly, our oceans will collapse. (2013 p. 3)

With a variety of sources of pressure on the oceans, marine ecology has a key role in identifying the proportions of each issue, presenting them to all involved stakeholders, and helping governments to take measures accordingly. Despite the relevance of each of the above-mentioned threats to the oceans, it is safe to say that, thanks to the constant work of marine researchers, the issue of marine pollution—the subject of this book—is finally gaining the deserved popular and institutional attention.

1.3 Water pollution and marine litter

The list of anthropogenic sources of water pollution is rather consistent. Following *EcoLexicon*, by water pollution any pollutant agent, "involving any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks, uses or lives in it"[7] is indicated. The problem has many complex ramifications. The first difference is to be made between point and non-point sources of pollution: in the first case, an individual entity pollutes a waterway, so the polluting source is easily traceable; in the second case, pollution comes from non-identifiable sources, so it is impossible to guess the origin of pollutants. Non-point pollutants from land are transported by air and water, entering the open waters directly or from seashores; once into the ocean, they easily travel around the globe regardless of their provenience. Pollutants themselves can be classified as biodegradable—for example organic waste, sewage, all natural materials easily decomposed in nature or through

[7] http://ecolexicon.ugr.es/visual/index.html (last accessed March 7, 2018).

water treatment systems—and non-degradable—man-made agents which are slow to degrade.

It is important to underline that the majority of water pollution derives from on land activities, in particular around 80% of marine pollution comes from land-based sources—such as sewage, pesticides and nutrients from agriculture, textile chemicals, oil spills, discharges from factories—as a result of inappropriate waste management or human behavior. Added to this, shipping, deep-sea mining, and fishing contribute to littering the world's oceans, for example by accidental loss or intentional dumping of waste from commercial vessels, cargo ships, cruise liners, or discarded fishing gears from fishing boats. The risks arising from water pollution are many and diverse, depending on the type of pollutant; another consideration is that pollution enters the marine ecosystem in very high quantities at an unsustainable rate, making disposal by natural degradation or removal interventions inefficient and insufficient.

In particular, marine litter has devastating ecological and socio-economic consequences affecting habitats, species, ecosystems, but also human health and safety, and economic sectors such tourism and fishing activities[8]. Given the proportions of ocean ecosystems and the fact that garbage moves constantly, it is extremely hard to quantify the amount of debris already accumulated in global waters; recent studies[9] estimated an amount of litter—divided into macro-debris (>20 mm diameter), meso-debris (5—20 mm), and micro-debris (<5mm) depending on its size—entering the oceans every year between 4.8 and 12.7 million tons for plastics alone.

Marine litter accumulates on beaches and seashores, on the sea-floor of the oceans, or on the water surface following specific circulation patterns. Media attention has been paid to plastic debris and to the five great gyres located in the North and South Pacific, North and South Atlantic, and the Indian Ocean: these are massive vortexes

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[8] See Joana Mira Veiga *et al.*, "Enhancing Public Awareness and Promoting Co-Responsibility for Marine Litter in Europe: the Challenge of *Marlisco*", *Marine Pollution Bulletin* 102, no. 2 (2016): 309.

[9] See Jambeck *et al.*, "Plastic waste inputs from land into the ocean" and Dris *et al.*, "Beyond the ocean: contamination of freshwater ecosystems with (micro-) plastic particles", both quoted in Francois Galgani, "Marine litter, future prospects for research", *Frontiers in Marine Science* 2, no. 87 (2015): 1; David K. A. Barnes *et al*, "Accumulation and Fragmentation of Plastic Debris in Global Environments", *Philosophical Transactions Royal Society of London Series B Biological Sciences* 364, no. 1526 (2009): 1986.

of trash where the majority of marine litter gathers. More specifically, a gyre can be defined as "a large-scale system of wind-driven surface currents in the ocean"[10] creating accumulation zones for marine debris; according to The 5 Gyres Institute, these zones are a result of diminished winds and currents creating desert zones where plastic gets trapped for long periods of time. The five gyres have often been portrayed as "plastic islands" by the media; however, this myth perpetuates the plastic pollution problem, "positioning it as something that we can sweep up and 'away', while continuing to use plastic without consequence"[11]. As a matter of fact, research expeditions in the last 20 years have confirmed what Captain Charles Moore made clear in *Plastic Ocean*:

> [W]hat we came upon was *not* a mountain of trash, an island of trash, a raft of trash, or a swirling vortex of trash—all media-concocted embellishment of the truth. [The Great Pacific Garbage Patch] was and is a thin plastic soup, a soup lightly seasoned with plastic flakes, bulked out here and there with "dumplings": buoys, net clumps, floats, crates, and other "macro debris". (2011 p. 4)

The reasons for the ongoing marine littering are many and varied; for centuries people have regarded the marine environment as "a convenient dumping ground, too vast to be affected by anything we do" (Tanzer *et al.*, 2015 p. 24), believing that oceans and other waterways had limitless capacities. The idea that the world's oceans belong to no one and everyone is what has legitimated their exploitation, as still more than 64% lie beyond national jurisdictions (the high seas); also, the presumed right to plunder the oceans contributed to create a "Wild West" (Greenpeace, 2013 p. 42) approach to resource management which governments only started to abandon during the 1960s and '70s. After the RIO +20 UN Summit of 2012, marine litter has been recognised as one of the major pollution problems in the world, with particular attention on plastics coming from both marine and land-based activities.

1.3.1 Marine Plastic Pollution

Plastics are ubiquitous in everybody's everyday life, and their use has colonised people's daily habits so fiercely, by replacing or adding to all

[10] https://www.5gyres.org/faq (last accessed March 7, 2018).
[11] *Ibid*.

kinds of objects made of other materials, that it is now difficult to imagine living without them. In a biological sense, plastic is a material “fill[ing] so many commodity niches” (C. J. Moore, 2008 p. 133) that has almost become a living organism to observe from a scientific perspective. In the last 60 years**,** plastic production has increased from less than 0.5 million tons in 1950 to over 380 million tons in 2015 (Geyer *et al.*, 2017 p. 1). As for the main fields of use, packaging represents the principal application of plastics in Europe (39.9%), followed by consumer and household goods (furniture, sport, health etc.) accounting for around 24% of plastics produced, building and construction (19,7%), and automotive (10%). Other sectors include electrical and electronic products, and agriculture.

The so-called “age of plastics” started at the beginning of the 20th century following the achievements of some determined minds who had been working on the products of petroleum processing, and had started to create plastic derivatives for limited, specialty uses. In the early 1950s, further intuitions transformed plastics into the widespread material used today. Even so, plastics were still used mainly for toys, industrial parts and some consumer goods for a while; then, the birth of the “throwaway living” in the years after World War II (mid 1950s-1960s) opened to the invasion of disposable items and packaging—in our lives and in the global environment—with most plastic debris only generated in the last sixty years.

The prominence of plastics in studies on marine debris is nowadays so great that it has slowly but steadily catalysed the attention of the scientific community. Starting as a problem of minor concern in the mid-1970s, it has kept growing on the researchers’ agenda until becoming a popular issue for laypeople, national governments, and international non-governmental organisations. In the early 1970s, reports of floating plastic micro-debris in the North Atlantic were first published in scientific literature, raising concerns about potential ingestion of plastic by marine organisms and possible physical and chemical impacts of plastic on marine wildlife. In particular, initial studies reporting interactions between marine organisms and litter concerned plastic items ingested by seabirds and lions, or accidents by entanglement[12]. Many studies in the 1970s and 1980s confirmed the presence of plastic particles in the North Pacific, Bering Sea and Japan

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[12] See: Peter G. Ryan, “A Brief History of Marine Litter Research” in Melanie Bergmann *et al.*, eds., *Marine Anthropogenic Litter* (Cham: Springer International Publishing, 2015), 3-5.

Sea; the issues of plastic pellets in the North Atlantic, as well as the widespread beach littering also started to be mentioned. Yet, the topic remained largely ignored by the international scientific community for many years. Only in the 1980s did concern for marine plastic pollution start to increase, leading to the first national and international resolutions; as awareness of the issue was raised among experts and non-experts, more and more information, scientific literature, and data became available.

At present, research on plastic pollution offers new interesting developments, with studies on recently-discovered topics such as primary and secondary microplastics, seabed and coastal plastic pollution, and the garbage patches. With reference to water pollutants, plastic is extremely durable and resistant to aging and degradation; given its relatively young age, the amount of time needed for its full biodegradation is unknown, but research estimates it is in the order of centuries or even thousands of years. When exposed to the combined action of UV radiation from sunlight, atmospheric oxidation, and water hydrolysis, plastic items become embrittled, and fragment into smaller pieces, eventually becoming (secondary) microplastics. While it is evident that all plastic items are in time bound to become microplastics, the category of (primary) microplastics also comprises raw material for plastic preproduction in the form of small pellets or "nurdles", microbeads used in cosmetics, cleansing and industrial products.

It is now acknowledged that plastic accounts for 40% to 80% of mega- and macro-marine non-natural (non-degradable) debris in the world's oceans, with packaging, shopping bags, footwear, cigarette lighters and other domestic items among the most common debris; plastics comprise between 50-80% of the waste on beaches, on the ocean surface and seabed, with peaks of 95% in some areas of the world, and microplastics representing 10% of the total weight of floating plastic. Research has also suggested that plastics tend to get lost from the sea surface and sink with fragmentation. For what concerns quantitative analyses, the estimated amount of litter in the three main oceans ranges from around 11 billion to 54 billion items, excluding the Arctic and Antarctic Ocean; considering also coastal waters, the number of estimated large plastic debris items on the global sea floor rises from 71.5 to 116 billion, microplastics excluded. Some studies indicate a number of rough 8 million tons of plastic entering the oceans every year[13]. Of course researches on the sea-floor habitat or on deep-sea activities require incredible economic and scientific efforts, therefore scientific studies are often focused on more easily-detectable kinds of plastic debris.

The array of risks arising from plastic pollution is what motivates such scientific interest: beyond the visible, aesthetic consequences on the world's beaches and coastal waters, major risks include choking and entanglement of wildlife, ingestion of bigger plastic pieces by fish, marine mammals, turtles, and seabirds, and ingestion of smaller fragments by smaller animals, up until planktonic assimilation of microplastics (with plastics entering food-webs from the bottom). Release of harmful toxic chemicals or persistent organic pollutants (POPs) is another dangerous consequence of plastic pollution, with still little known effects on human beings. Clearly, numerous and various research fields are open for scientists and experts to delve into.

1.4 Plastic pollution in the Mediterranean Sea

While the world's oceans are described as an open-water marine ecosystem, other semi-enclosed seas, such as the Mediterranean Sea, constitute independent ecosystems. However, with reference to the plastic pollution phenomenon, it is not improper to compare the Mediterranean Sea with larger oceans.

One of the most studied seas in the world, the Mediterranean Sea is home to roughly 4% to 18% (depending on the taxonomic group) of all the world's marine species: an impressive number, considering that this small sea covers an area representing only the 0.82% of the world's oceans. Together with its continental basin, the Mediterranean Sea is one of the richest biodiversity hotspots on Earth. This region has been described as "remarkable for its climate and the common sea that links three continents, for the richness of its biodiversity, for its classical heritage and the diversity of its landscapes and its cultural places, for the feeling of belonging of the populations of the three shores" (H. Bazairi, 2010 p. 14). For these reasons, the Mediterranean is also one of the natural areas most sensitive to climate change, a region where violent and abrupt natural events will hit harder and sooner. This is why Mediterranean countries should implement coherent plans for sustainable development: a point also found as a

[13] See https://www.plasticoceans.org/the-facts/ and http://plastic-pollution.org/ (last accessed March 7, 2018).

strategic objective of the Union for the Mediterranean (UFM) with reference to "[p]rotect[ing] the Mediterranean Sea, its environment, and overall sustainable development"[14]. As a matter of fact, all kinds of human activities constitute the main driver of pressure affecting the Mediterranean Sea, given that both land and sea-based activities in this area (farming, fishing, industry, tourism, etc.) result in serious consequences for the marine ecosystem, with impacts such as habitat loss and destruction, erosion of biodiversity, invasive species, climate change, and of course pollution, to mention a few.

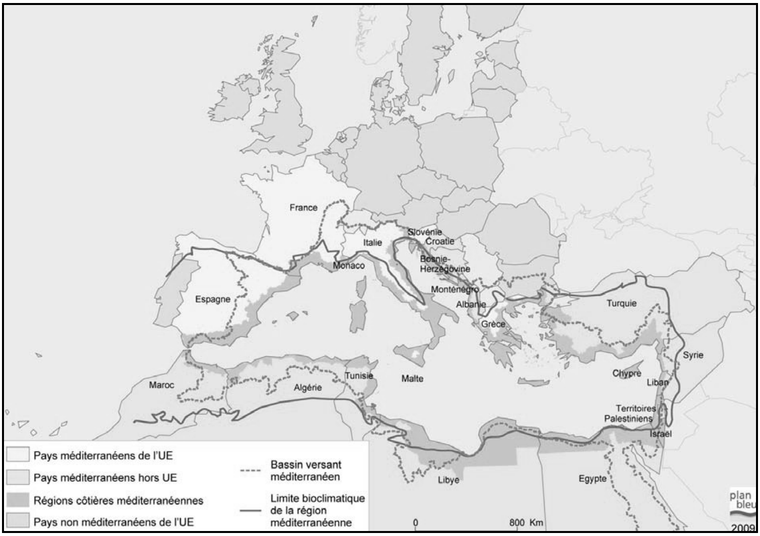

Figure 1.1. The Mediterranean Sea[15].

For what concerns pollution, the presence of plastics in the Mediterranean ecosystem is observed similarly as in the globe's oceans, although the unique features of this sea make this issue even more alarming. As for debris accumulation in the Mediterranean, the area tends to show even greater densities compared to other oceans because of the limited water circulation and debris dispersion—being this sea a semi-enclosed water basin with currents coming from the

[14] http://ufmsecretariat.org/water-environment/ (last accessed March 7, 2018).
[15] Retrieved from:
https://planbleu.org/sites/default/files/publications/soed2009_en.pdf, 17.

Atlantic Ocean and the Red Sea—and a combination of densely populated coastlines and human activities such as fishing and shipping. Whereas bottom debris become trapped in areas of low circulation and sediment accumulation, floating debris accumulates in coastal areas, thus causing accumulation mainly in bays rather than in the open sea (D. K. A. Barnes, 2009 p. 1991). Consequently, the state of plastic pollution appears rather composite, with a majority of bottom debris found in the seabed and surface debris carried along considerable distances by winds and currents. Accumulation has such high rates within the Mediterranean—with about $3x10^9$ debris items (floating or sunk) (p. 1993)—that it is comparable to that in the five oceanic gyres; no wonder that the Mediterranean has been proposed as "the sixth great accumulation zone for marine litter" (G. Suaria *et al.*, 2016 p. 2).

A number of reports on marine litter in the Mediterranean have stressed the increasing occurrence of plastic waste. The 2015 UNEP-MAP's *Marine Litter Assessment in the Mediterranean* combines results of monitoring at a regional and national level, confirming that the majority of marine litter in the Mediterranean originates from land-based rather than sea-based sources. More specifically, marine litter found on beaches originates from tourism and recreational activities; it is composed mainly of plastics (bottles, bags, caps/lids, etc.), aluminium (cans, pull tabs), and glass (bottles), with marine litter from smoking related activities accounting for up to 40% (p. 10). In terms of marine litter floating in the sea, plastics account for more than 85%; as for litter on the sea-floor, plastics are prevalent, ranging from 45% to 95%. Finally, fishing related litter, including ghost nets, prevail in commercial fishing zones. At the EU level, marine litter is getting the deserved attention, being recognised as a complex problem with implications both for the marine and coastal environment and all human activities. Acknowledged as a trans-boundary issue, it has become a key environmental challenge in recent European national and international environmental programmes aimed at reducing marine litter.

In a 1999 document, the European Environmental Agency (EEA) framed the state of the Mediterranean by envisioning its economic potential, defining it as "a fantastic asset" that, if properly used, would provide "the basis for diversified economies in the basin while keeping a unique Mediterranean entity" (EEA, 1999 p. 6). However, the text acknowledged that this area was subject to "excessive pressures". With reference to *pressures*, these were identified in the first reports by the United Nations Environment Programme Mediterranean Action Plan

(UNEP-MAP) and the EEA in the 1990s. Factors like urbanisation, tourism, agriculture, fisheries, aquaculture, industry, and maritime transport were listed among primary causes of concern. To these pressures, direct *impacts* usually corresponded, namely: eutrophication, microbial contamination and human health risks, land use and coastal erosion, heavy metals and organochlorine compounds, oil pollution, radioactive contamination, climate change, biodiversity, and ecosystem changes.

These classification methods are basically stress-response frameworks used in socio-environmental systems (SES) research to classify and systematically present all elements of the environmental discourse. The DPSIR model (Driver-Pressure-State-Impact-Response) was originally developed in the 1970s and further improved by the European Environment Agency in 1995. It is a valuable model to help policy makers identify causes and relationships between complex issues, offering a systematic approach with options for managing and protecting marine and coastal systems (R. L. Lewison *et al*., 2015 p. 111). The five categories of the DPSIR framework could be summarised as follows:

- *drivers*: these include all social, demographic and economic developments in societies, with corresponding changes in life styles, consumption and production patterns;
- *pressures*: all developments in emissions, use of resources, and use of land by human activities are described under this indicator;
- *states*: this indicator provides a description of the quantity and quality of physical, biological and chemical phenomena in a given area;
- *changes*: a change in a state produces impacts on the functions of the environment, namely human and ecosystem health, resources availability, capital losses, and biodiversity;
- *responses*: these are the actions taken by groups and individuals in society and governments to prevent, compensate or adapt to changes in the state of the environment (P. Gabrielsen, P. Bosch, 2003 pp. 8-9).

Over the years, documents by different organizations have been drafted to include other pressures and impacts; for example, the UNEP-MAP RAC/SPA report of 2010 considers climate change effects and deep seas ecosystem modifications as “emerging issues”. In