Preface

The ocean is of eminent importance to mankind. Twenty-three per cent of the world's population (~1.2 billion people) live within 100 km of the coast (Small and Nicholls 2003), a figure, which is likely to rise up to 50 % by 2030 (Adger et al. 2005). Furthermore, the ocean sustains nearly half of the global primary production (Field et al. 1998), a great share of which fuels global fisheries (Pauly and Christensen 1995). The marine environment hosts a substantial biodiversity, and tourism is an important and constantly growing economic sector for many coastal countries. Although human welfare is intricately linked with the sea and its natural resources, people have substantially altered the face of the ocean within only a few centuries. Fisheries, pollution, eutrophication, deep-sea hydrocarbon exploration, ocean acidification and global ocean warming accompanied by sea-level rise as a consequence of rapid glacier melting and thermal expansion of sea water (IPCC 2014) are prominent examples of man-made pressures exerted on the oceans with severe ecological and socio-economic repercussions. As a result, marine environmental protection and management have become integral political and societal issues in many countries worldwide. However, effective environmental management requires a proper understanding of the ecological implications of human activities and should, therefore, be accompanied by sound multidisciplinary research, scientific advice, education and public outreach.

In recent decades, the pollution of the oceans by anthropogenic litter has been recognized as a serious global environmental concern. Marine litter is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP 2009). Since its first mention in the scientific literature in the 1960s, research efforts addressing marine litter have constantly grown as has the amount of litter in the oceans. Many studies have shown that it consists primarily of plastics with a continuously increasing global annual production of 299 million t (PlasticsEurope 2015). It has been estimated that 10 % of all plastic debris ends up in the oceans (Thompson 2006), and Barnes (2005) suggested that the 1982 figure of 8 million litter items entering the oceans every day probably needs to be multiplied several fold. Eriksen et al. (2014) estimate a minimum of 5.25 trillion plastic particles weighing 268,940 tons

afloat in the sea, but this figure does not include debris on the seafloor or beaches. The increasing use of single-use products, uncontrolled disposal of litter along with poor waste management and recycling practices is the main reason for the accumulation of litter in the sea. Increasing quantities of litter are lost from municipal waste streams and enter the oceans (Barnes et al. 2009). The ubiquity of litter in the open ocean is prominently illustrated by numerous images of floating debris from the ocean garbage patches and by the fact that the search for the missing Malaysia Airlines flight MH370 in March 2014 produced quite a few misidentifications caused by litter floating at the water surface.

Since plastic accounts for the majority of litter items in the sea, the chapters of this book primarily focus on plastic litter and its implications for the marine environment. Numerous quantitative reports on marine anthropogenic litter from various parts of the world's oceans indicate that anthropogenic litter is ubiquitous at the shores as well as in the pelagic and benthic realms. Global surveys revealed that plastics have already reached the shores of the remotest islands (Barnes 2005) and even polar waters far off urban centres (Barnes et al. 2010; Bergmann and Klages 2012). The use of advanced technology, such as remotely and autonomously operated vehicles, revealed that anthropogenic litter has conquered the deep sea before mankind set eye upon it suggesting that the deep seafloor may constitute the ultimate sink for marine litter (Pham et al. 2014). However, we are just beginning to understand how litter actually "behaves" at sea and to identify the drivers of the temporal and the spatial distribution of litter in the oceans. Still, we have already started to generate a mankind memory made out of plastic in the world ocean.

Marine anthropogenic litter causes harm to a wide range of marine biota. Seabirds, fish, turtles and marine mammals suffer from entanglement with and ingestion of marine litter items as illustrated by countless pictures of animals injured and strangled by discarded fishing gear in the public media. However, we have only limited knowledge about the implications of marine litter for the many less charismatic invertebrate species that easily escape public perception but play important roles in marine ecosystems. Although already mentioned in the late 1980s (Ryan 1988), it took Thompson's time series (Thompson et al. 2004) to raise public awareness of the widespread presence of microplastics, which are used in industrial production processes, cosmetics and toothpaste or generated through degradation of larger items. Indeed, substantial concentrations of microplastics were recently reported from remote and presumably unspoiled environments such as the deep seafloor (Woodall et al. 2014) and Arctic sea ice, which is considered a historic global sink at least until its plastic load is released into the ocean during the projected increase of ice melts (Obbard et al. 2014). Microplastics are available for ingestion by a wide range of organisms, and there are indications that microplastics are propagated over trophic levels of the marine food web (Farrell and Nelson 2013; Setälä et al. 2014). However, scientists have only recently started to investigate whether the contamination of marine organisms with plastics and associated chemicals is causing harm to ecosystems and human health (Browne et al. 2013; Bakir et al. 2014; De Witte et al. 2014; Van Cauwenberghe and Janssen 2014).

The accumulation of litter at sea and along coastlines worldwide and the many open questions concerning the amount, distribution and fate of marine litter and potential implications for marine wildlife and humans have raised public awareness, stimulated scientific research and initiated political action to tackle this environmental problem (UNEP 2014). Identification, quantification and sampling of marine litter do not necessarily require professional scientific skills so that NGOs as well as committed citizens and other stakeholders have contributed substantially to the collection of data on marine litter pollution and to the global perception of the problem (Rosevelt et al. 2013; Anderson and Alford 2014; Smith and Edgar 2014). Scientists, politicians, authorities, NGOs and industries have started to share knowledge at international conferences aimed at developing managerial solutions. These joint activities, public awareness and, finally, the scientific curiosity of numerous committed researchers have stimulated a rapidly increasing number of publications from various scientific disciplines in dedicated volumes (Coe and Rogers 1997; Thompson et al. 2009). This latest volume on *Marine Anthropogenic Litter* was inspired by the remarkable recent progress in marine litter research. A large proportion of the references reviewed in this book was published in the last three years demonstrating the topicality of this book and the issue as a whole. Because of the high dynamics in this field of research, this volume may already be outdated when published.

This book consists of five major sections. In the first section, Peter Ryan gives a historical synopsis of marine litter research starting from the first mention of floating debris in the famous novel *20,000 Leagues Under the Sea* by Jules Verne in 1870 but with a focus on the past 50 years, which have seen a strong increase in the production of plastics. The reader will learn about the rapid development of this research field, and a series of international key conferences such as the "Honolulu Conferences", which brought together scientists, environmentalists, industry, NGOs and policy makers and fuelled numerous publications and new research and management schemes.

The second section of the book addresses abiotic aspects of marine litter pollution. François Galgani, Georg Hanke and Thomas Maes portray the abundance, global distribution and composition of marine litter, which illustrates the ubiquity of litter in the oceans from the urban centres of human activity to the Earth's remotest sites. Anthony L. Andrady describes the physical and chemical processes involved in the degradation of plastics in the marine environment.

The third section of the book covers the biological and ecological implications of marine litter. Susanne Kühn, Elisa L. Bravo Rebolledo and Jan A. van Franeker summarize the deleterious effects of litter on marine wildlife. The authors compiled an extensive list of 580 species, ranging from invertebrates to fish, turtles, birds and mammals that have been shown to suffer from the effects of marine litter. Toxicity of contaminants associated with marine plastic debris as well as health implications is described by Chelsea Rochman who demonstrates that plastics are more than a mechanic threat to marine biota. Tim Kiessling, Lars Gutow and Martin Thiel show how marine litter facilitates the dispersal of marine organisms, which are capable of colonizing litter items floating at the sea surface. The authors compiled a list of 387 taxa that have been found rafting on floating litter,

and they evaluate how marine litter might facilitate the spread of invasive species. This may alter the face of biodiversity with yet unknown consequences for ecosystem functioning.

The fourth section of this book is dedicated entirely to the young but rapidly expanding field of microplastic research. Since the recent rise in public awareness of microplastics in the marine environment, intensive research on this topic has yielded a considerable amount of important scientific results. Accordingly, this topic deserves an entire section, which is introduced by a synopsis of microplastic research by Richard C. Thompson. The various primary and secondary sources of microplastics and the pathways through the environment to the biota are outlined by Mark A. Browne who also highlights the need for hypothesis-driven approaches in microplastic research. Because of the small size and the diversity of plastic polymers, the detection, proper identification and quantification of microplastics are challenging, which hampers the comparability of results from different studies. Therefore, Martin G.J. Löder and Gunnar Gerdts composed a critical appraisal of methods and procedures applied in this field including a case study that demonstrates how improper methodology easily leads to a misevaluation of the contamination of habitats and organisms. The global distribution and the environmental effects of microplastics are summarized by Amy Lusher. She compiled a list of 172 taxa, which have been found to ingest microplastics either in the field (131) or in laboratory experiments (46) with variable effects on the behavior and health status of the organisms.

Although deleterious effects of microplastics have been demonstrated for a considerable number of marine organisms, the role of these particles as vectors for chemicals from the environment to the organisms is subject to intense debate. Albert A. Koelmans used a modeling approach to critically evaluate the transfer of environmental contaminants to marine organisms. Nanoparticles are of even smaller particle size (<1 μm). They are of particular concern as they are more likely to pass biological membranes and affect the functioning of cells including blood cells and photosynthesis. Albert A. Koelmans, Ellen Besseling and Won J. Shim summarize what little is known about this litter fraction, whose significance in the marine environment is just coming to light.

The final section of this book moves away from natural science towards the socio-economic implications of marine anthropogenic litter. Tamara S. Galloway reviews the current knowledge on how chemicals associated with plastics may affect human health. As top consumers of ocean-based food webs, humans likely accumulate contaminants, which may compromise fecundity, reproduction and other somatic processes. The accumulation of litter in the oceans can be considered a result of market failure on land. The root of the problem is probably—as so often—that producers/manufacturers of goods (plastics) are not economically held responsible for the products they sell. Stephanie Newman, Emma Watkins, Andrew Farmer, Patrick ten Brink and Jean-Pierre Schweitzer describe economic instruments that were used in different parts of the world to reduce litter inputs to the sea. Although a number of international policies have been in place for quite some time to manage the input of litter to the sea, their shortcomings make them unlikely

to result in significant reductions of marine litter (Gold et al. 2013). Chung-Ling Chen describes and assesses key multilateral and national regulative measures with respect to their sufficiency to tackle marine litter pollution. Another way to reduce the input of litter to the ocean is suasion of citizens and stakeholders, which requires public awareness of the problem through education and outreach activities (Hartley et al. 2015). Ideally, such initiatives also generate data that can be used for assessments of marine litter pollution and distribution. In the last chapter, Valeria Hidalgo-Ruz and Martin Thiel review the potential of "citizen science" initiatives for supporting research on this global environmental issue.

The solution of the marine litter problem requires expertise from various sectors, including industries, science, policy, authorities, NGOs and citizens. We hope that this book will facilitate the exchange of knowledge amongst the various actors and contribute to finding solutions to this challenge.

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References

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science, 309*, 1036–1039.

Anderson, J. A., & Alford, A. B. (2014). Ghost fishing activity in derelict blue crab traps in Louisiana. *Marine Pollution Bulletin, 79*, 261–267.

Bakir, A., Rowland, S. J., & Thompson, R. C. (2014). Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. *Environmental Pollution, 185*, 16–23.

Barnes, D. K. A. (2005). Remote Islands reveal rapid rise of Southern Hemisphere, sea debris. *The Scientific World Journal, 5*, 915–921.

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B, 364*, 1985–1998.

Barnes, D. K. A., Walters, A., & Gonçalves, L. (2010). Macroplastics at sea around Antarctica. *Marine Environmental Research, 70*, 250–252.

Bergmann, M., & Klages, M. (2012). Increase of litter at the Arctic deep-sea observatory HAUSGARTEN. *Marine Pollution Bulletin, 64*, 2734–2741.

Browne, M. A., Niven, S. J., Galloway, T. S., Rowland, S. J., & Thompson, R. C. (2013). Microplastic moves pollutants and additives to worms, reducing functions linked to health and biodiversity. *Current Biology, 23*, 2388–2392.

Coe, J. M., & Rogers, D. (1997). *Marine debris. Sources, impacts, and solutions*. New York: Springer.

De Witte, B., Devriese, L., Bekaert, K., Hoffman, S., Vandermeersch, G., Cooreman, K., et al. (2014). Quality assessment of the blue mussel (*Mytilus edulis*): Comparison between commercial and wild types. *Marine Pollution Bulletin, 85*, 146–155.

Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., et al. (2014). Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea.

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

Field, C. B., Behrenfeld, M. J., Randerson, J. T. & Falkowski P. (1998). Primary production of the biosphere: Integrating terrestrial and oceanic components. *Science*, 281, 237–240.

Gold, M., Mika, K., Horowitz, C., Herzog, M., & Leitner, L. (2013). Stemming the tide of plastic marine litter: A global action agenda. *Pritzker Policy Brief, 5.*

Hartley, B. L., Thompson, R. C., & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin, 90*, 209–217.

IPCC (2014). Climate change: Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change (pp. 151). Geneva, Switzerland.

Obbard, R. W., Sadri, S., Wong, Y. Q., Khitun, A. A., Baker, I., & Thompson, R. C. (2014). Global warming releases microplastic legacy frozen in Arctic Sea ice. *Earth's Future, 2*, 315–320.

Pauly, D. & Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature, 374*, 255–257.

Pham, C. K., Ramirez-Llodra, E., Alt, C. H. S., Amaro, T., Bergmann, M., Canals, M., et al. (2014). Marine litter distribution and density in European seas, from the shelves to deep basins. *PLoS ONE, 9*, e95839.

PlasticsEurope. (2015). Plastics—the Facts 2014/2015. http://www.plasticseurope.fr/Document/plastics—the-facts-2013.aspx?Page=DOCUMENT&FolID=2, http://issuu.com/plasticseuropeebook/docs/final_plastics_the_facts_2014_19122.

Rosevelt, C., Los Huertos, M., Garza, C., & Nevins, H. M. (2013). Marine debris in central California: Quantifying type and abundance of beach litter in Monterey Bay, CA. *Marine Pollution Bulletin, 71*, 299–306.

Ryan, P. G. (1988). The characteristics and distribution of plastic particles at the sea-surface off the southwestern Cape Province, South Africa. *Marine Environmental Research, 25*, 249–273.

Setälä, O., Fleming-Lehtinen, V., & Lehtiniemi, M. (2014). Ingestion and transfer of microplastics in the planktonic food web. *Environmental Pollution, 185*, 77–83.

Small, C. & Nicholls, R. J. (2003). A global analysis of human settlement in coastal zones. *Journal of Coastal Research, 19*, 584–599.

Smith, S. D. A., & Edgar, R. J. (2014). Documenting the density of subtidal marine debris across multiple marine and coastal habitats. *PLoS ONE, 9*, e94593.

Thompson, R. C. (2006). Plastic debris in the marine environment: Consequences and solutions. In J. C. Krause, H. Nordheim, & S. Bräger (Eds.), *Marine nature conservation in Europe* (pp. 107–115). Stralsund, Germany: Bundesamt für Naturschutz.

Thompson, R. C., Moore, C. J., vom Saal, F. S., & Swan, S. H. (2009). Theme issue 'Plastics, the environment and human health: Current consensus and future trends'. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*, 2153–2166.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., et al. (2004). Lost at sea: where is all the plastic? *Science, 304*, 838.

UNEP. (2009). *Marine litter: A global challenge*. Nairobi.

Van Cauwenberghe, L., & Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. *Environmental Pollution, 193*, 65–70.

Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L. J., Coppock, R., Sleight, V., et al. (2014). The deep sea is a major sink for microplastic debris. *Royal Society Open Science, 1*, 140137.

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