ETC/ICM Report 5/2022

Marine Litter in Europe
An integrated assessment from source to sea

Prepared by:

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ETC/ICM Consortium Partners:
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European Environment Agency
European Topic Centre on Inland, Coastal and Marine Waters

Cover photo
© Mario De Moya F on istockphoto.com #1208182476

Layout
F&U confirm, Leipzig

ISBN 978-3-944280-22-6

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Suggested citation
Veiga, J.M., Winterstetter, A., Murray, C., Šubelj, G., Birk, S., Lusher, A., van Bavel, B., Aytan, Ü., Andersen, J.H., Sholokhova, A., Kideys, A., Smit, M.J., Arnold and M., Aydın, M., 2022, Marine litter in Europe – An integrated assessment from source to sea. ETC/ICM Technical Report 05/2022: European Topic Centre on Inland, Coastal and Marine Waters, 198 pp.

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Specific contributions:	This technical report was developed by experts from ETC/ICM and ETC/WMGE between 2021 and 2022. Chapters were developed by lead authors and contributors as follows: **Chapter 1**: J.M. Veiga **Chapter 2**: J.M. Veiga, A. Winterstetter **Chapter 3**: A. Winterstetter, A. Sholokhova, J.M. Veiga, G. Šubelj, M. Arnold **Chapter 4**: S. Birk, G. Šubelj, M.J. Smit **Chapter 5**: C. Murray, A. Lusher, B. van Bavel, Ü. Aytan, G. Šubelj, A. Kideys, J.H. Andersen **Chapter 6**: J.M. Veiga, G. Šubelj **Chapter 7**: J.M. Veiga, S. Birk, C. Murray Overall report coordination and edition: J.M. Veiga.
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The authors would like to thank Mustafa Aydin (EEA), Stéphane Isoard (EEA), Almut Reichel (EEA), Lars Mortensen (EEA), Tobias Nielsen (EEA) and Angel Borja (ETC/ICM, AZTI) for the valuable suggestions and constructive feedback; Daniel González-Fernández (University of Cádiz) and Tim van Emmerik (Wageningen University) for providing data, figures and feedback on the analysis performed in Chapter 4.

Finally, we thank Michail Papadoyannakis (DG ENV), Georg Hanke (JRC) and Eionet experts from Italy, Romania, Malta, Türkiye, Poland, Portugal and Sweden for providing comments and suggestions, which were taken into account in the final version of this report.

List of abbreviations

ALDFG	Abandoned, lost and discarded fishing gear
AMAP	Artic Monitoring and Assessment Programme
BAL	Baltic Sea
BS	Black Sea
DPSIR	(D) Drivers – (P) Pressures – (S) State – (I) Impacts – (R) Responses
EC	European Commission
ECRINS	European catchments and rivers network system
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
EMODNet	European Marine Observation and Data Network
EMSA	European Maritime Safety Agency
EPR	Extended Producer Responsibility
EU	European Union
EUROSTAT	Statistical Office of the European Union
EQR	Ecological Quality Ratio
ETC/ICM	European Topic Centre on Inland, Coastal and Marine Waters
ETC/WMGE	European Topic Centre on Waste and Materials in Green Economy
FAO	Food and Agriculture Organization of the United Nations
FML	Floating macrolitter
G20	Group of Twenty
GDP	Gross Domestic Product
GES	Good Environmental Status
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
HELCOM	Baltic Marine Environment Protection Commission
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IMAP	Integrated Monitoring and Assessment Programme
MALT	Marine Litter Assessment Tool
MED	Mediterranean Sea
MFA	Material Flow Analysis
MLW	Marine Litter Watch
MPW	Mismanaged plastic waste
MSFD	Marine Strategy Framework Directive
MSW	Municipal solid waste
NEA	North-East Atlantic Ocean

NGO	Non-governmental organisation
NUTS3	Nomenclature of Territorial Units for Statistics – level 3
OSPAR	Convention for the Protection of the Marine Environment in the North-East Atlantic
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PPSI	Plastic packaging and small non-packaging plastic items
PS	Polystyrene
PVC	Polyvinyl chloride
SAU	Spatial assessment unit
SDG	Sustainable Development Goal
STECF	European Scientific, Technical and Economic Committee for Fisheries
SUP	Single-Use Plastics
TGML	Technical Group on Marine Litter
UK	United Kingdom
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environmental Programme
UNEP/MAP	United Nations Environmental Programme – Mediterranean Action Plan
Waste Directive	Waste Framework Directive
WFD	Water Framework Directive
WWTP	Wastewater Treatment Plant
ZPAP	Zero Pollution Action Plan

Executive Summary and Key Messages

The issue of marine litter and plastic pollution is high on global political agendas, namely that of Europe. It is directly addressed by the Marine Strategy Framework Directive (MSFD), while the recent Zero Pollution Action Plan includes specific reduction targets for waste generation, plastic litter at sea and input of microplastics. Many other European policy initiatives, including the Circular Economy Action Plan, the Strategy for Plastics and the Single-Use Plastics Directive, aim at preventing litter pollution by driving changes along the life cycle of plastics, from production and consumption, down to waste management. These policies work in an articulated manner and influence how the European society produces, uses, reuses, recycles and disposes of materials, such as plastic. As such, it is essential to assess whether improvements in these performances are leading to reduced leakages and levels of plastic litter in the environment.

Marine litter originates from a multitude of sources, namely, the direct discard or loss at sea from maritime activities such as fishing and shipping; from inappropriate waste disposal by citizens, visitors and industries; or losses from waste management, including during collection, sorting or from unsanitary landfilling. These can take place in coastal areas or further inland, from where litter can be transported and discharged into the sea, for example, via rivers. Ultimately, marine litter originates from *mismanaged* waste, which results from the combination of inadequate production and consumption, waste disposal behaviour and waste management.

This report serves as the technical background for the EEA's web-report "*From Source to sea: Untold Story of Marine Litter*". Its general objective is to assess the issue of marine litter from *source to sea*, i.e. across the three environmental compartments where most litter originates from (land); via which it is transported from inland into the sea (rivers); and, finally, the receiving marine environment. The study intends to emphasize the causalities between socio-economic drivers, such as trends in plastic production; pressures, in terms of waste generation and particularly the fraction that is not adequately managed; and the state of pollution in coastal and marine environments. It focuses primarily on the fraction of waste corresponding to plastic packaging and small non-packaging plastic items ([1]) (PPSI), given its prevalence in post-consumer plastic waste and pervasiveness in the marine environment.

Two years were selected – 2012 and 2018 – as they define the first implementation cycle of the MSFD and are used here to compare possible changes in the management of plastic waste and the state of marine pollution.

The report is structured around **six specific objectives**:

- to describe the key economic **drivers** of plastic litter and the European policy **responses** that are relevant, at different stages of its life cycle (Chapter 2);
- to assess the level of **pressure** in terms of generation and mismanagement of PPSI waste in the EEA 32 countries + UK and the regional seas' coasts for the years 2012 and 2018 (Chapter 3);
- to scope estimates of **riverine litter inputs** into European seas, based on published scientific literature (Chapter 4);
- to assess the **state of marine litter pollution** in the European seas in relation to defined thresholds, based on accessible data covering the years 2010–2021 (Chapter 5);
- to **assess perceived trends** concerning **European policy objectives and targets**, using key assessment results as evidence (Chapter 6);
- to provide **recommendations** for future integrated assessments of marine litter (Chapter 7).

[1] Small non-packaging plastic items include household, leisure, sanitary and medical items

The assessment applied various methodologies, including material flow and spatial analyses, a multi-metric indicator-based status assessment and a literature review. A summary of critical assessment results across drivers-pressures-state is presented in Table ES.1, and key messages and highlights from the study are provided below.

Table ES.1 Summary of appraised status on drivers, pressures and state of marine (plastic) litter in Europe and regional seas (BAL = Baltic Sea; NEA = North-East Atlantic Ocean; MED = Mediterranean Sea; BS = Black Sea; GDP = Gross Domestic Product; PPSI = Plastic packaging and small non-packaging plastic items)

Theme	**Status 2018** (colour) and **perceived change** in relation to **2012** (↘↗)				
	EUROPE	**BAL**	**NEA**	**MED**	**BS**
DRIVERS					
Plastic packaging production	Increasing trend	?	?	?	?
Decoupling of plastic packaging waste generation from GDP	↘ (red)	?	?	?	?
REDUCTION OF PRESSURES					
PPSI waste generated per capita	↘ (orange)	↘ (orange)	↘ (red)	↘ (red)	↘ (green)
Share of mismanaged PPSI waste	↗ (orange)	(orange)	(green)	(orange)	(red)
Mismanaged PPSI waste per capita	↘ (orange)	(orange)	(orange)	↘ (orange)	(red)
Total mismanaged PPSI waste generated	↘ (orange)	(orange)	↘ (orange)	↘ (red)	(red)
Pressure mismanaged PPSI waste at the coast	(orange)	↗ (green)	↗ (orange)	↘ (red)	↘ (red)
Riverine floating litter discharged into the sea	(orange)	(orange)	(orange)	(red)	(red)
STATE OF POLLUTION IN THE MARINE ENVIRONMENT					
Overall status of the coast and marine waters	↘ (orange)	(orange)	↘ (orange)	(red)	(orange)
Status of offshore areas	(orange)	(orange)	(orange)	(red)	(orange)
Status of coastal areas	(orange)	(orange)	(orange)	(red)	(red)
Abundance of beach litter	? (orange)	? (orange)	? (red)	? (red)	? (orange)
Abundance of PPSI litter on beaches	↘ (orange)	↗ (orange)	? (orange)	↘ (red)	↘ (red)

Legend and colour code
red – not acceptable/poor situation
orange – reasonable situation but not sufficient
green – satisfactory/good situation
↗ – situation in 2018 is perceived as better than in 2012
↘ – situation in 2018 is perceived as worse than in 2012

Plastic packaging is the largest demand for plastic production and has been increasing steadily until 2018. Because of the prevalence of single-use, short-lived items in recorded marine litter, this assessment gives special attention to the PPSI waste.

With plastics proliferating in our societies, global plastic production has increased since the 1950s. The largest application is packaging, demanding 40 % of the plastic produced in Europe from virgin resins, and whose growth has accelerated as the world shifted from reusable to single-use applications and towards the prevalence of convenient but disposable items. For this reason, the assessment focuses mainly on the plastic packaging fraction and non-packaging small plastic items (e.g. household and sanitary items), which combined make almost 80 % of the post-consumer plastic waste and are amongst the top litter items recorded on European beaches.

In the EU-27, per capita generation of plastic packaging waste is increasing, even at a faster pace than the Gross Domestic Product (GDP). Such an increasing trend is not in line with the policy goal of preventing waste.

Increasing plastic production leads to an intensification in the generation of plastic waste. This is particularly true for packaging, since it is quickly converted into waste. In the EU-27, plastic packaging waste generated per capita increased between 2011 and 2020, a trend that is not in line with the European policy goal of significantly preventing waste. Furthermore, the per capita generation of plastic packaging waste seems to be increasing at a faster pace than GDP, providing evidence that the EU is not moving towards decoupling this specific pressure from economic growth.

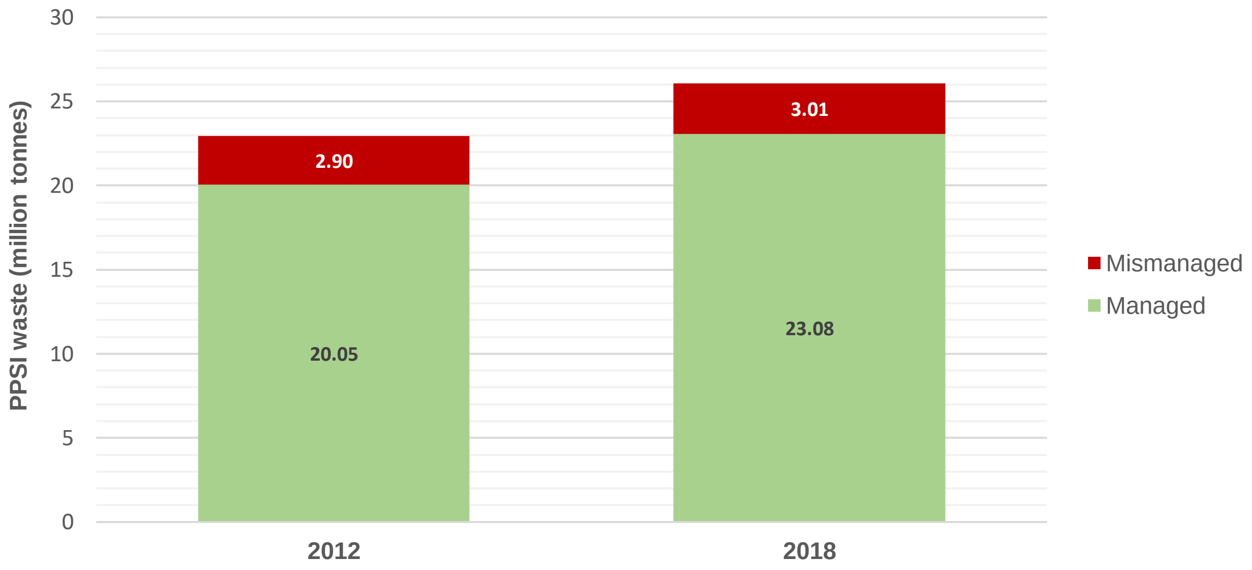
Total amounts of generated PPSI waste, as well as per capita, have generally increased across the EEA 32 countries + UK when comparing 2018 to 2012.

The assessment reveals that, with few exceptions, the PPSI waste generated both in absolute amounts and per capita was consistently higher in 2018 than in 2012, in the overall EEA 32 countries + UK. The region collectively produced a total of 26.1 million tonnes of PPSI waste in 2018, while in 2012 it generated 22.9 million tonnes. Similarly, the PPSI waste generated per capita increased from an average of 38.7 kg in 2012 to 42.9 kg in 2018.

Responses at both upstream and downstream of the plastics life cycle are required to transition to a Circular Economy. Improvements carried out mainly at the waste management level were insufficient to reduce mismanaged PPSI waste in the EEA 32 + UK.

Expanded waste collection coverage and programmes against illegal dumping and poorly managed landfills in some countries have resulted in smaller shares of mismanaged PPSI waste in 2018, compared to 2012. However, these efforts were not sufficient to offset the increase in the overall amount of PPSI waste generated, especially in countries with already very high waste management performances (Figure ES.1). Significant improvements in reducing the share of mismanaged PPSI waste have been accomplished mainly because of interventions at the latter stages of the plastics life cycle. Nevertheless, responses at both upstream (design-production-use) and downstream (collection-recycling-disposal) stages are needed to transition to a Circular Economy and prevent plastic leakages.

Figure ES.1: Total amounts of generated PPSI waste (million tonnes) that is managed (green) and mismanaged (red) in the overall EEA 32 countries + UK, in 2012 and 2018. (PPSI: plastic packaging and small non-packaging plastic items).



Most mismanaged PPSI waste in coastal territories is generated in the Mediterranean Sea and the Black Sea and the pressure has intensified in these two regions.

Pressure at the coast from mismanaged PPSI waste is particularly intense in the Mediterranean Sea and the Black Sea, which collectively make up 90 % of the total mismanaged PPSI waste estimated for the coastal territories in Europe in 2018. This is most likely driven by population density and the intense tourism in these regions, which lead to high amounts of PPSI waste generated, combined with weaker performances in terms of waste management, prevalent in some countries. The assessment results suggest that the total amount of mismanaged PPSI waste at the coast even increased in these two regions in 2018, compared to 2012, while in the North-East Atlantic Ocean (NEA) and Baltic Sea it slightly decreased.

Rivers constitute critical pathways of transport of litter from land into the sea. Over 600 million floating items, corresponding to almost 3,400 tonnes of litter are discharged by European rivers into the sea annually. The Mediterranean Sea receives the largest fraction of discharged litter.

Despite being understudied when compared to marine litter, observations and modelling of riverine litter show how important rivers are in transporting and discharging litter from land into the sea. A recent study (González-Fernández et al., 2021) estimated that 626 million floating macrolitter annually enter the European regional seas via rivers from 32 European and Eurasian coastal countries. This amounts to an annual loading of 3,382 tonnes of floating litter per year. The Mediterranean Sea is receiving the largest share, more than one-third of the total of floating litter discharged by the rivers modelled. Nevertheless, the uncertainty level related to observations and modelling of riverine plastic remains very large.

Most of the assessed areas in terms of litter pollution in the coastal and marine environment are classified as "potential problem areas" and the situation may deteriorate.

Intensification in the pressure in terms of PPSI waste generated, and particularly the mismanaged fraction, means that more of this plastic waste may end up in the environment and possibly the sea. Even considering litter pollution in general, the assessment shows that the situation is far from acceptable, with roughly 75 % of the areas assessed in European seas classified as "potential problem areas". When comparing the periods around 2012 and 2018, the assessment results suggest that the situation has not improved and may have even worsened.

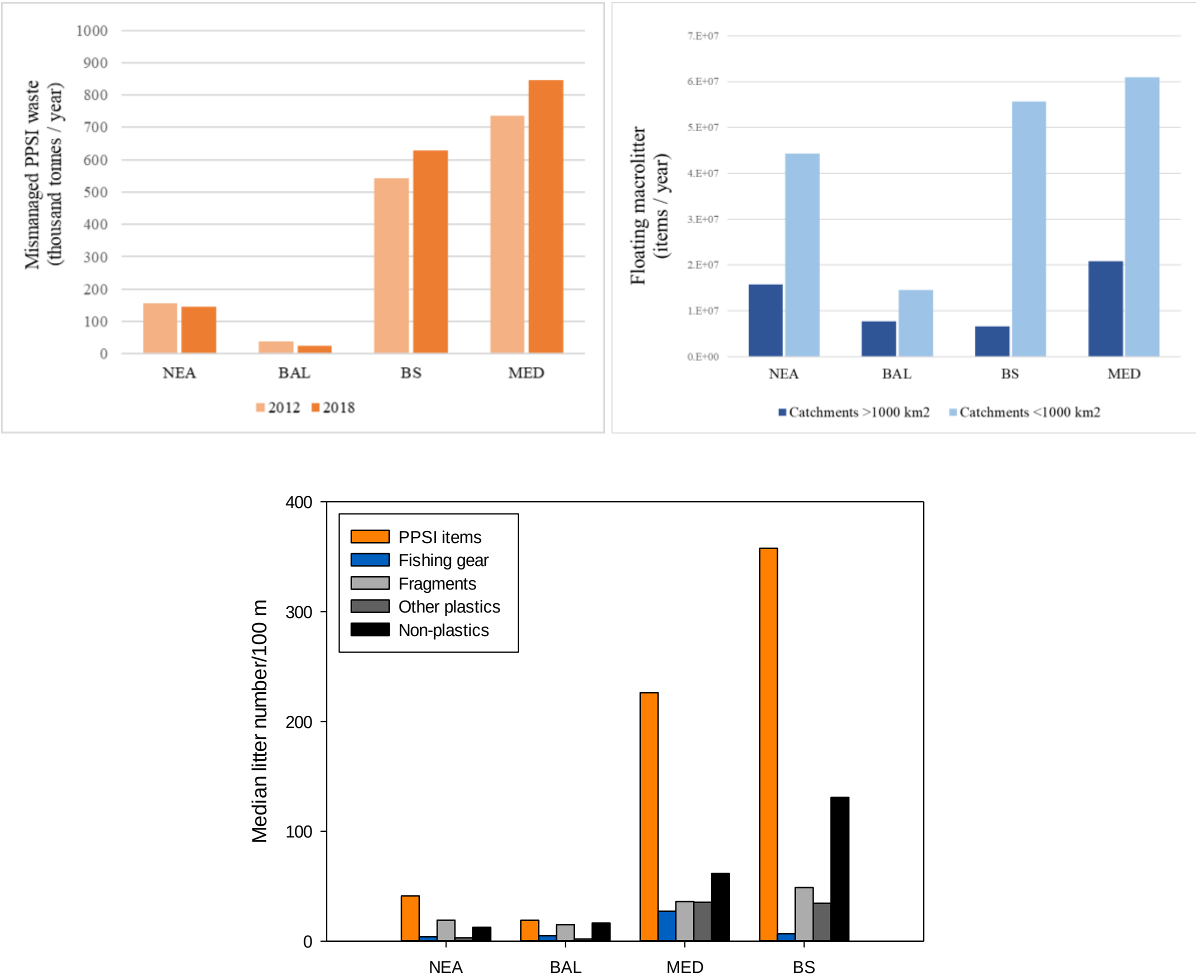
PPSI waste is found extensively on coastlines in Europe, representing the largest fraction of litter recorded, particularly in the Black Sea and Mediterranean Sea beaches. Shares (%) of PPSI litter, and its abundance seem to have generally increased in Europe, between 2015 and 2021.

Analysis of the Marine Litter Watch (MLW) monitoring dataset suggests that the abundance of beach litter attributed to PPSI has increased in recent years, in European beaches. Similarly, data reveal an increment in the share of PPSI to total items, which increased from 44 % in 2015 to 65 % in 2021. Zooming into the four regional seas, the Black Sea and the Mediterranean Sea present the highest shares of PPSI in total beach litter, 67 % and 53 %, respectively. In all seas, except the Baltic Sea, the amount of PPSI litter items recorded seems to have increased during the analysed period. Nevertheless, interpreting these trends must be done with caution due to the limited number of years covered, the changes in the MLW monitoring effort and the potential impact of the Covid-19 pandemic in recent years.

Among the four European regional seas, the Baltic Sea region presents the lowest figures in mismanaged PPSI waste, riverine floating litter and beach litter. The Mediterranean Sea and the Black Sea are the regions with the highest values.

Comparing the abundance of beach litter and PPSI recorded on beaches of the four European regional seas, the Baltic Sea presents the lowest median annual values, followed by the NEA. Contrastingly, the Mediterranean Sea and the Black Sea are the most polluted concerning both total litter and PPSI litter amounts. These results are in line with the regional differences found in the estimates of mismanaged PPSI waste in coastal territories (NUTS3) and the modelled results of riverine litter discharges from a previous study. This is illustrated in Figure ES.2 below, which summarises some of the key results from the assessment components of this study.

Figure ES.2: Top left: total mismanaged PPSI (plastic packaging and small non-packaging plastic waste) in coastal NUTS3 in 2012 and 2018 (based on authors' estimates); Top right: sum of median estimates of riverine floating macrolitter (based on modelled estimates by González-Fernández et al., 2021); Bottom: median number of beach litter of different groups (based on MLW monitoring data, 2015–2021) (BAL = Baltic Sea; NEA = North-East Atlantic Ocean; MED = Mediterranean Sea; BS = Black Sea)



Many European instruments are articulated to drive a systemic transition in the EU concerning plastics and the impacts of mismanaged waste. Marine litter data collected under MSFD monitoring programmes help to inform and underpin other related policies.

The recent European action plans on Circular Economy and Zero Pollution drive the systemic transition of the EU. Many European Directives relate to plastics, waste and marine litter, at different life cycle stages, from production to pollution by mismanaged waste. These instruments work in an articulated manner. The MSFD, for example, has helped establish regionally coordinated monitoring programmes that generate essential data, which, in turn, help design and inform the effectiveness of other relevant policies, such as the recent Single-Use Plastics Directive. The impact of these policies may become conspicuous in upcoming marine litter assessments.

1 Marine Litter – how linear economies impact our seas

1.1. The issue of marine litter

KEY MESSAGES

- Marine litter and plastic pollution have significant harmful implications to marine life including potential human health risks that are yet poorly understood.
- Marine litter can originate from a wide range of sources, from activities both on land and in the sea. The complex dynamic factors affecting the distribution of litter lead to a wide spatial and temporal variability. As such, it is difficult to derive trends in terms of reductions or increase in limited observed field concentrations.
- To design and assess effective policies that prevent marine litter at source, it is important to consider not only the state of marine pollution but also its sources and pathways. This includes assessing the generation of plastic waste and its management, as these can lead to plastic leaking into the environment.
- This technical report uses a "source-to-sea" assessment framework, considering that marine litter mainly originates from mismanaged waste that is inadequately disposed of or contained. Subsequently, this waste can become litter and end up in the environment, including the coast and sea, part of which transported and discharged via runoff and rivers from inland sources.
- To inform policies and action, it is important to relate marine litter pollution with how efficiently societies are using, reusing, and recycling materials, such as plastic, and if improvements in these performances lead to reduced levels of litter in the environment.
- By focusing also on production and consumption, waste prevention and management, this assessment will support assessing the level of pressure much closer to the root causes of marine litter, which is also what preventive measures need to address.

Marine litter represents all persistent, synthetic, or processed solid items or fragments that have been discarded, disposed of, or abandoned, either directly into the coastal and marine environments or somehow transported from land to the sea (Veiga et al., 2016). Most of this litter is composed of plastic items and, globally, it is estimated that between 19 and 23 million tonnes of plastic waste entered the aquatic environment in 2016 (Borelle et al., 2020). The rapid increase in global plastic production, the short-lived nature of many of the products designed and used, combined with improper disposal behaviour and inadequate waste management are all factors leading to an ever-increasing amount of plastic contaminating the environment (Geyer et al., 2017). Seas and oceans are the most likely final "sink", as litter can be mobilised by rainfall or wind and transported into the sea, e.g. via rivers (Lebreton et al., 2017; Meijer et al., 2021). Global plastic inputs into the sea are estimated at around 10 million tonnes per year (Jambeck et al., 2015).

With the expected increase in population to 8.5 billion in 2030 (UN, 2019) and expected Gross Domestic Product (GDP) growth, the production and consumption of plastics will also grow, increasing the demand for limited natural resources and materials. "Business as usual" will lead to more significant amounts of plastic waste generated and potentially large inputs of marine litter. Without significant improvements, it is estimated that global inputs into aquatic environments will almost triple in 2040 (Lau et al., 2020). Even in a scenario where the current ambitious commitments made by nations across the world are met, between 20 and 53 million tonnes of plastic waste are still expected to leak annually into water bodies in 2030 (Borelle et al., 2020).

Marine litter harms marine biota through entanglement or ingestion, transfer of contaminants, and a transport vector of non-indigenous species over long distances (Werner et al., 2016; Fossi et al., 2018). Accumulation of plastics and contaminants in marine biota and potentially the transfer of pathogens can also threaten human health (Revel et al., 2018). Moreover, marine litter can have economic and social implications as it directly affects coastal tourism, fisheries, aquaculture and energy supply (Werner et al., 2016). Although less studied, plastic pollution affects freshwater (Wagner et al., 2014) and terrestrial ecosystems, even before reaching the marine environment. Mismanaged plastic waste, in general, is an issue of public health.

1.1.1. Sources of marine litter

Marine litter can originate from a multitude of diffuse and point sources (Morales-Caselles et al., 2021). Litter can either be directly discarded or lost from maritime and coastal activities (e.g. fishing, shipping and coastal tourism) or transported into the sea via rivers, runoff and sewerage from inland sources. Once in the marine environment, it can move with currents, be deposited on the coast or sink. Over time plastic litter accumulates in the environment and gradually fragments into smaller pieces (Peng et al., 2017).

Sources of microplastics include losses in the manufacturing, transport (e.g. pellets) or use of micro-sized particles, e.g. in cosmetics (so-called "primary microplastics"); or result from the wear away and fragmentation of larger waste items or products that are in everyday use, such as the weathering of road tyres, synthetic textiles, geotextiles and paints ("secondary microplastics") (Galafassi et al., 2019). For example, it has been estimated that over 500 thousand tonnes of microplastics are generated annually from the eroding of automotive tyres in Europe (Eunomia, 2018). Microplastics can be transported and enter the marine environment via runoff, wastewater effluents, sewage sludge, rivers and even atmospheric deposition (Thompson, 2016; Prata, 2018; Galafassi et al., 2019).

The complex dynamic of factors affecting the distribution and fate of marine litter makes it difficult to detect clear trends in the recorded number of items in the different marine compartments (Thompson, 2016; Galgani et al., 2021). Together with the fact that the original purpose of many litter items may be unrecognisable (e.g. pieces and fragments of plastic) or are, by nature, not sector-specific makes the attribution of marine litter to specific human processes, economic sectors or geographic origin particularly challenging (Veiga et al., 2016). Still, understanding and quantifying the causes that originate this pollution is essential to define appropriate interventions and monitor the effectiveness of prevention measures. As such, assessing the processes that lead to mismanaged waste, as well as the state of litter pollution in transitional environments, notably rivers, provides informative insights into how well policies and human activities are effectively preventing litter leakages in the first place.

1.2. Why we need to assess marine litter from source to sea

Currently, litter assessments tend to focus predominantly on the marine environment, i.e. on the state and impact of litter as a marine pollutant. Similarly, most of the research on plastic pollution is also focused on the marine domain (Blettler et al., 2018). However, given the current limitations in monitoring data and the complexity of factors affecting the distribution of litter in the sea, it is challenging to derive trends on the state of pollution, as well as insights into the causes that generate that pollution. Moreover, although it is a marine issue and partly results from maritime activities, it is broadly recognised that most of the plastic litter originates from land-based sources. Thus, its drivers, governance and mitigation measures need to be considered beyond the maritime domain.

In the same way that addressing marine litter requires coordinated action across different sectors and stages of litter items' life cycle, the problem needs to be assessed across the domains and environmental compartments where litter originates from and flows through before becoming marine litter. A knowledge-based assessment will best inform policies and actions if it relates litter pollution to how efficiently societies are using, reusing, and recycling materials, such as plastic, and if improvements in these performances lead to reduced levels of litter in the environment. Broadening the scope and focusing also on production and consumption, waste prevention and management will support assessing the level of pressure much closer to the root causes of marine litter, which is what preventive measures need to address.

This technical assessment has been developed within a ***source-to-sea* framework**, for these reasons. The concept of “source to sea” was originally coined by the Stockholm International Water Institute – SIWI (Berggren and Liss Lymer, 2016; Granit et al., 2017), as a way to look at environmental issues that recognizes the continuum across environmental compartments. Similar approaches have already been applied in regional assessments done by the European Environment Agency (EEA), namely on contaminants, eutrophication and waste/marine litter, carried out as part of the H2020 Initiative for a cleaner Mediterranean (EEA, 2020). Moreover, this technical assessment is also structured around a ***Drivers-Pressures-State-Impact-Responses* (DPSIR) framework**. Both these frameworks accentuate the causality of processes that lead, in this case, to marine litter pollution and recognise the interconnection between different disciplinary domains and environmental compartments (as illustrated in Figure 1 and Figure 2), which contrasts with the often fragmented governance and management domains.

Figure 1: Key sources (land and sea-based) and pathways of marine litter, and solid waste management (SWM) responses (Source: Deltares)

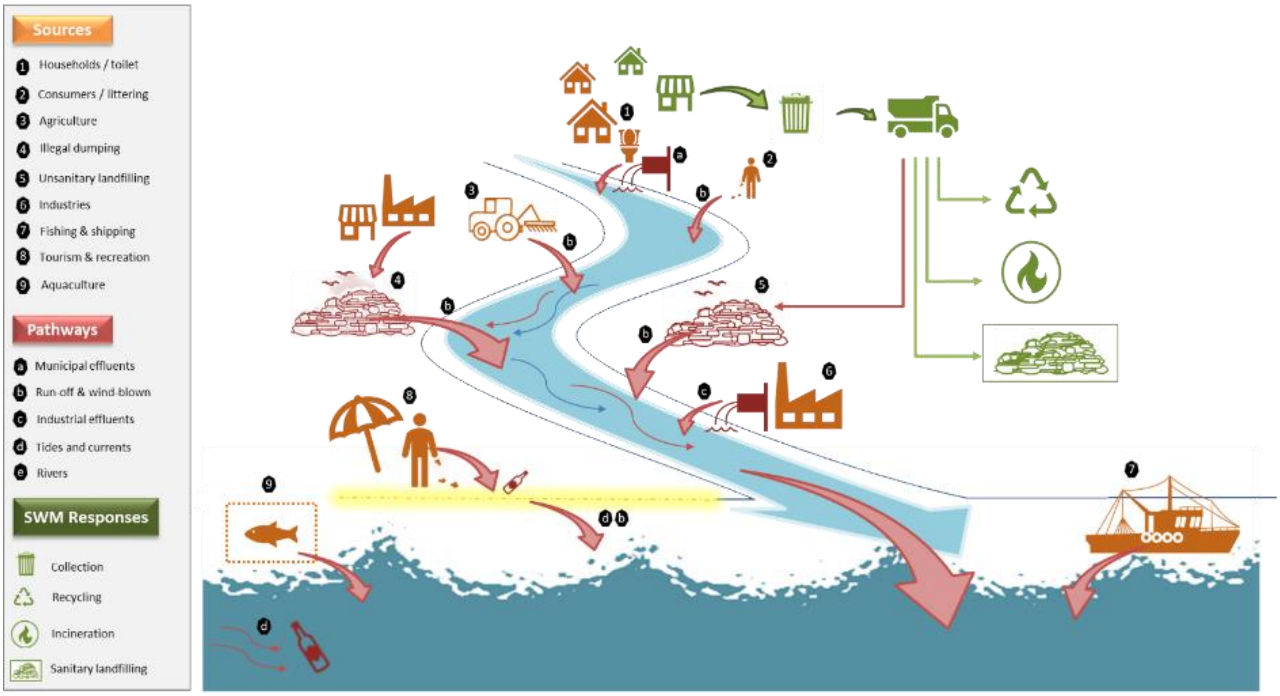
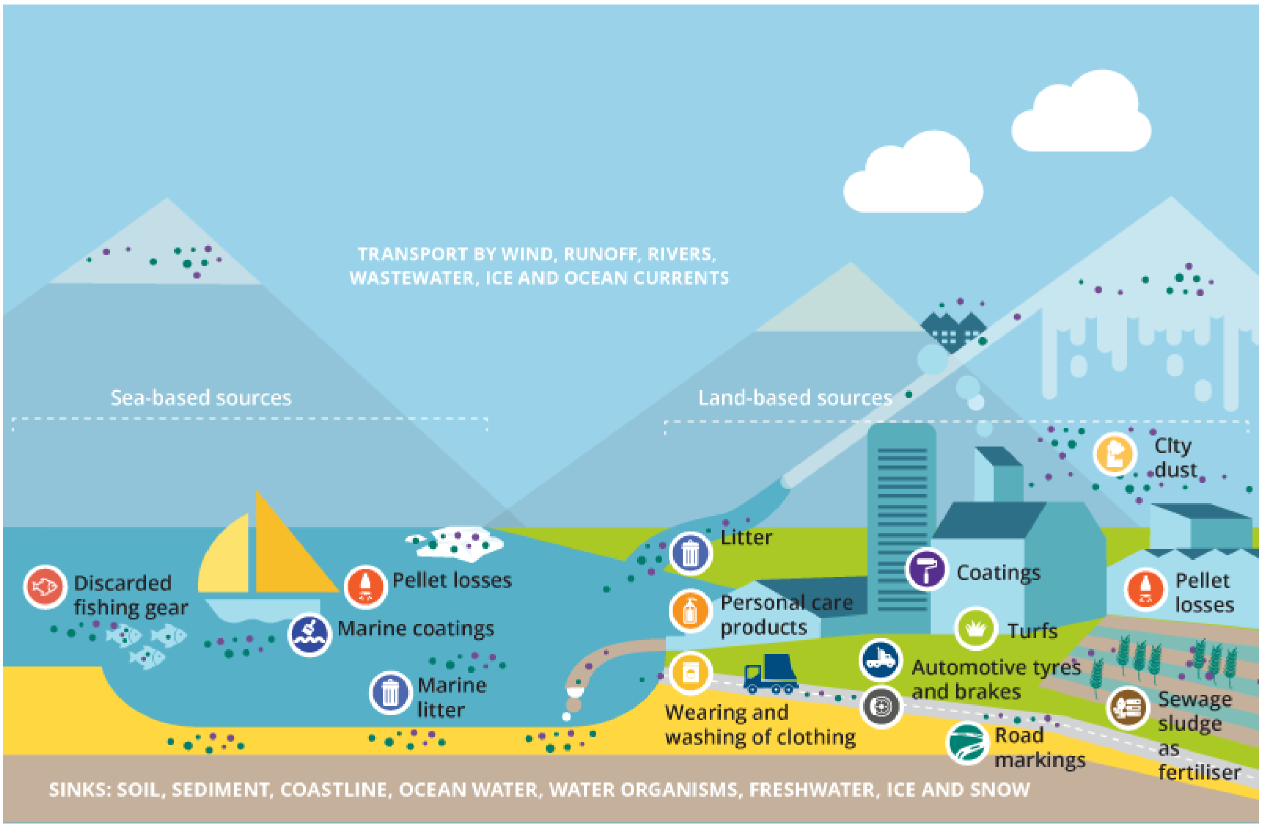


Figure 2: Sources, pathways and sinks of microplastics (original illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) for the European Topic Centre on Circular Economy and Resource Use (ETC/CE) and the EEA)



1.3. About this report

1.3.1. Objectives

In this study, marine litter is looked at as resulting from inadequate material production, consumption, waste disposal and/or management. As a consequence, waste becomes litter and may end up in the environment, including the coast and sea, part of which is transported and discharged via runoff and rivers from inland sources.

> The main objective of this report is to **assess the situation of marine (macro)litter in Europe, with a special emphasis on the plastic packaging fraction, from *source to sea*,** i.e. across the three environmental compartments where most litter originates from (land), via which it is transported from inland into the sea (rivers) and, finally, the receiving marine environment.

As specific objectives, the report aims at:

a) describing the **key economic drivers** of plastic litter and the **European policy responses** that are relevant, at different stages of its life cycle;

b) assessing the level of **pressure** in terms of generation and mismanagement of plastic waste, specifically the fraction corresponding to packaging and small non-packaging items;

c) scoping the **estimated inputs** of litter inputs into European seas via rivers, based on published scientific literature;

d) assessing the **status of marine litter pollution** in the European Seas in relation to defined thresholds, based on marine litter indicators, and complemented by a literature review;

e) **assessing perceived trends** in relation to **European policy objectives and policies**;

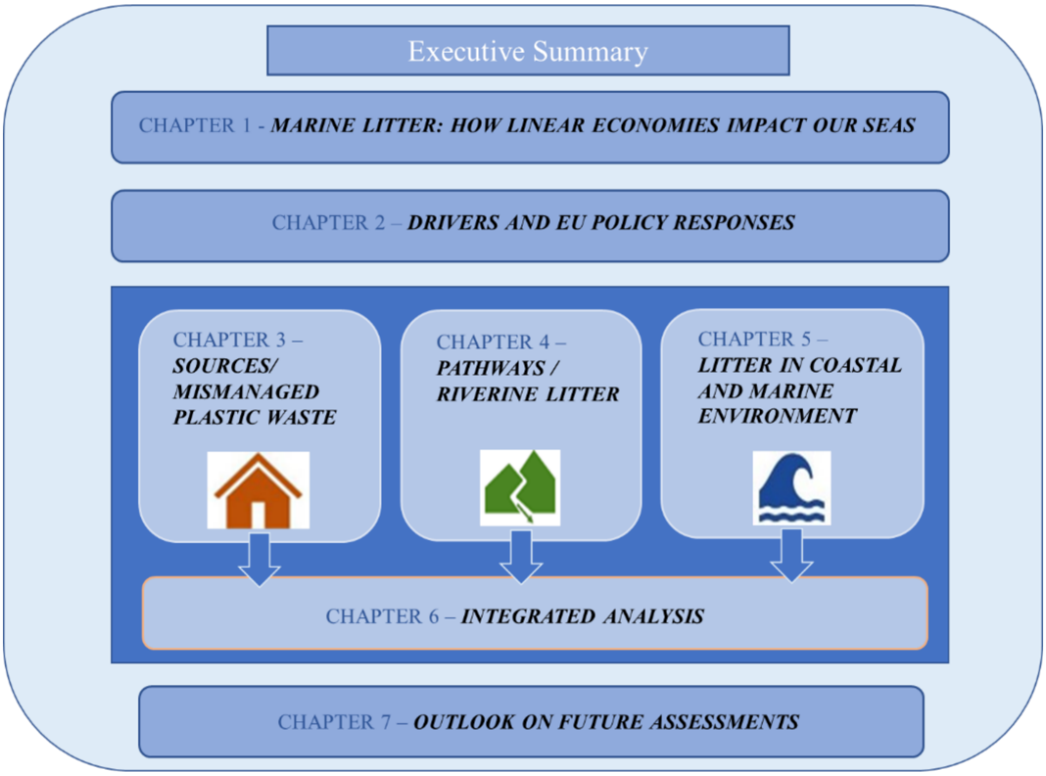
f) providing **recommendations** for future integrated assessments of marine litter.

This integrated assessment makes use of existing indicators and data sources, which are usually looked at as separate disciplines. This pan-European scale study brings together the domains of production and consumption, waste management and environmental litter pollution. The general ambition is to support a better understanding of the drivers and pressures that lead to marine litter, and particularly the prevailing plastic packaging fraction, how these may relate to the current state and trends of pollution, and thus provide a more holistic, yet informative, picture of this complex issue.

1.3.2. Guide to the reader

The structure of the *Marine Litter Integrated Assessment* is illustrated in Figure 3 below. It is composed of a technical report, which constitutes the evidence-based and detailed analytical assessment, and an Executive Summary, where key outcomes and conclusions of the overall assessment are presented, particularly those most relevant to policy. In addition, *Key Messages* are presented at the forefront of each chapter.

Figure 3: Structure and analytical components of the Marine Litter Integrated Assessment report



The technical report is divided into seven chapters:

- **Chapter 1** is an introductory chapter that contextualises the issue of marine litter within a larger context of production-consumption and waste management; and describes the objectives, scope and general framework used in the assessment.
- **Chapter 2** focuses on the socio-economic ***drivers*** and the European ***responses***, as EU Directives that are relevant to marine litter, across its life cycle spectrum.

- **Chapters 3**, **4** and **5** constitute the three main analytical components of the report, encompassing the domains of land (sources), rivers (pathways) and coastal/marine (state of pollution), respectively.
  - **Chapter 3** focuses on the level of ***pressure*** exerted by the generation and mismanagement of plastic waste in Europe, from which plastic marine litter (from ***land-based sources***) originates from. This is based on a material flow analysis conducted in each of the EEA-32 countries + UK for two selected years (2012, 2018). It focuses specifically on plastic packaging and small non-packaging items (PPSI), as these correspond to the majority of recognisable items found in the European coastline.
  - **Chapter 4** covers the freshwater domain, particularly on ***rivers as*** ***pathways*** of litter from land-based sources into the sea. Key studies on riverine litter pertinent to Europe are reviewed and regional differences in terms if riverine discharges are analysed.
  - **Chapter 5** addresses the ***state*** of pollution of ***marine litter*** and microplastics in each European Regional Seas. It includes a literature review on the state of knowledge on occurrence in different marine environmental compartments (beach, water column, seafloor) and in biota, as in indicator of ***impact***; selected results from an analysis of the available Marine Litter Watch (MLW) dataset; and an indicator-based assessment on the status of the regions in relation to specific abundance thresholds.
- **Chapter 6** constitutes a synthesis, bringing together the main findings from previous Chapters within a ***Source to Sea*** narrative and across the ***Drivers-Pressures-State***. It uses the critical assessment results as evidence for appraising the situation in relation to European policy objectives and targets.
- Finally, **Chapter 7** provides the outlook and technical recommendations in view of better integrated assessments of marine litter.

1.3.3. Scope of the assessment

The three analytical components of this report have specific assessment characteristics in terms of scope, data sources and analytical methods used. These are summarised in Table 1 below.

Table 1 Scope boundaries of the analytical components used in the assessments in Chapters 3, 4 and 5

	Chapter 3	Chapter 4	Chapter 5
	LAND SOURCES	**RIVERINE PATHWAYS**	**STATE OF MARINE POLLUTION**
Key analytical output	**Estimation of PPSI (2) waste generated and mismanaged**	**Input of riverine litter into the sea**	**Status of marine litter pollution**
Geographic coverage	Individual 32 EEA countries, including EU-27 + UK (3). Part of the analysis includes other non-EU countries.	Catchment approach – EEA countries' basins that discharge into European regional seas and where data are available.	Four European regional seas and coastlines: Baltic Sea, NorthEast Atlantic Ocean; Mediterranean Sea and Black Sea.
Type and size of litter considered	Macroplastics, specifically the fraction of waste corresponding to plastic packaging and small non-packaging plastic items (4) (PPSI).	Macrolitter (> 2.5 cm).	Macrolitter (> 2.5 cm) and microlitter (5).
Key data sources used in the assessment	Eurostat; Plastics Europe; scientific and grey literature; EEA country fact sheets on municipal waste management; World Bank (non-EU countries).	Scientific literature (González-Fernández et al., 2021; Meijer et al., 2021).	Beach litter and seafloor monitoring data available in EMODnet Chemistry; Marine Litter Watch (MLW).
Spatial resolution	Input data at national level; population at NUTS3 to compute estimates in coastal regions.	Estimate results from modelling over 32 thousand rivers discharging into the European regional seas.	Assessment made in 20 x 20 km grid cells in coastal areas and 100 x 100 km grid cells offshore. Aggregated results for the four European regional seas.
Period of the assessment	Two years: 2012 and 2018.	Field observations: 2016–2017 (González-Fernández et al., 2021). Other data are scattered.	Period from 2010 to 2021. MLW: 2013–2021. EMODnet Chemistry: 2010–2021.
Main analytical method(s) used	Material Flow Analysis (MFA) to estimate the fraction of PPSI waste that is mismanaged.	Literature review; spatial analysis.	Literature review; multi-metric indicator-based status assessment.

[2] PPSI – Plastic packaging and small non-packaging plastic items. Plastic packaging data account for all packaging, whether it originates from industrial or commercial sources, offices, shops, services, households or any other entities
[3] The withdrawal of the United Kingdom from the European Union did not affect the production of the report. Data reported by the United Kingdom are included in all analyses and assessments contained herein, unless otherwise indicated.
[4] Small non-packaging plastic items include: household, leisure, sanitary and medical items
[5] Microlitter is only covered in the literature review

2. Drivers and EU policy responses

KEY MESSAGES

- A large part of the litter found in the marine environment is associated with food production, delivery and safety, as well as human health and well-being. These items are mostly made of plastic and designed for single use. Therefore, the challenge is to harness the benefits such applications bring to society without the environmental damage they create, particularly the plastic emissions into the sea.
- Marine litter is high on global and particularly European political agendas. The recent action plans on Circular Economy and Zero Pollution drive the systemic transition of the EU. Many European Directives relate to plastics, waste and marine litter, at different life cycle stages, from production, down to pollution by mismanaged waste. These instruments work in an articulated manner. The MSFD, for example, has helped establish regionally coordinated monitoring programmes that generate important data, which, in turn, support the design and inform the effectiveness of other relevant policies.
- In line with global trends, plastic production in Europe has been increasing steadily in previous decades. This is also the case for the production of plastic packaging, at least until 2018. Plastic packaging represents roughly 40 % of the total plastic demand in Europe.
- Between 2010 and 2018, total waste generated increased 7 % in the EU-27, which is not in line with the EU policy goal of reducing waste generation. This seems to be primarily driven by the economy and consumption patterns. Although there is evidence that the increasing rate of waste generation is relatively lower than GDP, it is clear that Europe has not yet reached an absolute decoupling between waste generation and economic growth, as envisioned by a transition to a Circular Economy.
- Specific economic activities can generate significant pressures in terms of waste generation or as direct sources of marine litter. This is the case for coastal tourism and recreation, as well as maritime activities, such as fishing, aquaculture and shipping. Although most litter found on beaches is associated with consumers, a significant amount can be attributed to industrial activities.
- Tourism can be responsible for a considerable fraction of the waste generated in tourist destinations. Particularly packaging and other disposable items are used in large amounts by restaurants and accommodation providers. Coastal tourism has a marked predominance in regions such as in Southern Europe, and its seasonality is also documented in the number of litter items found on beaches, which can double during the summer in the Mediterranean Sea.
- The impact of maritime activities such as fishing and aquaculture is visible in the composition of beach litter. As expected, higher proportions of this type of litter are found in those areas where these activities are intense, such as in the North Sea and the Adriatic Sea.
- Despite international shipping regulations that promote the delivery of waste to port reception facilities, it is estimated that up to one-third of the litter generated by merchant shipping is not delivered and could, instead, be illegally discharged into the sea. This is, however, difficult to assess reliably due to scarce information and up-to-date data.

2.1. Drivers of plastic marine litter

Drivers directly related to marine litter are those human needs, and corresponding economic sectors, that will lead to the generation of (mismanaged) waste or the loss of items that will become marine litter. A significant part of marine litter is associated to the production (e.g. fishing gear), delivery, consumption and safety of food (e.g. food and drink packaging), as well as human health and well-being (e.g. single-use cutlery, cotton-bud sticks) (Abalansa et al., 2020). In turn, these rely largely on plastic materials and consist, very often, in single-use, short-lived items. In fact, the largest market of plastics is packaging, whose growth has accelerated with the global shift from reusable to single-use applications (Geyer et al., 2017).

One of the challenges is therefore, to respond adequately to the fundamental human needs of food, hygiene and well-being, while minimising degradation and pollution of the environment as a consequence. As Thompson (2016) argues, harnessing the benefits that plastic items bring to society does not require emission of end-of-life plastics to the oceans.

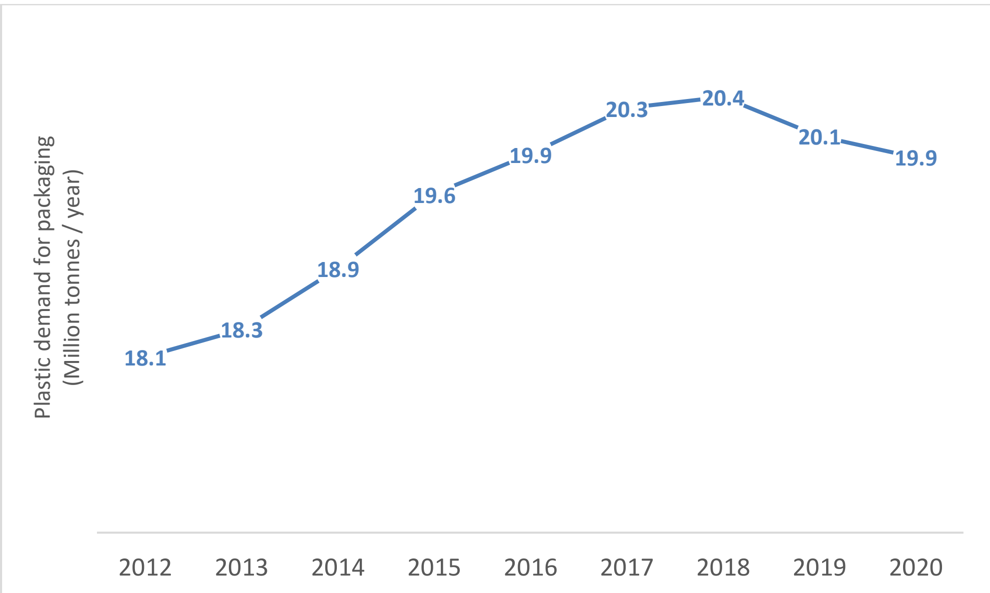
2.1.1. Plastic production and packaging demand

In line with global trends, although at a different pace, plastic production in Europe has been increasing since its large-scale industry started in the 1950s. In 2016, the total virgin plastic polymers and fibres production in the EU-27 + UK amounted to 66,786 thousand tonnes (Hsu et al., 2021). This includes polyethylene terephthalate (PET), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), other thermoplastics, thermosets, and synthetic fibres. According to data from Plastics Europe, plastic production from virgin resins has increased steadily at least until 2017.

Packaging represents the largest segment in terms of plastics demand (Geyer et al., 2017). According to Plastics Europe (2019), in Europe, packaging represents roughly 40 % of the total plastic demand, in particular for PE, PP and PET (Figure 4). The plastic demand for conversion to packaging has increased steadily between 2012 and 2018 (
Figure 5). The other 20 % is converted to small non-packaging items, used, amongst others, in consumer goods, household appliances, sport, health and safety. Another significant proportion of plastics is used in synthetic fibres for clothing, household and industrial textiles. In 2018, the EU production of synthetic fibres totalled 2.24 million tonnes (EEA, 2021a). Although this is one of the largest applications for plastics (particularly PET/polyester), textile fibres are usually not included in the statistics for plastics (EEA, 2021b; Bartl, 2020).

Figure 4: European plastics demand by segments in 2018 (Source: Plastics Europe, 2019). Note that these refer only to virgin plastic resins.

Figure 5: Plastic converter demand for packaging in Europe (EU-27 + UK, NO, CH; except for 2012 and 2013, where data refers to EU-27 + NO, CH) between 2012 and 2020 (Source of data: Plastics Europe. Note: These figures refer only to plastic packaging production in Europe from virgin resins and may not reflect plastic packaging that is placed in the European market, i.e. accounting for exports and imports).



2.1.2. Specific economic activities linked to marine litter

Economic activities that take place near to or at sea can lead to direct inputs of litter into the sea or generate litter leakages that will have a higher likelihood of ending up in the marine environment. That is the case for maritime activities such as fishing, shipping, and coastal tourism. Nevertheless, it is generally referred to that approximately 80 % of marine litter originates from land-based sources, even if, as discussed in a study by Eunomia (2016), this figure is not well substantiated by data. In fact, care must be taken when inferring about the origin of marine litter (as discussed in section 1.1.1), as this depends largely on the methodology of allocation of items to sources (Veiga et al., 2016).

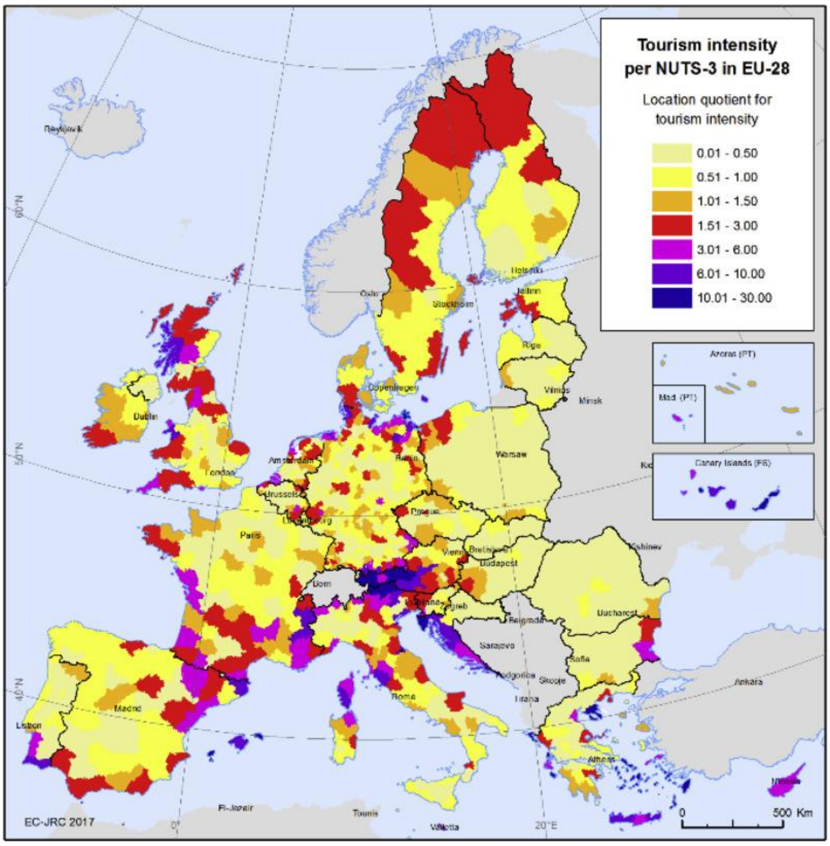
In any case, clear regional differences in terms of types of sources of marine litter in Europe emerge from existing data, as demonstrated by the early pilot study of Arcadis (2012), where beach litter items attributed to land-based sources were as high as 84 % in the Mediterranean Sea (Barcelona), while to sea-based sources were as high as 50 % in the North Sea (Oostende). Another study by Arcadis (van Acoleyen et al., 2014) analysed European beach litter data from 2012–2013. It indicated that 2/3 of the litter likely originated from individual consumers, while the other 20 % could be attributed to industrial activities.

2.1.2.1. Tourism

The tourism sector is known to exert intense environmental pressure, notably on the generation of solid waste, and in particular, because establishments such as restaurants, hotels and accommodations use large amounts of packaging and other disposable consumer items as part of their operations (Muñoz and Navia, 2015). There are, however, a minimal number of studies detailing the specific impact of tourism on waste generation in Europe. One of these few studies, focused on Madeira Island (Portugal), indicates that tourism represents 26.6 % of the regional GDP. In comparison, tourism is responsible for approximately 45 % of the solid waste generated per capita (Martins and Cró, 2021). Another study has estimated that for Menorca Island, each additional tourist will generate 1.3 kg of municipal solid waste (MSW) per day (Mateu-Sbert et al., 2013).

In Europe, this driver presents spatial and temporal differences across and within countries (Figure 6) due to the type of tourism and its seasonal oscillations (Batista e Silva et al., 2018). For example, coastal tourism has a marked predominance in certain regions, such as Southern European countries. In fact, the influence of coastal tourism and recreation seems to lead to significant increases in litter recorded in beach litter surveys in the Mediterranean (UNEP/MAP MEDPOL, 2015), which can double during the summer (Martínez-Ribez et al., 2007).

Figure 6: Tourism intensity in small regions (NUTS-3) in Europe (EU-28), in 2016 (Source: Batista e Silva et al., 2018)



It is worth highlighting that coastal tourism is one of the economic activities that can not only generate marine litter but also be highly impacted by it, both directly by the loss in aesthetic value of the beach, as well as by the significant costs of litter removal taken by the municipalities. For example, total annual costs of € 6,724,530, with an average of € 216,920 per municipality, was reported for the Adriatic-Ionian region (Vlachogianni, 2017).

2.1.2.2. Fishing and aquaculture

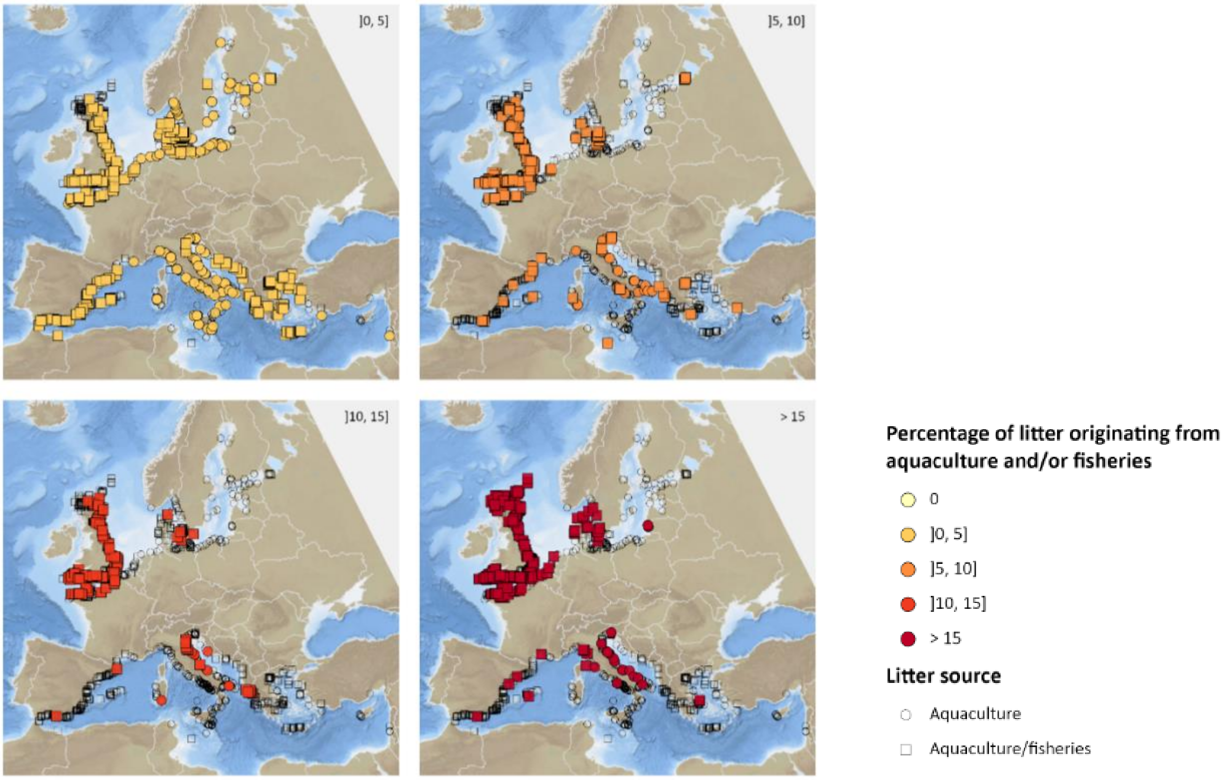
According to the European Scientific, Technical and Economic Committee for Fisheries (STECF, 2019) annual report, the EU fleet capacity trend is in a steady decline and is mostly composed of small-scale coastal vessels (75 % in 2017). While globally, aquaculture is the fastest-growing animal-food-producing sector in the world, in the EU-27, aquaculture production has remained quite stable (García and Vasilakopoulos, 2020).

The impact of fisheries and aquaculture can be visible in the incidence of items associated to these sectors in litter composition, which varies considerably between areas but is particularly evident near sites where these activities are intense.

This is illustrated, for example, by the reported occurrence of items associated to mussel farming found in the Adriatic Sea (Fortibuoni et al., 2019). Sea-floor surveys carried in the NEA and Mediterranean Sea, at depths of between 35 and 4,500m indicate that fishing lines and nets correspond to 34 % of the total items recorded and this type of litter dominates in seamounts, banks and ocean ridges, where fishing activity can be intense (Pham et al., 2014).

On the other hand, almost the entire Baltic Sea region (except for Denmark) shows relatively low numbers of aquaculture debris, which is consistent with the limited aquaculture activity in this region (Figure 7) (Sandra et al., 2020).

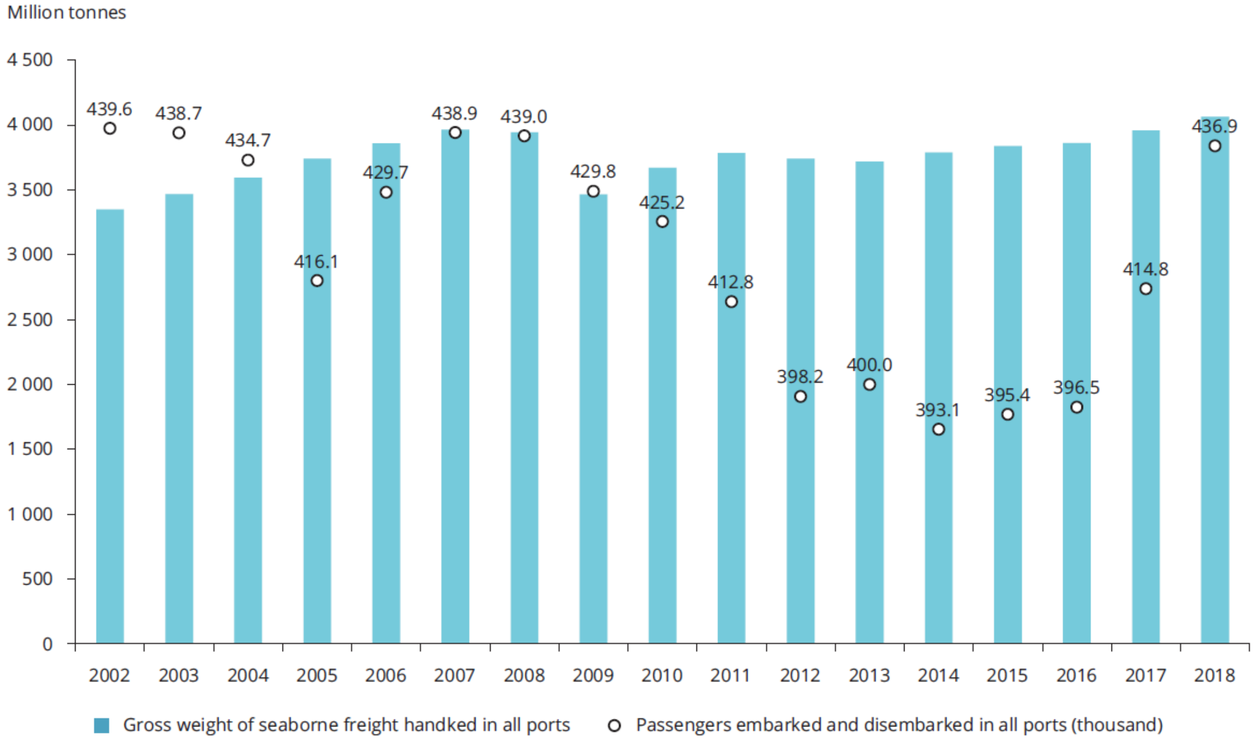
Figure 7: Percentage of litter originating from aquaculture and/or fisheries based on beach litter monitoring data in the North Sea, Baltic and Mediterranean (Source: Sandra et al., 2020)



2.1.2.3. Shipping

According to the EEA and EMSA (2021), maritime transport carries 77 % of the European external trade and 35 % of the internal trade, corresponding to almost four billion tonnes of cargo handled in European ports and 400 million passengers per year. Maritime traffic in the EU has been growing slowly in recent years, similarly to the global trend. The main ports in terms of port call activity are located in the North Sea (Rotterdam and Antwerp) and the Mediterranean Sea (Algeciras, Pirareus and Messina). The top five ports in what concerns cruise ships are all located in the Mediterranean region. The number of passengers embarking and disembarking in EU ports increased significantly since 2016, after a decade in which numbers fell consistently (Figure 8). Italy and Greece account for more than one third of the maritime passenger transport in 2018, while the Netherlands report the largest volume of freight handled annually in the EU.

Figure 8: Seaborn passengers (thousands) and gross weight (millions of tonnes) of seaborn freight handled in all EU-27 and UK ports (EEA and EMSA, 2021, original source: Eurostat)



Ship-generated waste, including litter, can pose a significant threat to the marine environment if disposed of inadequately. International ([6]) and European provisions are in place to prevent the direct dumping of litter from shipping into the sea, as is the case of plastic waste. Waste that cannot be reused on board or legally discharged at sea under international MARPOL standards must be delivered to port reception facilities. Nevertheless, an impact assessment from the EC (European Commission, 2018) estimated that between 7 % and 34 % of litter generated by merchant shipping is not delivered at port reception facilities and could, instead, be illegally discharged into the sea. However, these figures do not account for plastic waste nor new onboard practices for waste management (EEA and EMSA, 2021). As such, there is limited up-to-date information or scientific literature that can be used to assess how much marine litter originates from sea-based sources, particularly from shipping.

2.2. European policies that drive change

2.2.1. Marine litter is high on political agendas

The issue of marine litter and in particular plastic pollution has been gaining growing attention in the last decade and is high on political agendas globally and regionally. It is explicitly targeted by the United Nations' Sustainable Development Goal SDG 14.1 *(by 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution)* and the focus of Action Plans adopted by the G20 (2017) and G7. Just recently (March 2022, Nairobi), a global legally binding agreement on plastic pollution has been endorsed at the fifth session of the United Nations Environmental Assembly (UNEA 5.2) and will be shaped in the coming years (Sun et al., 2021).

[6] International Convention for the Prevention of Pollution from Ships (the MARPOL Convention)

In Europe, monitoring of marine litter started in 2001, in the NEA by the OSPAR Pilot Project on Monitoring Marine Beach Litter (2000–2006) (OSPAR, 2007). Since then, three of the Regional Sea Conventions have adopted Action Plans of Marine Litter: first for the Mediterranean Sea by UNEP/MAP, in 2013; for the NEA by OSPAR ([7]), in 2014 and 2022 ([8]); and the Baltic Sea by HELCOM, in 2015 ([9]) and 2021 ([10]). The Regional Seas Conventions help catalysing and coordinating actions related to marine litter and streamlining related European policies in the respective regions. The Technical Group on Marine Litter (TGML)[11] provides orientation on monitoring protocols on marine litter in Europe and since 2011 has published several guidance reports to ensure harmonisation of data and methodological approaches in Europe.

2.2.2. The European Green Deal, Circular Economy and Zero Pollution Action Plans

One of the cornerstones of the European Green Deal is the transition to a Circular Economy and its Action Plan, which aims at changing the way we produce and consume across the entire lifecycle, in sectors that include waste, plastics and packaging. Specifically for plastics, the EU Strategy for Plastics was adopted in 2018 to drive changes on how plastic products are designed, produced, used and recycled, with the aim to reduce marine litter and other environmental impacts associated with the plastics economy. Furthermore, the Zero Pollution Action Plan (ZPAP) ([12]) sets out an integrated vision for 2050, where pollution is reduced to levels that are no longer harmful to human health and natural ecosystems, as well as the steps to get there. Key 2030 reduction targets are defined, to speed up reducing pollution at the source, including three directly related to waste, marine litter and microplastics.

In addition, the ZPAP proposes a new framework to better monitor pollution levels and anticipate future trends – the Integrated Zero Pollution Monitoring and Outlook Framework – to monitor the progress towards the 2030 targets and the 2050 ambition, assess whether current actions are sufficient, make use of the advanced data sources and digital technologies (e.g. citizen science, Copernicus, Artificial Intelligence), as well as analyse synergies and trade-offs between different EU policies.

Zero Pollution Action Plan
2030 targets

- *Reduce significantly waste generated;*
- *Reduce 50 % residual municipal waste;*
- *Reduce 50 % plastic litter at sea and 30 % microplastics released into the environment*

[7] https://www.ospar.org/documents?v = 34422
[8] https://www.ospar.org/work-areas/eiha/marine-litter/regional-action-plan/rap2
[9] https://helcom.fi/media/publications/Regional-Action-Plan-for-Marine-Litter.pdf
[10] https://helcom.fi/action-areas/marine-litter-and-noise/marine-litter/marine-litter-action-plan/
[11] https://mcc.jrc.ec.europa.eu/main/dev.py?N = 41&O = 434&titre_chap = TG
[12] Communication from the Commission COM/2021/400 – EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'

2.2.3. European Directives relevant to marine litter

In Europe, the Marine Strategy Framework Directive (MSFD, 2008/56/EC) was the first legally binding instrument, transposed to national legislation, that directly addresses marine litter. It required "Good Environmental Status" (GES) for marine litter to be achieved by 2020, although our results indicate that this has not been the case (see section 0). Furthermore, as part of the implementation of the MSFD, monitoring programmes for marine litter, coordinated at the regional level, were put in place throughout Europe. As a result, important data are being generated, which are instrumental to design and inform appropriate measures. For example, monitoring of beach litter pollution has helped formulating the Single-Use Plastics (SUP) Directive, which targets those plastic items more commonly found on European beaches (see Table 2).

Figure 9: EU waste hierarchy, where prevention is the preferred option

Source: European Commission

Several other EU Directives have a direct impact on marine litter, as they cover production, consumption and solid waste management in general, or plastic waste in particular; target specific sources of marine litter associated to economic sectors (e.g. shipping); or pertain other environmental compartments that can be polluted or transport plastic waste into the sea, such as the case of freshwater systems and the coastal environment. For example, the 2015 Directive on plastic bags has been effective in reducing their consumption and occurrence in the environment, as suggested by a decreasing trend in the recorded number of plastic bags on the seafloor, in the North and Celtic Seas (Maes et al., 2018). Some other Directives are not new but have been recently revised to better operationalize the waste hierarchy (Figure 9) and support transition towards a Circular Economy, which would have direct impact on preventing marine litter. This is the case of the revised Waste Framework Directive (2008/98/EC), amended in 2018.
Table 2 summarizes the key EU policy instruments most relevant for marine litter grouped from a *source-to-sea* perspective:

- **Land or sea-based sources**: those policies that have a role in preventing marine litter at source;
- **Pathways**: policies that pertain environmental domains (e.g. rivers) or infrastructures (e.g. waste water treatment plants (WWTP)) that can carry litter and microplastics from land-based sources into the sea;
- **State and impact of pollution in the coastal and marine environment**: policies that directly address marine litter and/or its impacts.

More specifically, these instruments target distinct stages of the value-chain of products and waste, such as design and use of products, and disposal of waste; economic sectors that may generate marine litter, such as shipping and fishing; as well as different environmental compartments that can be polluted by marine litter, such as the freshwater systems and the marine environment (Figure 10).

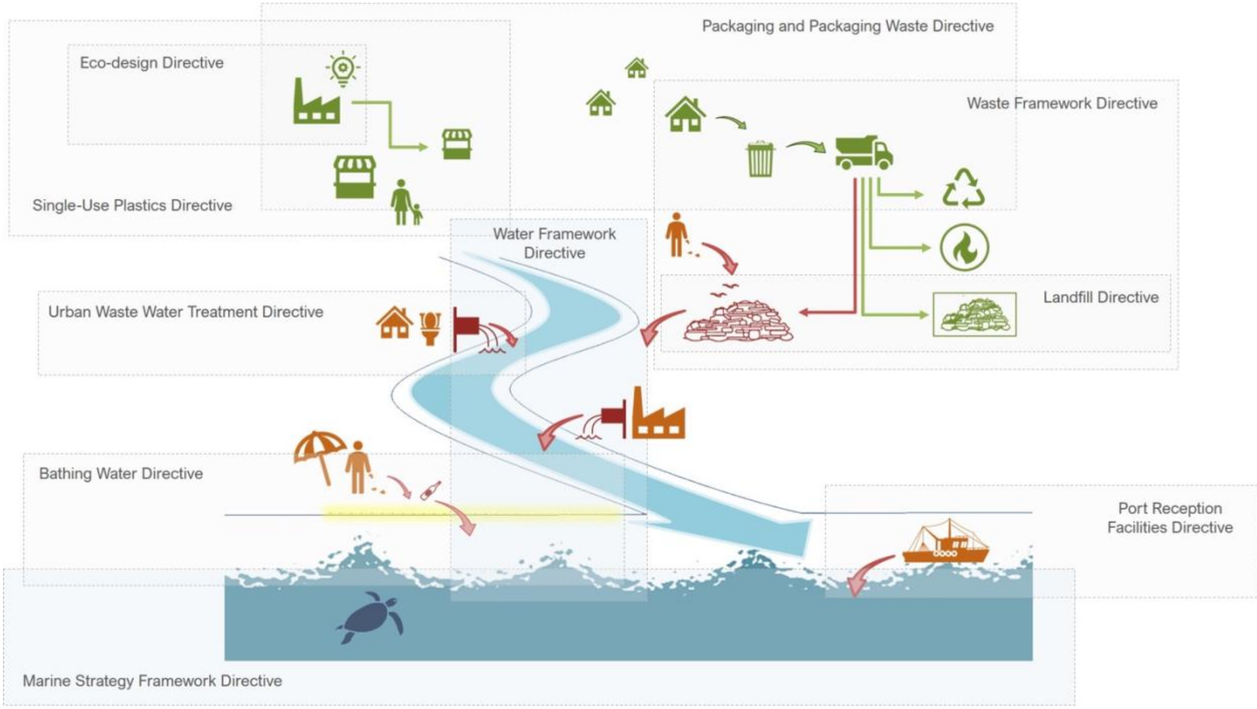
Table 2 Overview of European policy instruments relevant to marine litter

Domain targeted	EU Instrument	Short description
Overarching (soil, water, air)	***Zero Pollution Action Plan (ZPAP)***	Adopted in May 2021, the ZPAP is a key deliverable of the European Green Deal that aims at halting the impact of pollution on human health and the environment. It sets a vision for 2050 in which air, water and soil pollution are reduced to levels that are considered no longer harmful to health and natural ecosystems. A set of 2030 targets are to catalyse prevention of pollution at source and include the reduction of waste, plastic litter at sea and the release of microplastics into the environment.
Land-based sources (production, consumption, waste)	***Action Plan for the Circular Economy***	Plastics are one of the priority areas in the Circular Economy action plans (2015, 2020). The action plans set long-term targets to increase preparation for reuse and recycling of key waste streams, such as packaging. The recent action plan (2020) defines several actions on plastics value chain, namely plastic waste reduction measures for key products such as packaging, mandatory requirements on recycled plastic content, restriction of intentionally added microplastics and measures to prevent unintentional release of microplastics.
	Strategy of Plastics in a Circular Economy	Published in 2018, it is the first EU-wide policy framework taking a life cycle approach that integrates design, use, reuse and recycling of a specific material. It addresses environmental leakages of plastics and microplastics, including issues of recyclability, biodegradability, and presence of hazardous substances. One of the key goals outlined is that by 2030, all plastic packaging placed in the EU market is either reusable or can be recycled in a cost-effective manner.
	Waste Framework Directive 2008/98/EC (amend 2018/851)	Sets out the essential conditions for the management of all types of waste. Requires Member States to improve their waste management systems into the management of sustainable material, to improve the efficiency of resource use, and to ensure that waste is valued as a resource.
	Directive 1999/31/EC (amend 2018/850) on Landfill	Sets out strict operational requirements for landfill sites with the objective to protect both human health and the environment. Landfill location must consider the proximity of water bodies and coastal waters. It includes new provisions to support the EU transition to a Circular Economy, namely on restrictions on landfilling waste that is suitable for recycling (from 2030), as well as limits to the share of MSW landfilled to 10 % by 2035.

Domain targeted	EU Instrument	Short description
Land-based sources (production, consumption, waste)	***Directive 94/62/EC (amend 2018/852/EU) on Packaging and Packaging Waste***	Aims at preventing generation of packaging waste and their environmental impact, increase the reuse of packaging and the recycling of packaging waste, prioritizing prevention, following the waste hierarchy (Figure 9). Defined recycling targets for plastic packaging by 2025 and 2030 are 50 and 55 %, respectively; and Extended Producer Responsibility (EPR) schemes for all packaging are established by 2024.
	Directive 94/62/EC (amend 2015/720/EU) on Plastic Bags	The amended version requires Member States to take measures to reduce significantly the consumption of light-weight plastic carrier bags, which are one of the top ten littered items in Europe, by the end of 2019.
	Directive 2019/904/EU on Single-Use Plastics	Adopted in 2019, it targets upstream and the top 10 single-use plastic items most often found on Europe's beaches and seas: cotton bud sticks; cutlery, plates, straws and stirrers; balloons and sticks for balloons; food containers; cups for beverages; beverage containers; cigarette butts; plastic bags; packets and wrappers; wet wipes and sanitary items; as well as fishing gear. Distinct measures, such as limiting their use and increase collection, are to be applied depending on the product and availability of more sustainable alternatives.
	Regulation 2020/2174 on shipments of waste	EU Regulations implementing the Basel Convention provide rules on exports of waste, including plastics, and limit the export of plastic waste to third countries that may not have the capacity and standards to manage it sustainably. The new rules ban the export of hazardous plastic waste and plastic waste that is hard to recycle from the EU to non-OECD countries; control more strictly imports in the EU and the export of clean, non-hazardous plastic waste sent for recycling from the EU to OECD countries.
Sea-based sources	***Directive 2010/65/EU (amend 2019/883/EU) on Port Reception Facilities***	Aims to reduce the discharges from ship-generated waste and cargo residues into the sea, including from fishing vessels and recreational craft. The revised Directive includes provisions for incentives for ships to dispose their waste on land, notably a no-special fee, irrespective of the quantities delivered. This fee also applies to fishing vessels, to encourage disposal of end-of-life fishing gear and passively fished waste in the sea.
	Common Fisheries Policy Control Regulation	The policy contains provisions intended to retrieve lost fishing gear.
	Directive 2019/904/EU on Single-Use Plastics	Fishing gear is one of the type of items targeted by the Directive. Specifically, it requires Member States to report on gear containing plastics and EPR schemes for collection and clean-up of disposed or retrieved fishing gear.

Domain targeted	EU Instrument	Short description
Pathways	***Water Framework Directive (WFD) 2000/60/EC***	Aims at achieving that inland and coastal waters are ecologically sound. The WFD includes design and implementation of measures, some of which relate to marine litter management. However, the WFD does not refer to plastic litter in particular.
	Directive 91/271/EEC (amend 98/15/EC) on Urban Waste Water Treatment	WWTPs can have an important role in retaining and removing of microplastics and other plastic items from both urban sewage and storm water.
State and Impacts of marine pollution	***Marine Strategy Framework Directive (MSFD) 2008/56/EC***	Descriptor 10 on marine litter requires that 'properties and quantities of marine litter do not cause harm to the coastal and marine environment'. It foresees cyclical processes of target setting, monitoring and programme of measures to be implemented in order to achieve "Good Environmental Status" (GES).
	Directive 2006/7/EC on Bathing Water Quality	Requires bathing waters to be inspected visually for certain polluting items (including glass, plastics, rubber or other waste) and when such pollution is found it requires adequate measures to be taken.

Figure 10: European Directives relevant to marine litter and domains they target across the life cycle of plastics and waste



Source: Deltares

3. Plastic packaging and small non-packing waste in Europe

KEY MESSAGES

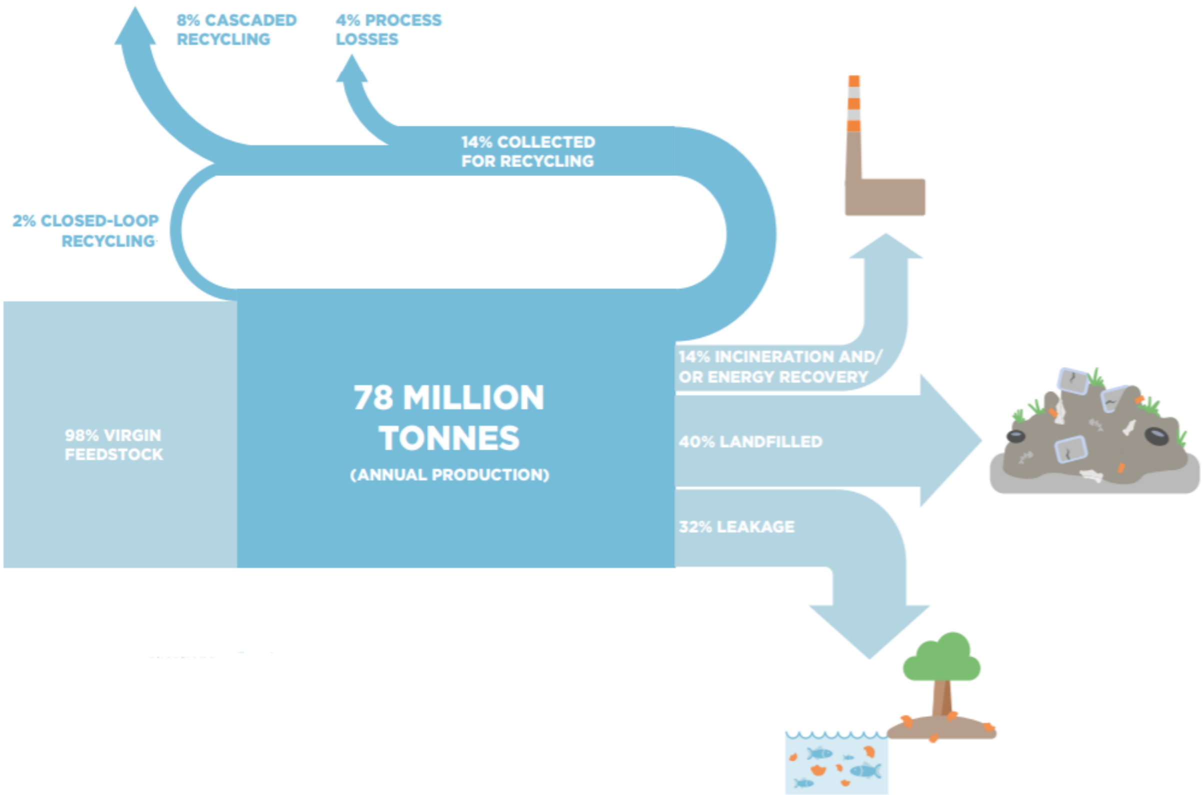
- Plastic packaging composes the most significant fraction of the plastic waste stream in Europe (around 60 %), reflecting the most important application of plastics produced, its single-use nature and the fact that it turns to waste very quickly, compared to other applications.
- The assessment focuses on mismanaged plastic packaging and small non-packaging plastic items (PPSI) waste in 32 EEA countries + UK, as this fraction of plastic waste is the origin of a large portion of marine plastic litter originating from land-based sources.
- The assessment results indicated that, in 2018, compared to 2012, the amounts of PPSI waste generated have increased in most countries.
- The management of plastic waste, particularly the PPSI fraction, has improved in many countries over the past decade, mainly thanks to the EU Packaging and Packaging Waste Directive.
- The share of mismanaged PPSI waste in the 32 EEA countries + UK ranges from minimal values of 2 % to almost 50 % of the total PPSI waste generated.
- Significant improvements are evident in terms of waste management but not sufficient to offset the increase in pressure of plastic waste generated: in several countries, the percentage of mismanaged PPSI waste decreased relative to the amount of PPSI waste generated. Yet, when looking at absolute amounts, only eight countries effectively decreased their amounts of mismanaged PPSI waste in 2018, compared to 2012. Nevertheless, such improvements are due to improved waste collection coverage and programmes against illegal dumping and poorly managed landfills.
- The total amount of mismanaged PPSI waste in the 32 EEA countries + UK increased by 3.8 % from 2.90 to 3.01 million tonnes between 2012 and 2018. In most the countries (25 out of 33), the absolute amount of mismanaged PPSI waste has increased. This is mainly due to a growth in PPSI waste generation, which could not be counteracted by improved waste management.
- Although many EU Member States report high recycling rates for plastic waste, a significant amount of this plastic is exported to developing countries for recycling, where the rejects can end up in waterways and the ocean.
- In this context, it seems fundamental to strengthen further the waste hierarchy principles, where waste prevention should take priority. Moreover, the waste management infrastructure, policies and economic instruments, mainly the Producer Pays Principle as anchored in the EU Packaging and Packaging Waste Directive, including monitoring and enforcement, are highly important. People's behaviour plays a critical role in littering or inadequate waste disposal.
- Data gaps and significant uncertainties require several assumptions to quantify mismanaged PPSI waste. For instance, good-quality data on land-based littering is generally not available.

3.1. Introduction

3.1.1. Plastic leakages from land-based sources

According to the Ellen MacArthur Foundation (2016), global plastic packaging material flows are largely linear, with only 14 % of plastic packaging collected for recycling and the large fraction (72 %) not recovered at all: 40 % is landfilled and 32 % can leak into the environment (Figure 11). In Europe, the flow of plastic packaging can be considered significantly *more circular*, with an average of a 41 % recycling rate reached by the EU-27 (data refers to 2019, from Eurostat, 2021c). Nevertheless, there is still an unaccounted amount of the plastic packaging waste that is mismanaged and, as such, can end up in the environment. This chapter attempts to address this knowledge gap.

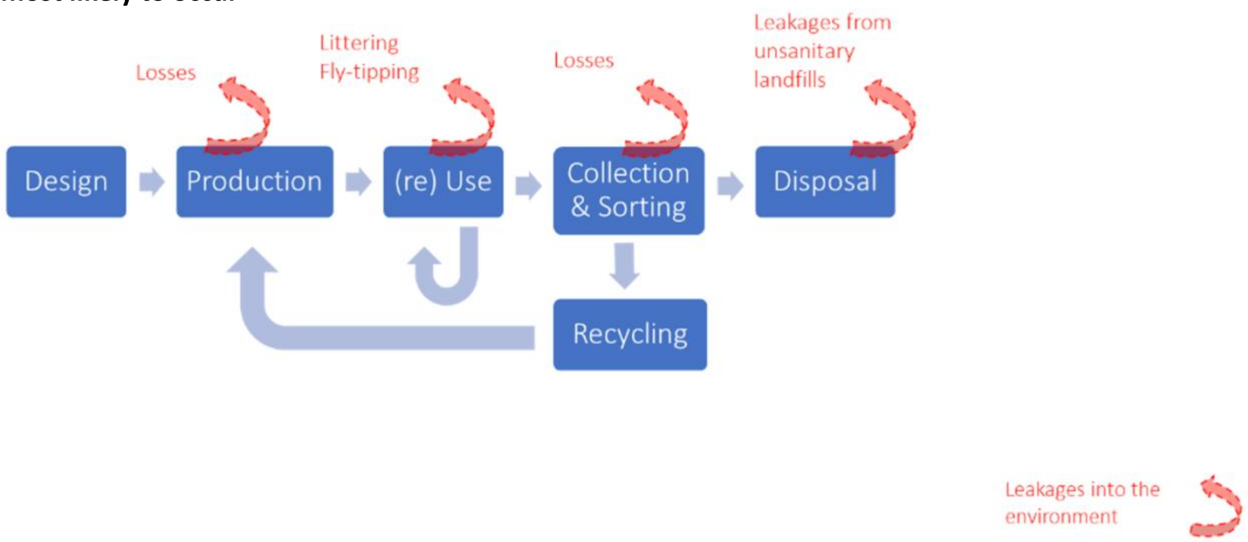
Figure 11: Production and fate of global plastic packaging placed on the market (2013)



Source: Ellen MacArthur Foundation, 2016

The primary points of plastic waste leakages from land-based sources to the environment stem from inappropriate management of waste, as well as littering/inappropriate disposal behaviour by citizens. The use-phase and the waste management phase are considered key stages in the plastics value chain where leakages that lead to marine litter occur (Figure 12) (UNEP, 2018) but the design phase is critical, as it influences later stages, namely to which extent the product will end up as waste or its recyclability.

Figure 12: Key phases in the plastics value chain and stages where leakages into the environment are most likely to occur



The most relevant land-based points of the leakage of plastics across the “use-phase” and “waste management phase” are summarised in Table 3. Littering occurs due to the inadequate waste disposal behaviour of citizens, usually shortly after usage, even in cases where waste management infrastructure is available. In some countries, however, there is still insufficient waste collection coverage, which means that parts of the population and businesses are not served by waste collection services. Therefore, a fraction of the waste generated remains uncollected. In addition, losses can occur during collection, transport, storage and treatment, e.g. overflowing waste bins, fly-off from sorting, separating, crushing, storage of light waste fractions, trucks or transfer stations. Even if a large share of waste is collected, it may not be managed adequately afterwards, and therefore bears a potential to end up in the environment. This is the case of unsanitary landfills (often landfills with permits, but not operating according to the conditions defined in the EU Landfill Directive), active dumpsites (usually not engineered and officially permitted, but known by local authorities) and / or illegal dumping activities (this refers more to fly-tipping, i.e. the illegal deposit of usually smaller amounts of waste onto land).

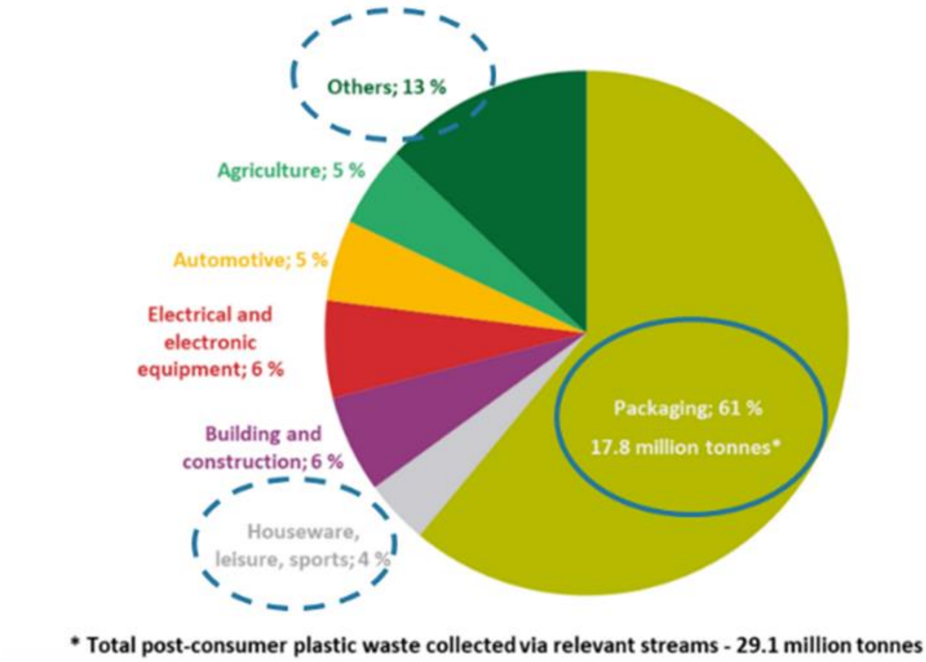
Table 3 Most important land-based sources of leakage of (macro)plastic across the waste chain and implications for the study (PPSI: plastic packaging and small non-packaging plastic items)

Stage in use / waste management phase	Source of leakage	Comments
Consumer disposal	**Littering** – Improper behaviour by consumers, despite existing infrastructure. Can be retained or not (e.g. cleaning of streets).	Very little information exists about littering rates. In this study, a 1 % littering rate (of PPSI waste generated) is assumed as default for countries with similar recycling rates as Austria (UBA-AT 2020). For other countries, a littering rate of 2 % was used when no better information is available (Jambeck et al., 2015).
Collection	**Uncollected waste** – Due to systematic insufficient waste collection coverage.	Country-specific: for EU Member States based on EEA – Eionet (2016), for non-EU based on World Bank (Kaza et al., 2018).
	Collection Loss – e.g. overflowing waste bins, fly-off from sorting, separating, crushing, storage of light waste fractions, trucks or transfer stations.	There is no data on losses during waste collection, transport, storage and treatment in Europe. In this study, a 1 % of PPSI waste generated as default loss is assumed.
Post-collection	**Unsanitary landfills, active dumpsites and / or illegal dumping activities**	In case of open infringement procedures by the European Commission (EC) regarding active dumpsites and / or poorly managed landfills and / or evidence, e.g. from NGOs that there are active illegal dumping activities, a default range of 1 – 10 % unless country-specific data are available.

3.1.2. Plastic packaging waste and small non-packaging plastic items as the focus of the assessment

Given the high fraction of application of plastics to packaging, it is not surprising that a large fraction of the plastic waste stream is composed of plastic packaging products, notably due to the short lifetime and single-use nature of these items, as compared to other applications. According to Plastics Europe (2019b), packaging represents 61 % of all plastic waste generated, while small non-packaging items represent 17 % of total plastic waste, i.e. household items, sports, leisure, medical and other (Figure 13).

Figure 13: Composition of the post-consumer plastic waste stream according to segments in 2018 (data from Plastics Europe, 2019b)



The assessment presented in this chapter aims to quantify mismanaged PPSI ([13]) waste in Europe as a potential land-based precursor of a large fraction of riverine and marine litter. Given the dominance of PPSI in post-consumer plastic waste, as well as in the reported plastic litter found on European beaches (Dahlbo, 2019, Addamo et al., 2017), we focus specifically on this specific fraction of plastic waste. Excluded are plastic wastes from agriculture, automotive, electrical and electronic appliances, and construction and demolition, as well as synthetic fibres/textiles, as these items have longer lifecycles and it would be somewhat more complex to model these waste streams and their management for each country.

3.1.3. Methodology

The assessment is done for each of the 32 EEA countries (27- European Member States, plus Norway, Iceland, Switzerland, Liechtenstein and Türkiye), and the UK ([14]). The results are analysed at the national level, computed for the coastal (NUTS3) units, which have been aggregated per regional sea.

The analysis included other non-European countries such as Russia and the Balkan states, for some outputs. For these countries, but also for EEA countries, namely Switzerland and Türkiye, that do not report packaging waste numbers to Eurostat, different data sources were used (see 3.1.3.1).

Material Flow Analyses (MFA) were performed for all individual countries and for two years – 2012 and 2018 – to compare the situation and any improvements in two points in time. These years define the first implementation cycle of the MSFD, while 2018 provided the most up-to-date datasets of reported EU waste data at the time this study was conducted.

The mismanaged PPSI waste is calculated according to the following general formula:

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[13] PPSI – Plastic packaging and small non-packaging plastic items

[14] The assessment period considered is prior to the UK’s withdrawal from the EU and UK data are therefore included

Mismanaged PPSI Waste =
UNCOLLECTED PPSI WASTE
(due to insufficient waste collection coverage)

+ COLLECTION LOSS
(due to overflowing waste bins, fly-off from sorting, separating, crushing, storage of light waste fractions, trucks or transfer stations) ([15])

+ LITTERING ([16])
+ PPSI COLLECTED BUT DISPOSED OF IN NON-SANITARY MANNER
(in case of the presence of unsanitary landfills, active dumpsites and / or illegal dumping activities) ([17])

All packaging put on the market and packaging waste generated in a country are covered, whether it originates from industries or any other sectors (Eurostat, 2021b). The packaging data for each EU country were used as reported to Eurostat (2021b), while the small non-packaging plastic items were added with a 17:61 ratio ([18]) (Plastics Europe, 2019b) to obtain the total relevant amount of generated PPSI waste. For non-EU countries, which do not have to report on packaging waste, the known plastic share present in total MSW with the 17:61 ratio was used to calculate the amounts of PPSI waste generated. The share of mismanaged PPSI waste is calculated using the share of MSW which is uncollected plus collected but mismanaged, based on World Bank data (Kaza et al., 2018).

Data gaps and uncertainties required several assumptions to quantify mismanaged PPSI waste. Country-specific data on plastic packaging waste, recycling rates and general information on waste management were used (see Annex 3). The main differences with other key studies that used or estimated mismanaged plastic waste (MPW) are discussed in Annex 1.

For detailed information about the methodology, data sources, assumptions and uncertainties, please refer to Annex 2.

3.1.3.1. Data sources

The main data sources used for the assessment are listed below.

- **Data on plastic production and demand segments and share of plastics in residual waste**: Plastics Europe (2013, 2019a, 2019b);
- **Data on plastic packaging placed on the market, plastic packaging waste generated, recovered and recycled** (as reported under the EU Packaging and Packaging Waste Directive): Eurostat (2019, 2020,

[15] Default 1 % of generated waste

[16] Default 1 % for countries with similar waste management systems as Austria (UBA-AT, 2020), for all others default 2 % (Jambeck et al., 2015).

[17] In case of open infringement procedures by the European Commission regarding active dumpsites and / or poorly managed landfills and / or evidence, e.g. from NGOs that there are active illegal dumpsites, a default range of 1–10 % unless country-specific data available.

[18] 61 % of total plastic waste is assumed to be plastic packaging waste and 17 % small non-packaging plastic items based on Plastics Europe (2019b).

2021a, 2021b, 2021c). Plastic packaging data account for all packaging, whether it originates from industrial or commercial sources, offices, shops, services, households or any other entities;

- National Producer Responsibility Organisations and Extended Producer Responsibility Schemes or deposit schemes (a country-specific example is provided in Annex 3);
- **Waste collection coverage**: data on collection of MSW were based on country profiles on the management of municipal waste — Eionet Portal (europa.eu) (EEA – Eionet, 2016) and assumed the same for PPSI waste;
- **Data sources on littering**: UBA-AT 2020, Jambeck et al., 2015;
- **Data sources on the situation of landfills and illegal dumping**: EC database with information on infringement procedures (European Commission, 2021), media (e.g., Cypriumnews, 2019) and / or researchers (e.g., Kubásek, 2011) (country-specific, see Annex 3);
- **Landfills:** Landfilled postconsumer plastic waste – Plastics Europe (2013, 2019); EEA / ETC WMGE Early Warning Reports and current information received from the questionnaires in preparation of the next early warning report;
- **Data for non-EU countries:**
    - **MSW generation and collection coverage in non-EU countries**: World Bank database (2018);
    - **PPSI waste**: calculated based on the share of plastics in MSW based on World Bank data, using an average value of 12 % for high-income and upper middle-income countries and a share of 10 % for low-income countries (assuming 50 % uncertainty). 80 % of this is assumed to represent PPSI waste;
    - For Türkiye, plastic waste imported in 2012 and 2018 was incorporated in the MFA (based on data from TÜIK- Türkiye İstatistik Kurumu ([19])).
- **Population in NUTS3 regions**: Eurostat indicator "Population on 1st January – total", from the dataset "Population change – Demographic balance and crude rates at regional level (NUTS3) [demo_r_gind3]" by NUTS3 (see Section 6.1.2);
- **Population share in catchment areas**: EEA population grid 1x1 km (Hermann Peifer methodology), based on Landscan Global Population 2008 dataset; the dataset provides the basis for calculating the sum of population by river catchments (see Section 4.2.1); and NUTS3 (see Section 6.1.2) for the units not covered by the Eurostat indicator (see details in Annex 2).

3.2. Plastic packaging and small non-packaging plastic waste generated across Europe

3.2.1. Total amounts of PPSI waste generated

In Figure 14 the results for the estimated total amounts of PPSI waste generated are displayed for 2012 and 2018. The difference between the two years, through an index of change, is depicted in Figure 15. Only in six countries (UK, Luxemburg, Switzerland, North Macedonia, Serbia and Ukraine), the total amounts of PPSI waste generated decreased in 2018, compared to 2012. In most (29) countries the amounts of PPSI waste generated increased by more than 10 % as compared to 2012 levels; in 13 countries by more than 20 %; in 9 countries more than 30 %; and in 4 countries there was an increase of more than 40 %, with Ireland showing an increase of over 50 %.

[19] https://data.tuik.gov.tr/Bulten/Index?p = Municipal-Waste-Statistics-2018-3066

Figure 14: PPSI waste generated (tonnes/year) in 2012 (left) and 2018 (right) in the 32 EEA countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)

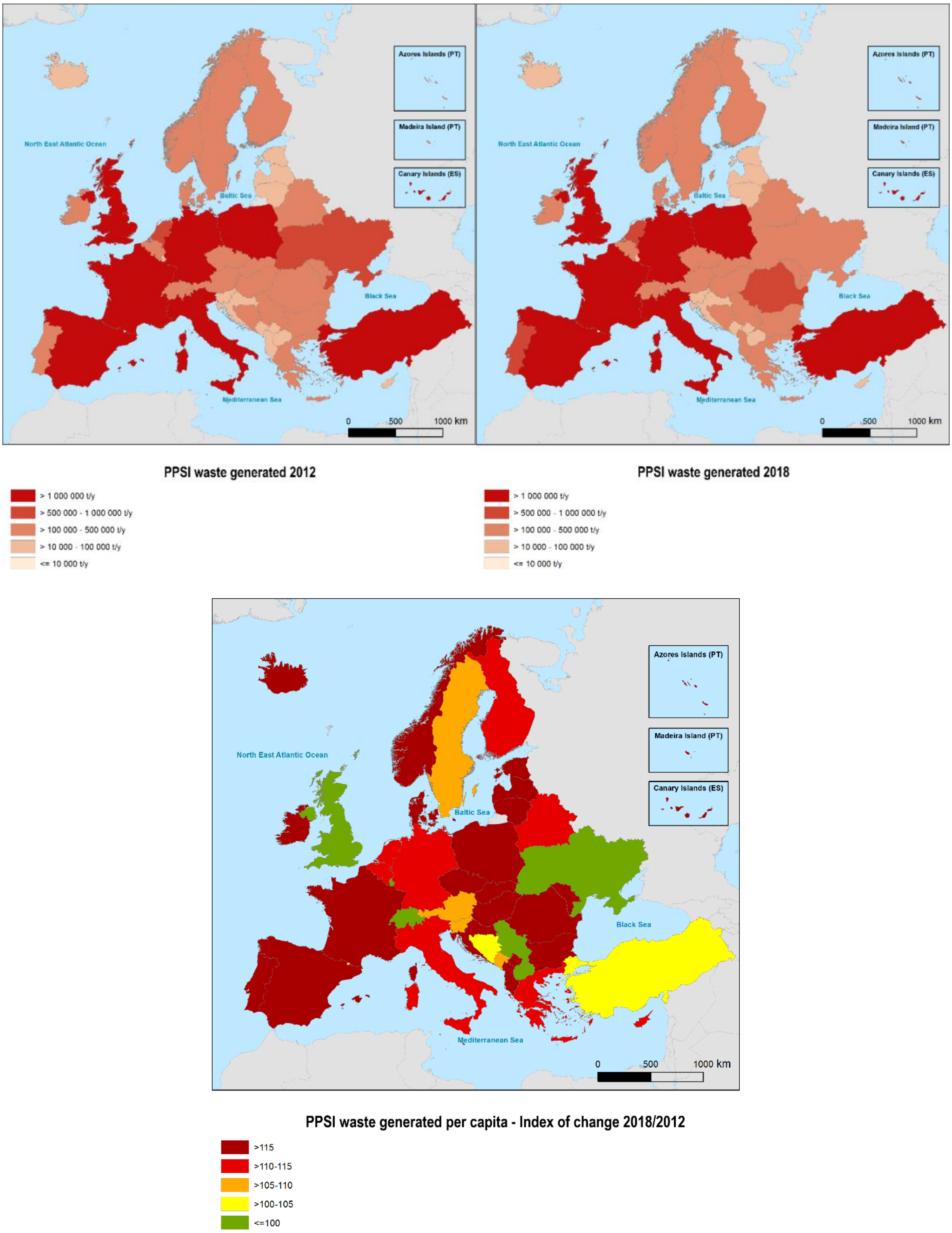
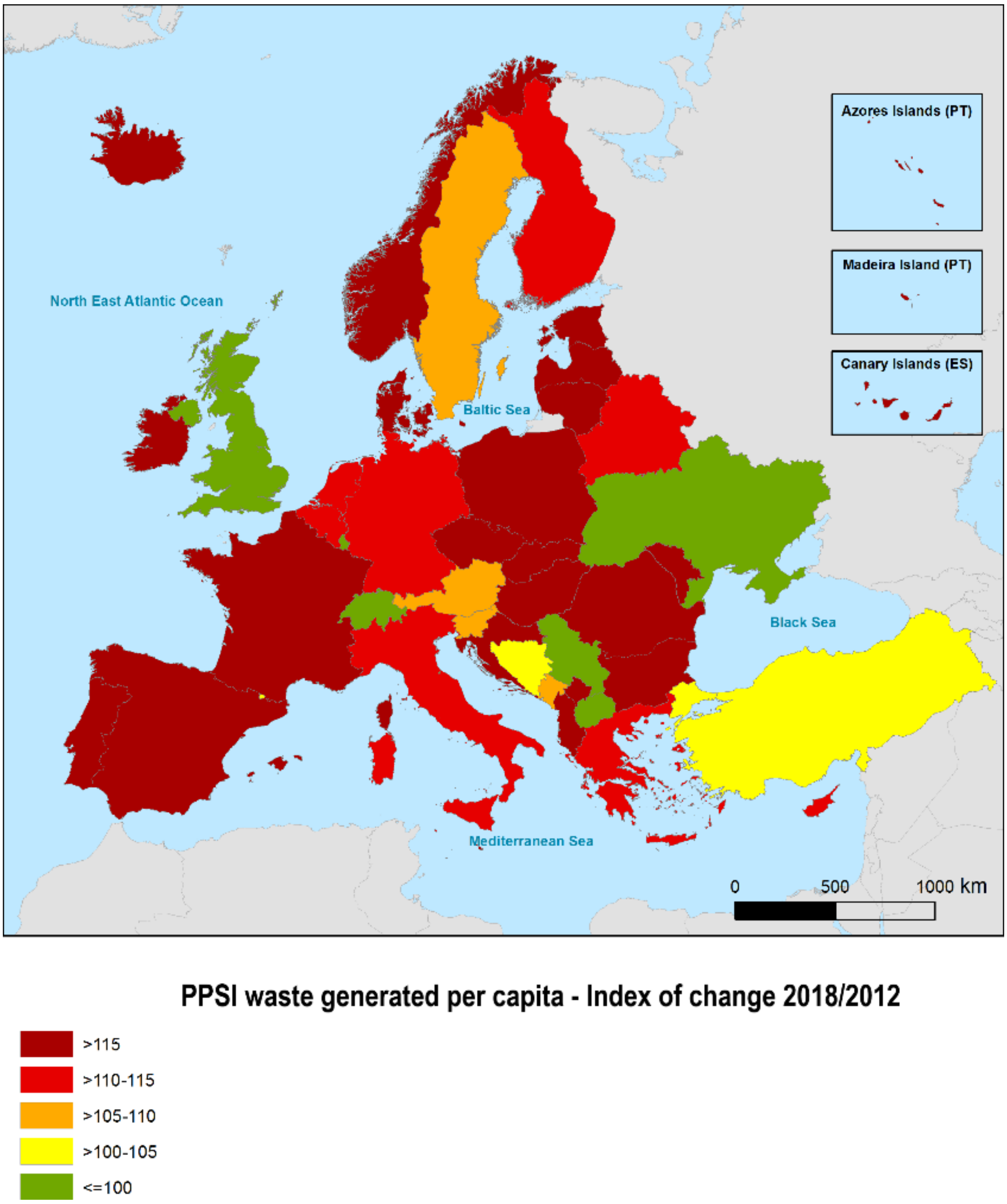


Figure 15: Index of change of PPSI waste generated (total amount, in weight) for 2018, in relation to 2012, in the 32 EEA countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)



3.2.2. PPSI waste generated per capita

The PPSI waste generated per capita varies widely between countries, from 20 kg (Croatia) to 69 kg per capita (Ireland) estimated for 2018. Overall, Western European countries tend to generate more PPSI waste per capita than Eastern European countries do. With a few exceptions (namely Switzerland, Luxembourg and the UK), a general increase in PPSI waste generated is also visible in terms of amounts generated per capita, compared to 2012 (see Figure 16 and Figure 17). Considering the whole EEA 32 + UK region, a citizen generated on average of 38.7 kg of plastic waste in 2012, while in 2018 it generated 42.9 kg per capita.

Detailed results of the estimated PPSI waste generated in 2012 and 2018 for the countries assessed are provided in Annex 3.

Figure 16: PPSI waste generated (kg per capita) in 2012 (left) and 2018 (right) in the 32 EEA countries +UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)

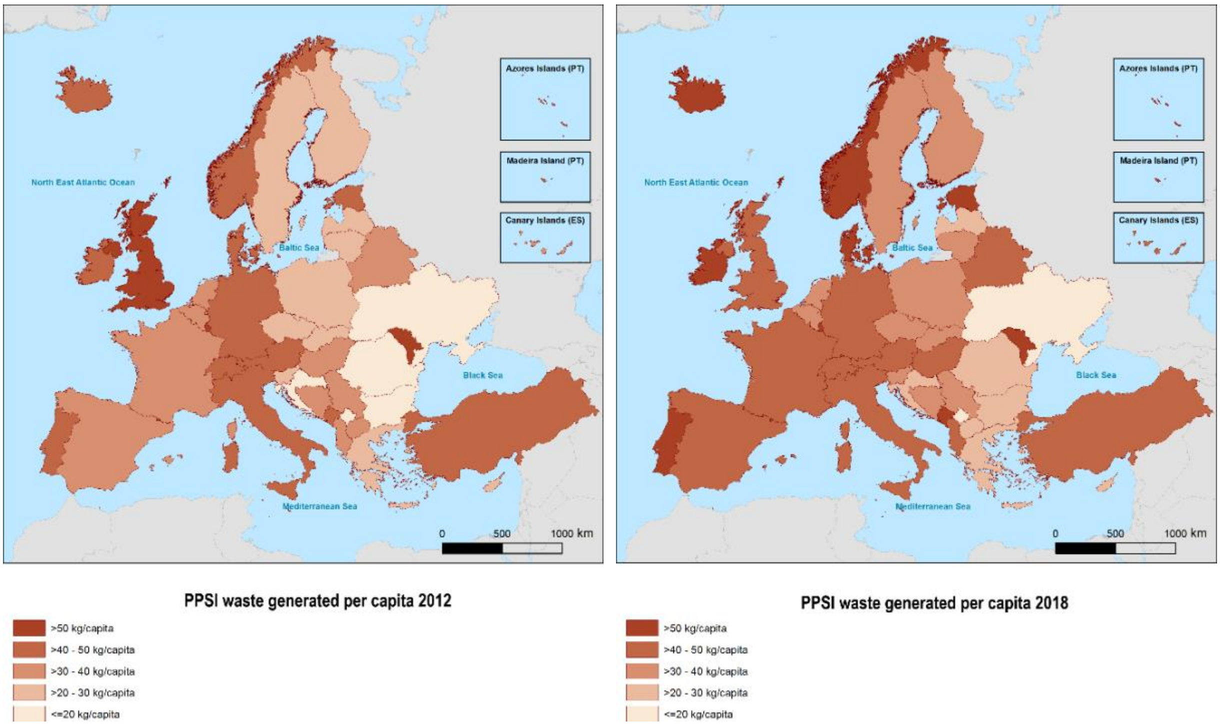
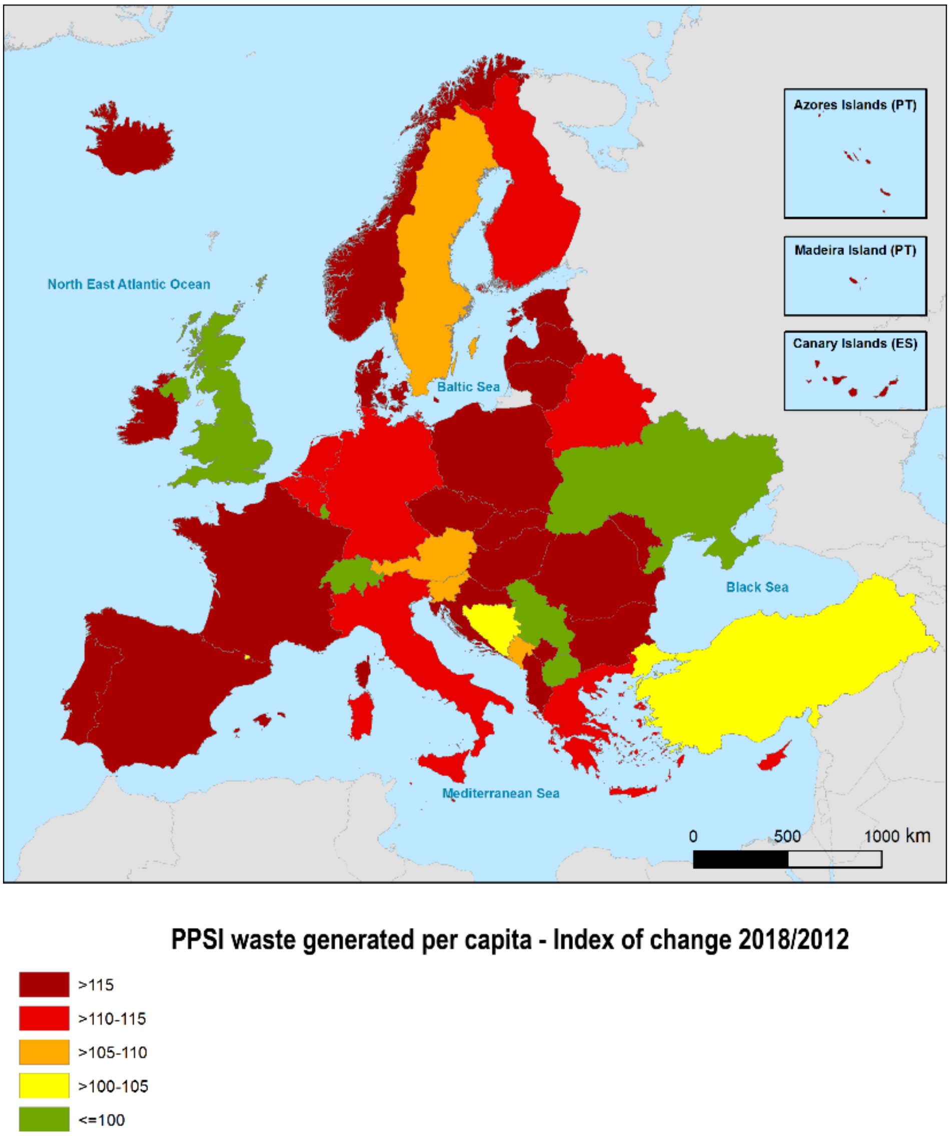


Figure 17: Index of change of PPSI waste generated per capita for 2018, in relation to 2012, in the EEA 32 countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)



3.3. Mismanaged plastic packaging and small non-packaging plastic waste across Europe

As a result of inadequate waste management and littering behaviour, a fraction of the PPSI waste generated will be mismanaged and, as such, be susceptible to ending up in the environment. This section presents the results of the quantities of mismanaged PPSI waste estimated for 2012 and 2018 for the EEA 32 countries + UK.

Detailed results of the estimated mismanaged PPSI waste in 2012 and 2018 for the countries assessed are provided in Annex 3.

3.3.1. Share of mismanaged PPSI waste

Figure 18 shows the mismanaged PPSI waste estimated for 2018, as a national amount per capita, and the index of change in relation to 2012. In Figure 19 the share (%) of mismanaged PPSI waste in relation to PPSI waste generated are presented for 2102 and 2018. Both the figures indicate clear regional differences, with Eastern and Southern countries generally presenting higher shares of mismanaged PPSI waste.

Figure 18: Mismanaged PPSI waste per capita in 2018 (left) and index of change in relation to 2012 (right) in the 32 EEA countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)

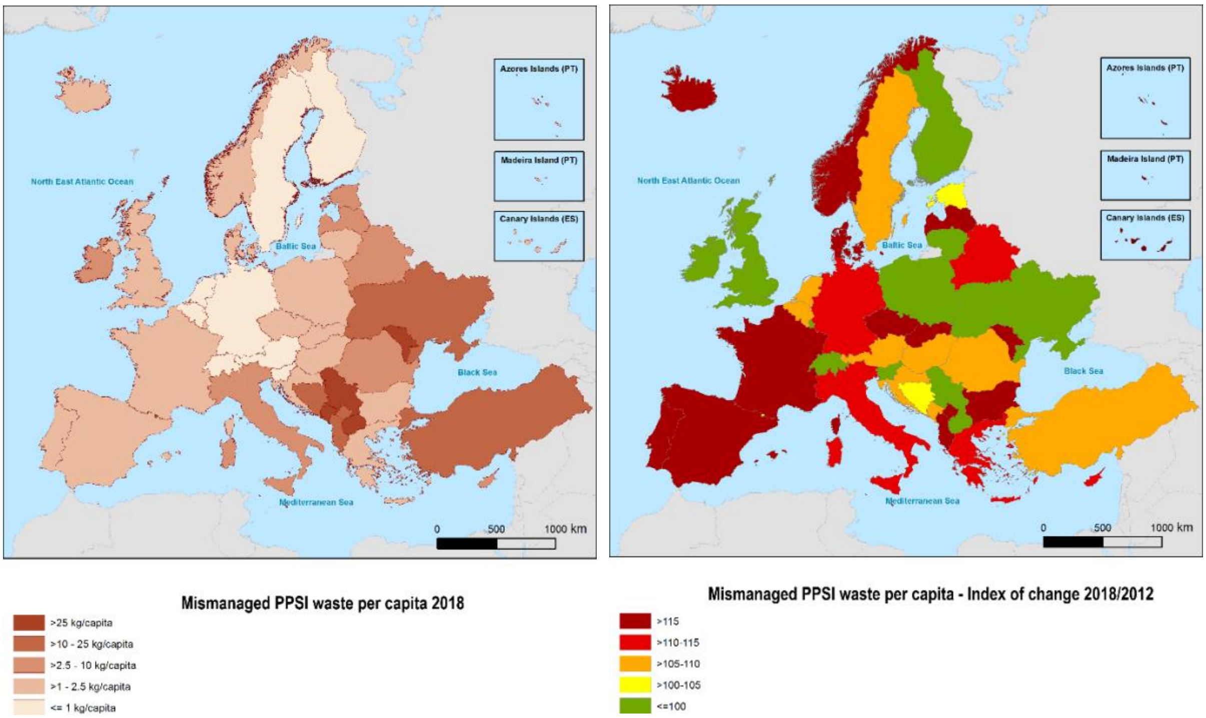
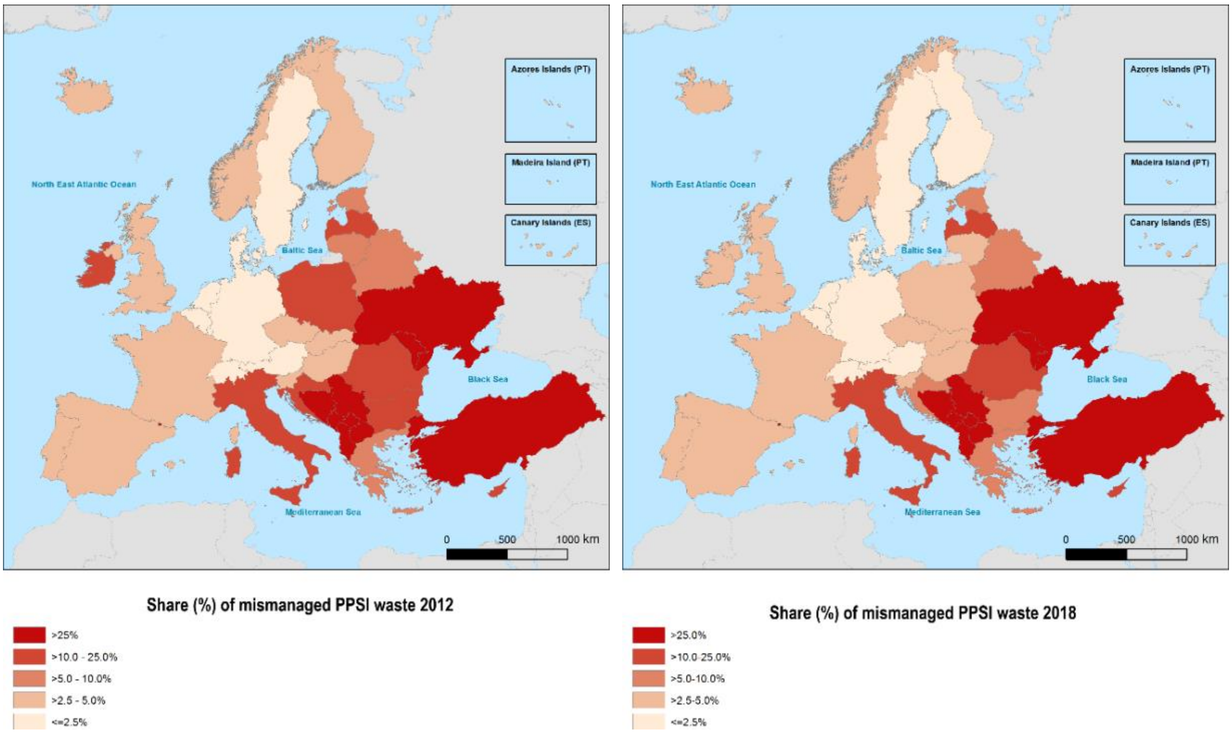
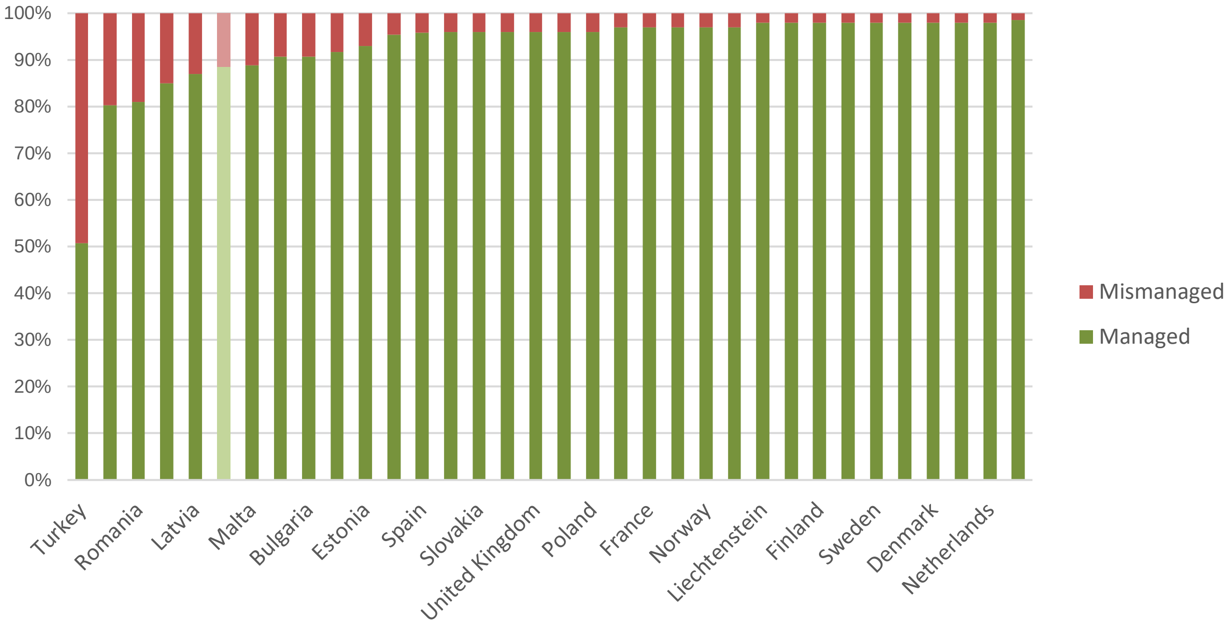


Figure 19: Share of mismanaged PPSI waste (% of total PPSI waste generated) for 2012 (left) and 2018 (right) in the 32 EEA countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)



These results show that, in 2018, the share of mismanaged PPSI waste, in relation to the total PPSI waste generated, varied widely among the EEA countries, from 2 % to 49 %, as shown in Figure 20. Comparing with the situation in 2012, it can be observed that several countries managed to reduce their share of mismanaged PPSI waste. In some cases these reductions have been significant, as it is in the cases of Poland, Ireland, Lithuania, Finland, Slovenia and Croatia (Figure 21). This is mainly due to improved waste collection coverage and/or programmes against illegal dumping and poorly managed landfills. In most countries, however, the percentage of mismanaged PPSI waste remained relatively unchanged in relation to 2012.

Figure 20: Share (%) of mismanaged PPSI waste in relation to total PPSI waste generated in 2018 in the EEA 32 countries + UK (PPSI: plastic packaging and small non-packaging plastic items)

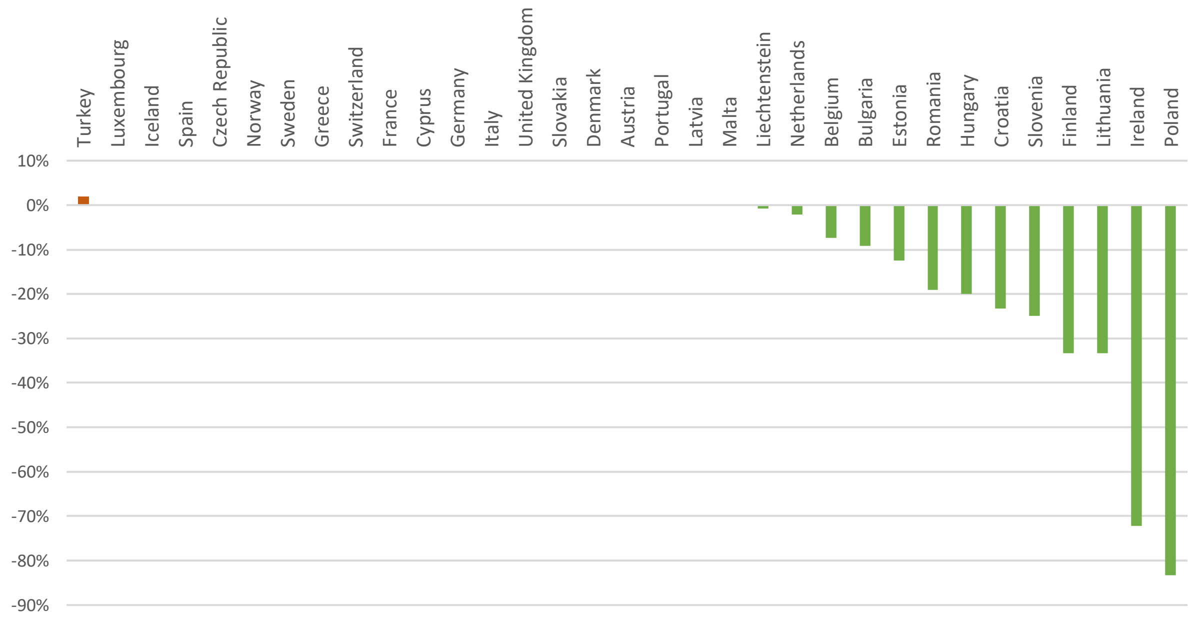


In Türkiye the share of mismanaged PPSI waste in 2018 is higher compared to 2012, even with improvements in the waste collection coverage, that led to a decrease in the share of uncollected waste from 23 % in 2012 to 12 % in 2018. Nevertheless, according to the World Bank (Kaza et al., 2018), 45 % of collected MSW is mismanaged due to poor/illegal landfills and a strong informal sector ([20]). The results obtained, however, may have been influenced by a shift in the destinations for exported plastic waste from Europe, since the importation of plastic waste was accounted for in the MFA of Türkiye for 2012 and 2018.

This raises attention to the implications of exportation of plastic waste by other European countries. Although many EU Member States report high recycling rates for plastic (packaging) waste, it must not be forgotten that significant amounts of plastic waste are exported to developing countries for recycling, where the rejects can end up in waterways and the ocean (Bishop et al., 2020). In 2015 and 2016, up to 300,000 tonnes of plastic waste have been exported monthly to China and Hong Kong, primarily (EEA, 2019). After China introduced a ban on plastic waste imports in 2017, exports have shifted to other countries, namely Malaysia and Türkiye. Note that in response to the exportation shift, Türkiye banned the import of certain plastic waste, and strengthened import controls for other plastic in 2021 (Ministry of Trade of the Republic of Türkiye, 2020).

[20] The Turkish Ministry of Environment and Urbanisation states that there have been substantial improvements in waste management and recycling capacities, especially after 2019.

Figure 21: Change in the share of mismanaged PPSI waste in 2018, compared to the levels in 2012, in the EEA 32 countries + UK (PPSI: plastic packaging and small non-packaging plastic items)



3.3.2. Total amounts of mismanaged PPSI waste

Figure 22 and Figure 23 show the estimated amounts of mismanaged PPSI waste for 2018 in tonnes/year and how it compares to the amounts in 2012. The overall total amount of mismanaged PPSI waste in the assessed area increased by 3.8 %, from 2.90 million tonnes in 2012 to 3.01 million tonnes in 2018. This results from the increase in the amount of mismanaged PPSI waste in most individual countries (27 out of 33) in 2018, compared to 2012. Such an increase seems to be mainly driven by higher amounts of PPSI waste generated in 2018, which could not be fully compensated by improvements in waste management.

Only six countries show a reduction in the absolute amounts of mismanaged PPSI waste in 2018. In Poland, Ireland, Slovenia, and Lithuania this is mainly due to improved collection coverage and / or programmes against illegal dumping and enhancement in landfill management. In the UK, it is due to a combination of reduction in the overall generation of PPSI waste, illegal dumping and poorly managed landfills (EEA – Eionet, 2016). In Finland, this was likely due to the implementation of preventive actions to reduce leakages from waste management operations (Dahlbo, 2019).

Figure 22: Total mismanaged PPSI waste (tonnes/year) in 2018 (left) and index of change in relation to 2012 (right) in the 32 EEA countries + UK and other non-EU countries (PPSI: plastic packaging and small non-packaging items)

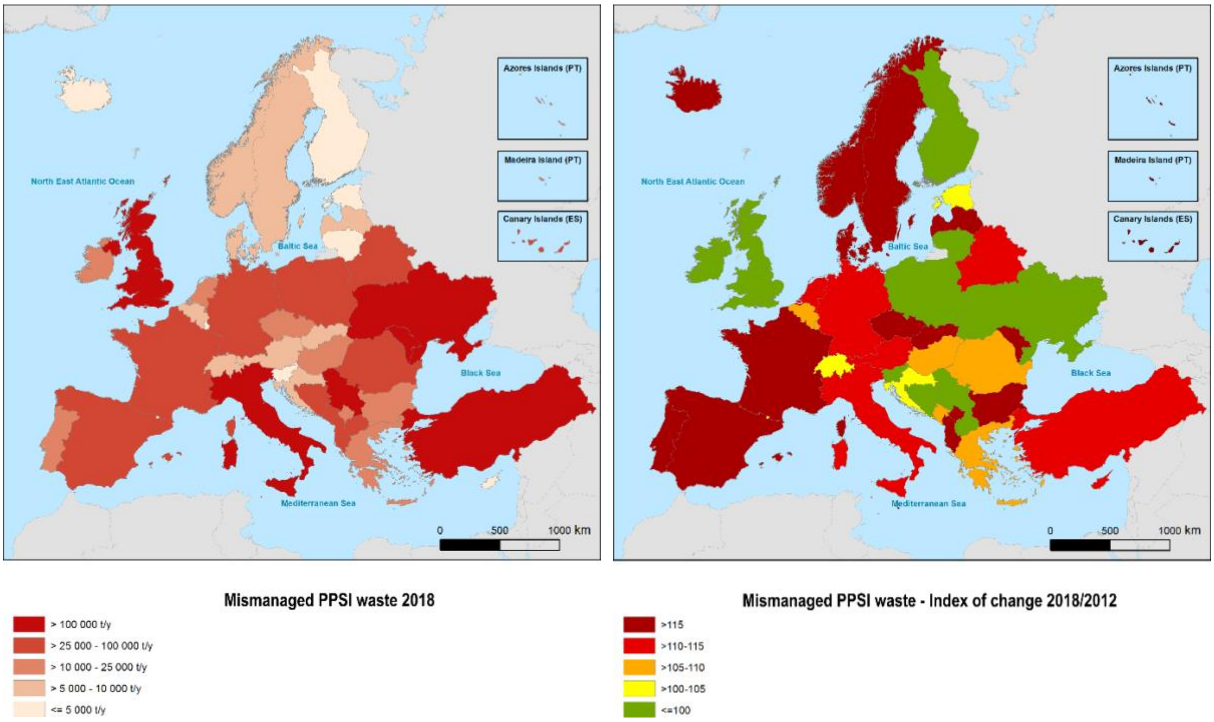
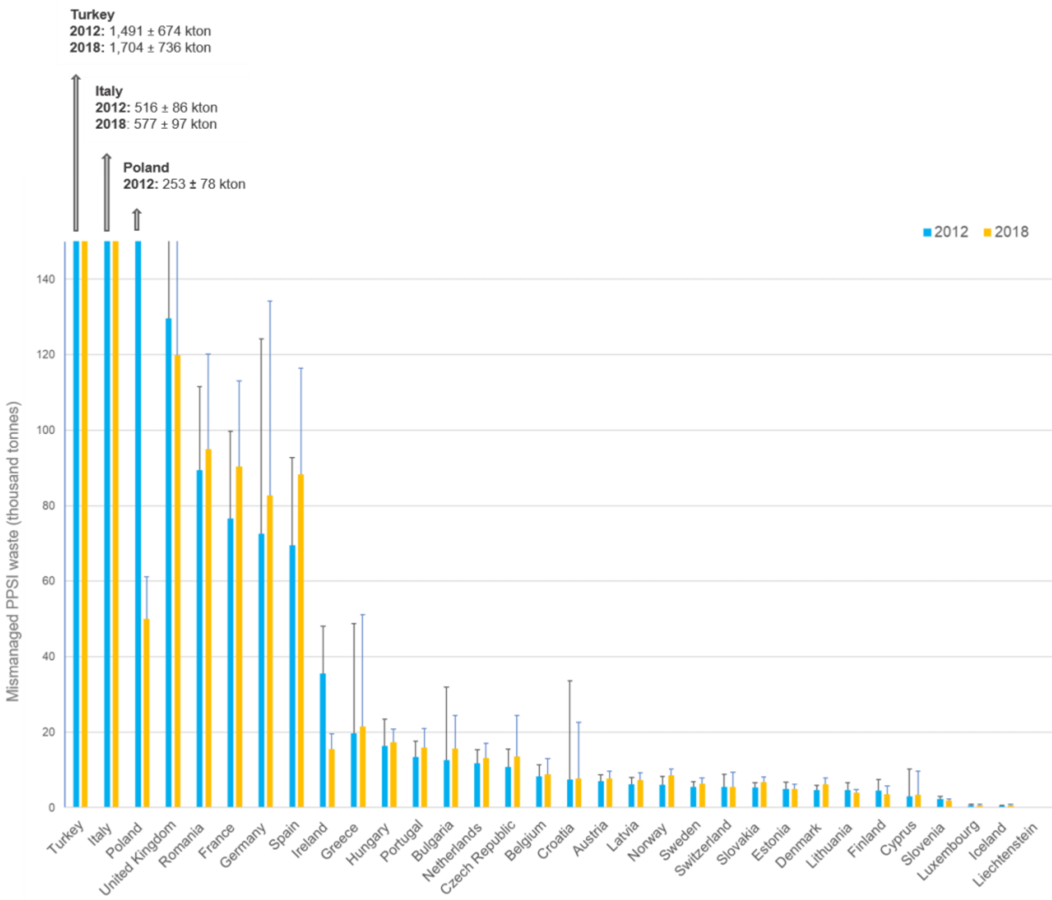


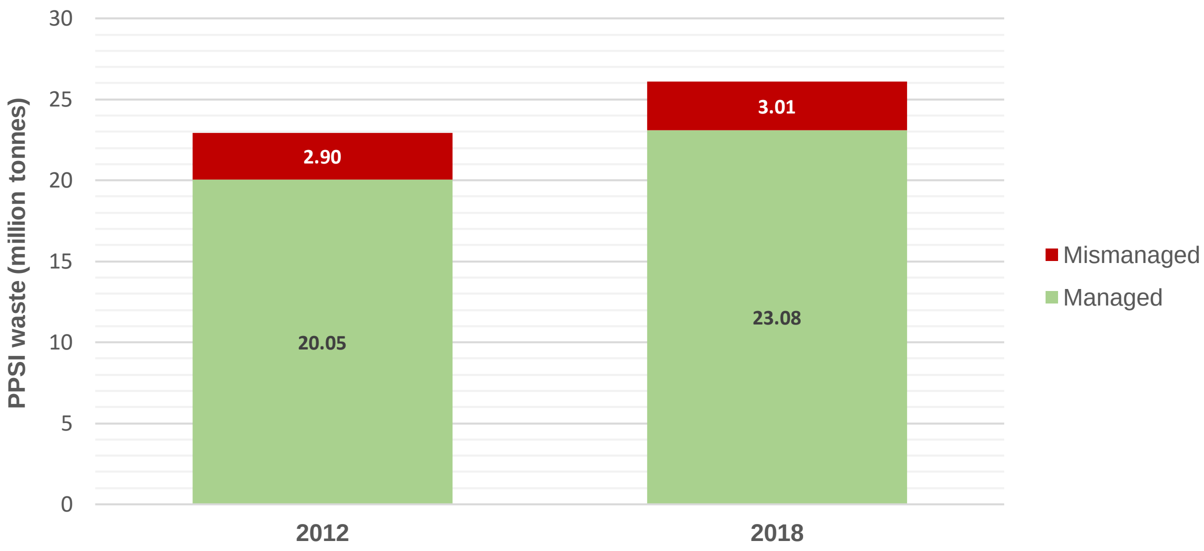
Figure 23: Total amount of mismanaged PPSI waste (thousands of tonnes, kton) in 2012 (blue bars) and 2018 (yellow bars) in the EEA 32 countries + UK. Uncertainties are represented in the bars. Note the difference in the scale for Türkiye, Italy and Poland (PPSI: plastic packaging and small non-packaging items)



In Figure 23 the uncertainties associated with the estimates of mismanaged PPSI waste are also displayed. In most countries these uncertainties have been reduced, when comparing the outputs of 2018 with 2012. This can be explained by more accurate reporting on packaging materials put on the market, and hence packaging waste generated. In general, the uncertainties linked to the reporting of packaging waste can be very high, dominating the other uncertainties linked to the estimations of mismanaged PPSI waste.

Despite the improvements in reducing the fraction of mismanaged PPSI waste in relation to PPSI waste generated and managing appropriately higher amounts of plastic waste, only a limited number of countries managed to effectively reduce the overall amount of mismanaged PPSI waste in 2018, compared to 2012. In fact, when considering the aggregated EEA 32 countries and the UK, the estimated total amount of mismanaged PPSI waste was 110 thousand tonnes higher in 2018 than in 2012 (3.01 and 2.90 million tonnes, respectively) (Figure 24). Considering the significant increase in PPSI waste generated, from 22.94 in 2012 to 26.09 million tonnes in 2018, this means, nevertheless, that countries are channelling higher proportions of their packaging waste to adequate end-of-life options. It also means that reducing the pressure at the level of plastic waste generation could lead to significantly less mismanaged PPSI waste with the current waste management performances.

Figure 24: Total amounts of generated PPSI waste (million tonnes) that is managed (green) and mismanaged (red) in the overall EEA 32 countries + UK, in 2012 and 2018. (PPSI: plastic packaging and small non-packaging plastic items)



4. From land into the sea – riverine litter

KEY MESSAGES

- Riverine plastic litter remains understudied compared to plastic pollution in the marine environment. Rivers as pathways of the transport of plastic pollution into the sea, including plastic mobilisation, accumulation and degradation and the role of river catchment characteristics and transversal barriers (weirs, dams) are poorly understood. Empirical data on monitoring riverine plastic loads and emissions are generally scarce.
- On a global scale, Asian watercourses disproportionately contribute to plastic emissions from rivers into the sea, amounting to 86 % of overall riverine plastic input. Europe's share of macroplastic litter coming from rivers is 1.1 % to 3.8 % globally.
- A recent study estimated that annually 626 million floating items enter the European regional seas from 32 EU and Eurasian coastal countries via rivers. This amounts to an annual loading of 3,382 tonnes of litter per year. Several high-income European countries are among the largest contributors.
- With over one-third of the total amount, the Mediterranean Sea receives the largest share of riverine floating litter. With almost two-thirds, river mouths in the Black Sea contribute the largest share relative to the number of emission points.
- The level of uncertainty related to both measurement and modelling of litter transport in riverine systems is still great. Methodologies and reported units should be better standardised, as these vary widely across assessments, hampering the comparison and ultimately, the synthesis of data.
- Limited reliability associated with the underlying waste management data used in many studies that attempt to quantify leakages of waste or plastic litter into the sea lead to high uncertainties and significant differences between these studies. Existing studies that estimate riverine emissions of (plastic) litter into European regional seas differ in the type and size of particles covered and use the rates of mismanaged waste that originate from non-European data sources. This hinders the comparison and integration with the estimations of mismanaged PPSI waste obtained in this report.

4.1. Introduction

4.1.1. Description of the river pathway

Rivers serve as connectors to other aquatic ecosystems such as downstream lakes and the coastal environment and act as important pathways of plastic pollution to the marine environment. Yet, the transport and fate of riverine litter remains understudied in comparison to marine plastic litter. This information gap emphasises the urgency to increase the global knowledge on plastic pollution in freshwater ecosystems (Winton et al., 2020; Lebreton et al., 2017; van Emmerik and Schwarz, 2019; Schirinzi et al., 2020). In the following, the knowledge on sources, transport and emissions of plastic macrolitter is summarised from the existing scientific literature.

4.1.1.1. Main emission sources

Lebreton et al. (2017) estimated that ~3–19 % of the coastal plastic emissions globally are river-borne and ~0.8–1.5x10^6 t/year reach the ocean from inland areas through rivers. The amount of river plastic emission shows a high correlation with population density, urbanization, wastewater treatment and waste management within the river catchment. Plastic waste enters the river system through either natural transport processes or direct dumping. Case-studies identified visitors as the most likely sources of litter for the main German rivers such as the Rhine, Weser and Elbe (Kiessling et al., 2019). Additional ways for plastic entering the river include wastewater discharge, inland navigation, industrial activities, leakage from flooded landfills, leakage of land-based plastic waste by urban runoff and wind, and discharge through urban streams (van Emmerik and Schwarz, 2020; Al-Zawaidah et al., 2021; Schmidt et al., 2017; Liro et al., 2020; Meijer et al., 2021; González-Fernández and Hanke, 2017).

4.1.1.2. The river pathway: transport, accumulation and degradation

The fate of plastic in freshwater systems is dependent on three processes: transport, accumulation/storage, and degradation (van Calcar and van Emmerik, 2019). Macroplastic transport begins when it starts to be moved by the river flow after its input into the river, or when stored macroplastic is remobilized by floodwater or bank erosion. After this, a part of the plastic item sinks to the river channel or strands at the riverbanks, and a part eventually reaches the river mouth. Vertical transport is determined by the characteristics of the plastic items such as buoyancy, density or shape. Objects with greater density than water are expected to be transported not only horizontally but also vertically, at a rate positively correlated with the object's density. Plastic items with larger surface-to-volume ratios are likely to sink due to more fouling organisms accumulating on the surface (Liro et al., 2020; Al-Zawaidah et al., 2021).

Accumulation (or storage) of plastic litter is induced by dams or weirs representing “transversal barriers” that block the transport of the litter items in river systems. These barriers may affect the variation of the river flow by changing the load of waste transported or by speeding up the litter transport away from the source. Further accumulation of plastic litter takes place in riparian vegetation, riverbed sediments or river floodplains. Plastic litter can be remobilized by the river flow or erosion processes (Schirinzi et al., 2020; Al-Zawaidah et al., 2021; González-Fernández et al., 2021; Liro et al., 2020).

Biochemical degradation and mechanical fragmentation are other processes that can affect the horizontal and vertical transport of plastic debris in riverine systems. Since degradation implies a decrease in size and an increase in surface area of the plastic items, horizontal transport increases with the decrease of macroplastic size. Additionally, vertical transport is influenced by the fouling and de-fouling rate as items change in size (Liro et al., 2020; van Emmerik and Schwarz, 2020; Al-Zawaidah et al., 2021). The rate of plastic degradation is dependent on exposure to UV radiation, biological degradation, mechanical erosion and exposure to temperature (Al-Zawaidah et al., 2021). Compared to the degradation rate of plastic at beaches, the river plastic litter is less susceptible to degradation (Al-Zawaidah et al., 2021; van Emmerick and Schwarz, 2020).

4.1.1.3. River catchment characteristics influencing plastic transport

Hydrological, morphological and climatic characteristics of the river basin influence the load, concentration, transport and fate of riverine plastic debris. Plastic debris transport is affected by hydrological factors such as water level, flow velocity and discharge. River discharge patterns shape sediment transport and determine bedforms including riffles and pools, the latter of which can act as locations trapping macroplastics. While high flow conditions result in rapid transport, plastic deposition is prevalent during low flow. Moreover, flood flows may lead to the accumulation of plastic debris in the floodplain. Morphological characteristics such as riverbank shape affect macroplastic transport, with riverbanks with high slopes will likely have less macroplastic deposition (Schmidt et al., 2017; Liro et al., 2020; van Emmerik and Schwarz 2020; Schirinzi et al., 2020; Al-Zawaidah et al., 2021). Climatic patterns such as wind and precipitation add seasonal variability to plastic waste transport. Heavy rainfall events, for instance, result in heavier loads of riverine litter (Schirinzi et al., 2020).

4.1.1.4. Unknown factors of the river pathway

Since the fate of macroplastics that end up in freshwater systems is still one of the largest unknowns in river plastic transport research, it is usually assumed that all plastics in rivers are likely to end up in the ocean. Additionally, very little is known about the transport processes of plastic debris in tidal zones. The influence of water management structures on the riverine pathway of plastic litter is poorly studied, including the role of dam functioning, reservoir levels, release mechanisms, coarse matter screening in hydropower plants, waste management and clean-up operations (van Calcar and van Emmerik, 2019; van Emmerick and Schwarz, 2020; González-Fernández et al., 2021; Al-Zawaidah et al., 2021). Ultimately, macroplastic storage and remobilization processes are overlooked in the literature but their understanding is fundamental for the assessment of the amount of plastic accumulated in the river system.

4.1.2. Current situation on river plastic pollution worldwide

On a global scale, Asian watercourses disproportionately contribute to plastic emissions from rivers into the sea, amounting to 86 % of overall riverine plastic input. Urban rivers in Southeast Asia and West Africa are the main hot spots for plastic emissions. The top 20 polluting rivers were mostly located in Asia, accounting for 67 % of the global annual input from rivers. This dominant contribution from the Asian continent might be due to a considerably high population density combined with relatively large plastic waste production rates, episodes of heavy rainfalls and high rates of mismanaged plastic waste production per inhabitant and country (Meijer et al., 2021; van Calcar and van Emmerik, 2019; Lebreton et al., 2017). Against the global estimates on riverine plastic litter emissions (0.8 to 2.7 million tonnes; Meijer et al. 2021), Europe's share of global plastic litter coming from rivers is estimated between 1.1 to 3.8 %.

4.1.3. Methodology

4.1.3.1. Data sources for Europe

River-borne emissions of litter into European Seas have been estimated by some studies, which established relationships of national mismanaged waste rates and available observation-data on litter transported by rivers. Using these relationships, litter rates entering the sea were extrapolated to estimate total amounts relevant for Europe or globally.

The two most recent studies of González-Fernández et al. (2021) and Meijer et al. (2021) have been selected for this report to inform on loads of litter coming from rivers into the European regional seas. A detailed comparison of the main characteristics of these two studies is provided in Annex 4.

González-Fernández et al. (2021) estimate floating macrolitter items discharged to the marine environment via rivers for Europe. The study includes modelled estimates for 32,561 drainage basins from 32 European Union and neighbouring Eurasian coastal countries. It is calibrated based on a harmonized data collection at the European scale, carried in 42 rivers and streams from 11 countries, developed by a collaborative network of research institutions and non-governmental organisations, and coordinated by the Joint Research Centre (JRC) of the European Commission.

Meijer et al. (2021) assess the global riverine macroplastic emissions into the oceans using most recent field observations and a newly developed distributed probabilistic model. The study includes a global dataset of 31,904 river mouth locations and their modelled emission estimates. The model has been calibrated and validated against 136 field measurements of monthly emissions of floating plastic from 67 different rivers.

4.1.3.2. Spatial Analysis

With the objective to derive the data on outflowing riverine litter by (a) MSFD marine region catchment and (b) river catchment, two main data components were needed for an overlay:

- point data on the outflowing riverine litter, located at river mouth; both floating macrolitter (FML) (González-Fernández et al., 2021) and Meijer et al. (2021) spatial data sets were used as the source;
- polygon data on the European sea and river catchments; the derived ECRINS ([21]) data set (produced by Globevnik et al., 2018) was used as the source; the data set includes all 1st stream order catchments larger than 1,000 km^2 that were within the spatial scope of the project – large parts of the Black Sea catchment are excluded; for catchments smaller than 1,000 km^2, only the river mouth polygon (defined in polygons of Functional Elementary Catchments – FEC) is available in the data set, but not the whole catchment;
- in addition, to correlate the quantity of outflowing litter with the upstream population, the EEA population grid 1x1 km (Hermann Peifer methodology), based on Landscan Global Population 2008 dataset, was used.

The following data processing steps were applied:

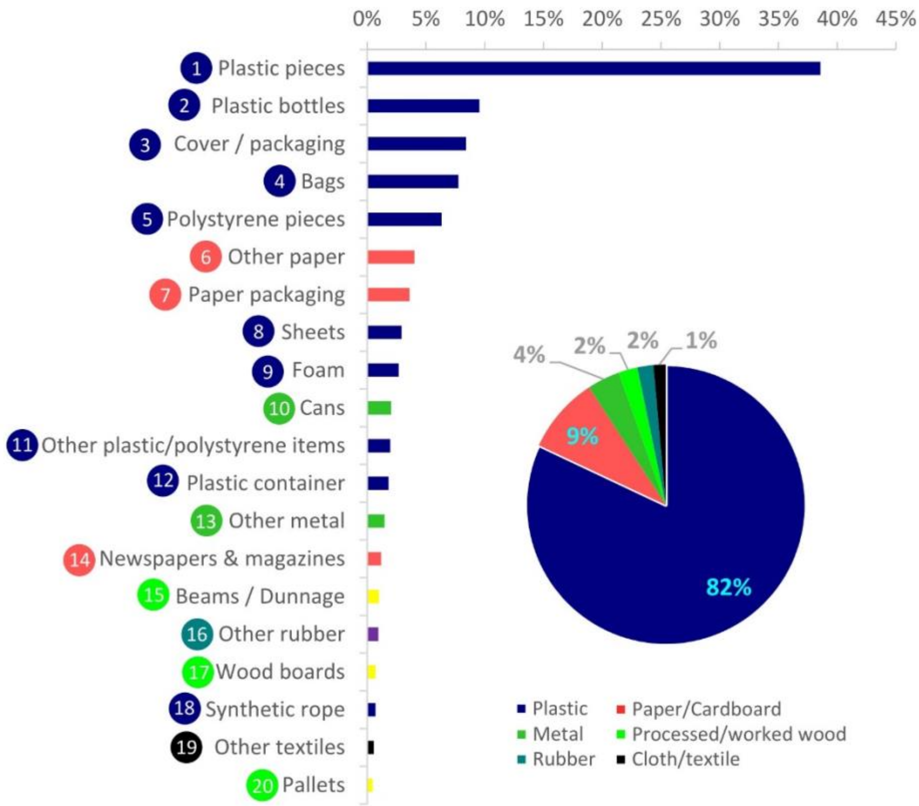
1. Overlay (a) FML points and (b) ECRINS 1st order catchments (Globevnik et al., 2018); the result is the value of floating macrolitter outflowing from each of the 443 catchments larger than 1,000 km^2, and 6,944 catchments smaller than 1,000 km^2; these results were also aggregated to the level of four MSFD marine regions, using a median-based approach;
2. Overlay (a) Meijer et al. (2021) points and (b) ECRINS 1st order catchments; the result is the value of floating macrolitter outflowing into each of the four MSFD marine regions, to support and compare the values produced under step 1;
3. Overlay (a) ECRINS 1st order catchments (Globevnik et al., 2018), (b) European countries (EEA, 2010) and (c) EEA population data grid; the result are the catchments intersected with countries, as the basis for calculating the contribution of each country to the total amount of litter outflowing through each catchment.

4.2. Riverine emissions of litter and plastic into the European seas

Based on comprehensive data observations of riverine FML across Europe, González-Fernández et al. (2021) estimated that annually 626 million floating items enter the European Seas (ranging between 307 and 925 million items). This amounts to an annual loading of 3,382 tonnes per year (ranging between 1,656 to 4,997 tonnes per year). One of the most recent global studies on macroplastic emissions from rivers, indicated that the top five contributing countries in Europe provided more than half of the riverine FML entering European sea basins. In terms of the items and materials contributing to the FML, plastic pieces were found to be most abundant (González-Fernández et al. 2021; Figure 25).

[21] Dataset "European catchments and Rivers network system (ECRINS)", available at https://www.eea.europa.eu/data-and-maps/data/european-catchments-and-rivers-network

Figure 25: Top riverine FML items and materials in European rivers shown as a fraction of the total (adapted from González-Fernández et al., 2021)



In contrast to the emission estimates for riverine floating macrolitter, the modelling study of Siegfried et al. (2017) assesses the river-borne influx of microplastic into the European Seas. The study calculated that in total about 14,400 tonnes of microplastics were exported from point-sources (e.g., household dust, laundry inputs, tyre wear) in the year 2000. Although this amount exceeds the estimates for floating litter by more than four times, it accounts for emissions from a larger set of countries, including non-EU countries bordering the Mediterranean Sea and Black Sea.

4.2.1. Assessment of riverine litter per regional sea's catchment area

González-Fernández et al. (2021) modelled the emissions from 32,641 river mouths across 32 European and Eurasian coastal countries into the four regional seas (Figure 26). With more than one-third, the Mediterranean Sea is receiving the largest share of FML, followed by the Black Sea and NEA. The Baltic Sea shows the smallest share of FML emissions (Figure 27A). Dividing the FML emissions by the number of river mouths into each of the four regional seas reveals the 'per-emission-point' proportions: With almost two-thirds, river mouths in the Black Sea contribute the largest share relative to the number of emission points (Figure 27B).

Comparing the amounts of FML stemming from small river catchments (< 1,000 km^2) close to the sea with the amounts of FML stemming from small river catchments (> 1,000 km^2) reaching farther inland, it is revealed that mainly the smaller catchments contribute to the majority of riverine litter entering the sea (Figure 28).

Figure 26: Spatial distribution of floating macrolitter (FML) from Europe into the sea based on modelled riverine input estimates across 32 European and Eurasian coastal countries. The coloured dots represent litter inputs predicted on the basis of the mismanaged waste in each individual drainage basin (adapted from González-Fernandéz et al., 2021).

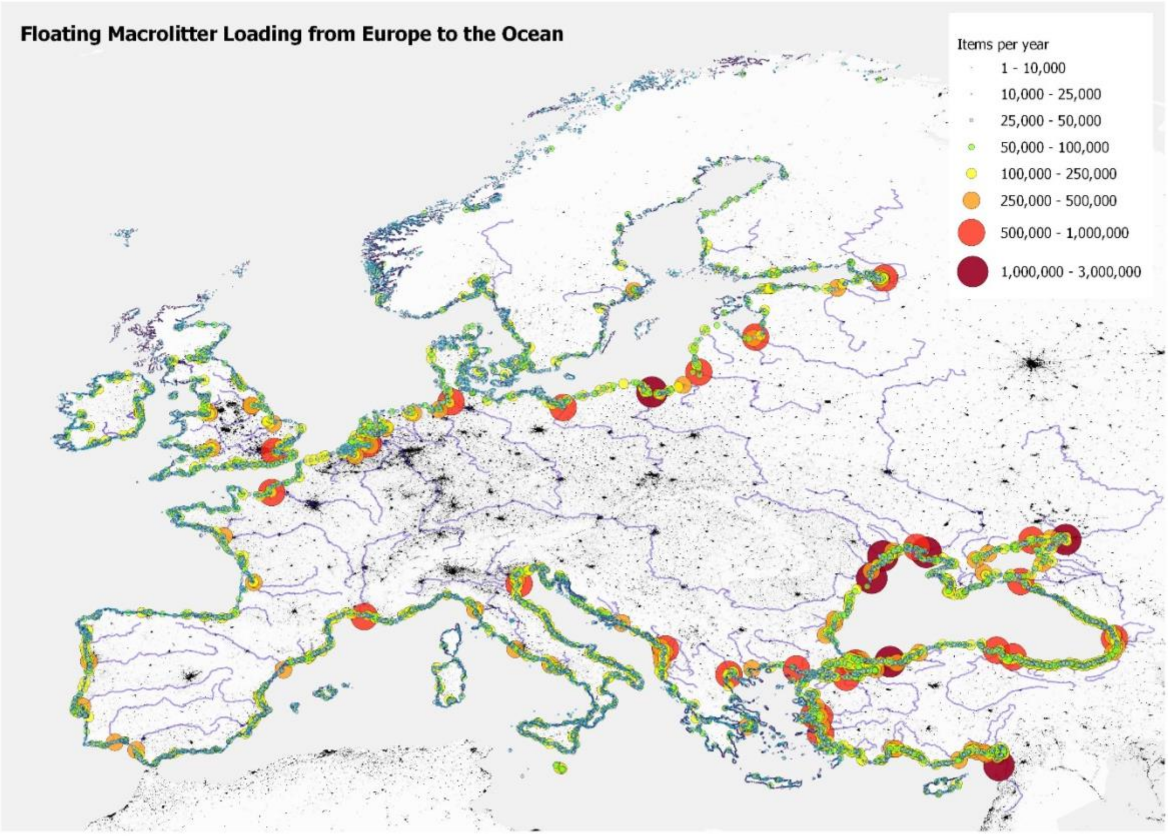
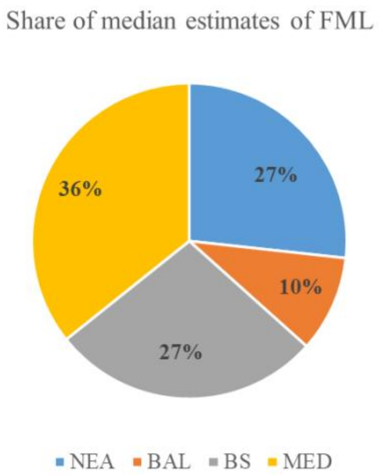


Figure 27: [A] Total share (%); and [B] relative share per emission point (%) of modelled estimates of floating macrolitter items (FML)/year within the main European regional seas: North-East Atlantic (NEA), Baltic Sea (BAL), Black Sea (BS) and Mediterranean Sea (MED) (based on the data of González-Fernández et al., 2021)



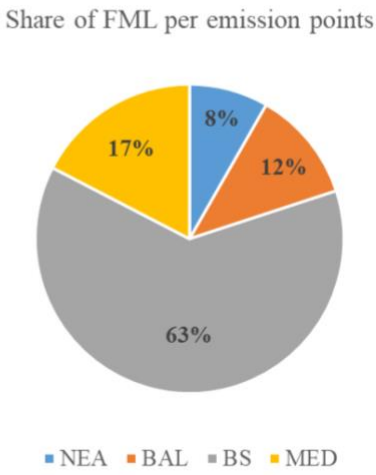
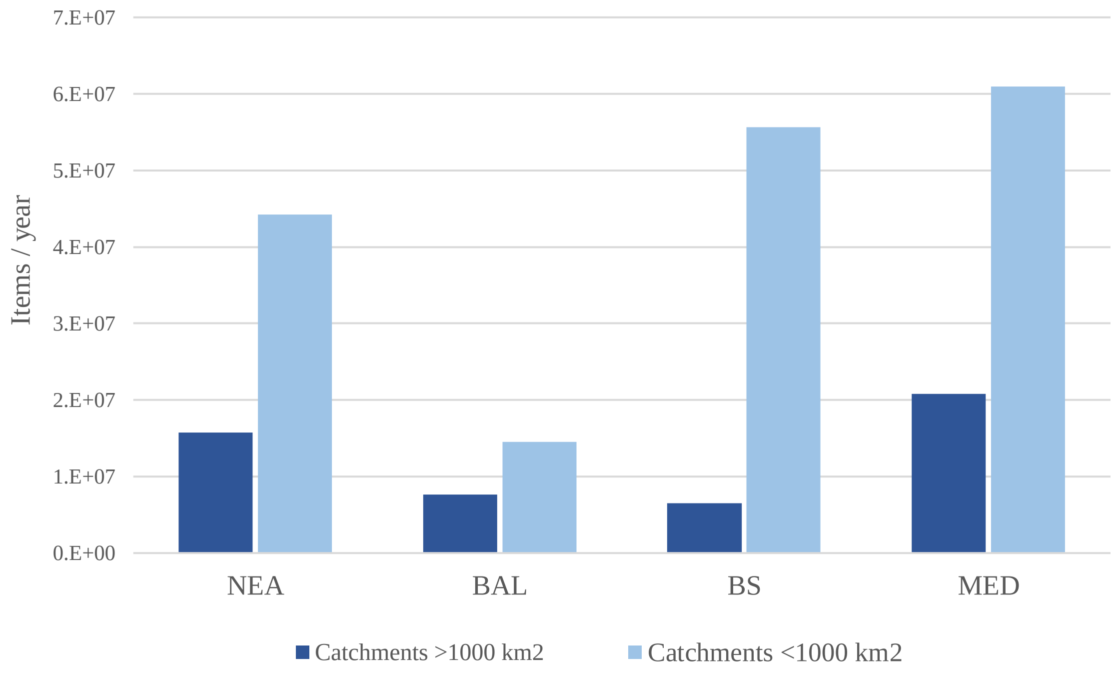


Figure 28: Sum of modelled estimates of floating macrolitter (FML) (median mid estimates, items/year) for larger catchments (> 1,000 km²) and smaller catchments (< 1,000 km²) within the European regional seas; Atlantic Sea (NEA), Baltic Sea (BAL), Black Sea (BS) and Mediterranean Sea (MED) (based on the data of González-Fernández et al., 2021)



4.3. Discussion on data and uncertainties

4.3.1. Integration of the riverine litter estimates with the remaining outputs from this report

The two riverine studies used in this Chapter consider different litter/size categories and riverine emission estimates are based on mismanaged waste data (whose sources are different from the ones used in Chapter 3). In addition, the fact that González-Fernández et al. (2021) provides estimates for floating riverine litter, based on an empirical regression model that computed overall mismanaged waste (i.e. not disaggregated by plastic packaging fraction), limits how far we can compare and integrate these riverine outputs with our estimates of mismanaged PPSI waste.

4.3.2. Uncertainties of assessing river-borne emissions of plastic into the European seas

Rivers are proposed as ideal study objects to better understand the transfer of terrestrial waste into the ocean (González-Fernández et al. 2021). Yet the complexity of the fate and transport of plastics render precise estimates highly uncertain.

Model uncertainties are related to three main aspects: (i) the observational data underlying the model estimates, (ii) the model design and (iii) the uncertainties of the input data on mismanaged plastic waste rates.

(i) Observational data underlying the model estimates
Visual observations seem to provide generally consistent results for the quantification of FML in rivers and are a suitable large-scale monitoring strategy. The low cost and simplicity of the visual census facilitates monitoring on a large geographical scale with high frequency (González-Fernández et al., 2021; Meijer et al., 2021).

The data of visual observations originate from monitoring sessions of variable, yet often short duration. This precludes capturing short-term pulses of FML linked to floods or heavy rainfall events (González-

Fernández et al., 2021). The distribution of monitoring sites is limited to selected locations, lacking extensive spatial coverage. This prevents litter assessments representative for specific regions and areas. The size of survey plastic litter is not often harmonized across different studies. For instance, Meijer et al. (2021) calibrated the model against visual observations of macroplastic litter larger than 0.5 cm in size, González-Fernández et al. (2021) modelled their estimates for macroplastic sizes larger than 2.5 cm. The different results may partly be caused by this methodological distinction.

(ii) Model design
The two studies analysed in this report differ fundamentally in the design of the numerical model, on which the litter estimates are based. Meijer et al. (2021) include a model component assessing plastic waste transport and mobilization probabilities on land, from land to river and from the river to the ocean. These probabilities are classified from remotely sensed or modelled data, which may not fully represent the actual conditions in the field. The model of González-Fernández et al. (2021) does not include any parameters estimating the transport and mobilization probabilities.

(iii) Estimates on mismanaged plastic waste
The riverine litter assessments of riverine litter are referring to mismanaged plastic waste (MPW) rates derived in earlier studies (Schmidt et al., 2017; Lebreton and Andrady, 2019; Jambeck et al., 2015). Such waste rates represent nation-wide estimates based on population densities, waste management practices and consumption patterns, which are subject to change leading to a varying generation of mismanaged waste (Meijer et al., 2021). In addition, there are inherent uncertainties associated to the original MPW data, which are discussed in detail in Edelson et al. (2021) and briefly in Annex 1. This may lead to disproportional predictions, making the estimation of mismanaged waste a considerable source of uncertainty.

5. Litter on the coast and in marine waters

KEY MESSAGES

- Marine litter, including microplastics, is an increasing environmental threat.
- Marine litter is found everywhere from the Artic to the Mediterranean Sea, in the Black Sea and the North-East Atlantic Ocean (NEA) – in offshore waters, on the seafloor and on coastal strips.
- An application of the prototype Marine Litter Assessment Tool (MALT) has identified ‘problem areas’ and ‘non-problem areas’ concerning marine litter by comparing recorded counts of litter items with threshold values. The counts included data from the period 2010–2021 on three indicators: beach litter, seabed litter and floating microlitter.
- Previously adopted European threshold value for beach litter of 20 litter items/100 m was applied. Preliminary threshold values for seafloor litter and floating microlitter were determined following a similar methodology. New threshold values for other litter indicators need to be developed.
- Through MALT status of approximately 19 % of the 10.2 million km^2 of Europe's Seas was assessed, with coverage ranging from 7.5 % in the Black Sea to 43.4 % in the Baltic Sea.
- Considering seafloor litter, beach litter, and floating microlitter data from 2010–2021, the assessment revealed that 74.2 % of the total assessed areas in the European seas could be considered “potential problematic areas”.
- Separate assessments for litter counts from two periods, 2011–2013 and 2017–2019, indicated that the fraction of areas classified as a "non-problem area" fell from 36 % to 21 %, suggesting that the overall status did not improve.
- Beach litter data (2015–2016) show apparent regional differences in litter pollution, with the Mediterranean Sea and NEA coasts appearing to be more polluted (median of 274 items/100m and 233 items/100m, respectively) than the Black Sea (median 106 items/100m) and the Baltic Sea (40 items/100m).
- Marine Litter Watch (MLW) monitoring data (2015–2021) reveal that identifiable items belonging to plastic packaging and small non-packaging plastic items (PPSI) compose roughly half of the litter recorded in Europe. The share and abundance of PPSI litter seem to have generally increased between 2015 and 2021.

5.1. Introduction

This chapter is dedicated to marine litter pollution, both macrolitter (being visible to the naked eye) and microlitter (being almost invisible), including microplastics. It makes use of published scientific studies and European datasets on marine litter to describe and assess the status of marine litter pollution in the four European regional seas.

5.1.1. Methodology

This chapter is structured around three approaches:

i) Firstly, published literature was reviewed to characterize the occurrence and effects of both macro and microlitter in relation to the shorelines, in the water column and on the seafloor, as well as in biota. For more information of the literature, please refer to the list of references;

ii) Secondly, key results from an analysis of the MLW monitoring dataset (2015–2021) are presented, which included a specific analysis on the occurrence of PPSI litter;

iii) Finally, a provisional integrated assessment was carried out and 'non-problem areas' and 'potential problem areas' with respect to marine litter were identified using a prototype multi-metric indicator-based assessment tool "Marine Litter Assessment Tool" (MALT). For detailed information about MALT and target values used, please refer to Annex 5.

5.1.1.1. Data sources used in MALT

EMODnet is currently the main repository for marine litter data in Europe ([22]), including for those data reported under the MSFD by Member States. Publicly accessible data in EMODnet were used for the MALT assessment. These data originated from multiple sources:

a) the **seafloor litter** data comprise 20,551 surveys at 20,021 sites in 22 countries, taken in the period 2010–2021. The surveys included in the dataset were done by their respective marine litter projects, which included MEDITS, EVHOE, Baltic International Trawl Survey, DeFishGear, Demersal Young Fish Survey, International Bottom Trawl Survey (IBTS), North Sea Beam Trawl Survey, and PROMARE;

b) the European **beach litter** data were collected by more than 72 originators (institutions and projects). The MLW data contained observations from 2013 to 2021, covering 1,424 individual beaches whilst the OSPAR data covered 124 beaches from 2012 to 2018. EMODnet data contained observations from 2010 to 2021 at 1,225 beaches. There was some overlap between these datasets. All of the OSPAR observations were found to be included in the EMODnet dataset whilst 664 beaches were included in both EMODnet and MLW datasets. Where several litter item counts were made on the same beach on different dates, the median of the counts was used;

c) floating **microlitter** data came from 839 trawls conducted on 60 cruises between 2011 and 2020.

5.2. Literature review on the occurrence of macro and microlitter in Europe

5.2.1. Litter in European coastlines

5.2.1.1. Macrolitter on beaches

Macrolitter pollution on beaches has been a focus of monitoring in the EU. A standardised macrolitter monitoring method (OSPAR, 2010; Galgani et al., 2013) is largely used. In short, this method utilises the "naked eye" to quantify macrolitter on beaches. It focuses on those that are rural or unmanaged which fit under the criteria for reference beach selection. As beach clean-ups have become more and more commonplace, the criteria for utilising the OSPAR macrolitter monitoring method becomes harder to fulfil. Beach clean-ups and litter collections could mask the actual variations in litter abundance and composition (Haseler et al., 2020; Addamo et al., 2017).

[22] https://www.emodnet-chemistry.eu/marinelitter

Hanke et al. (2019) analysed a pan-European harmonised beach macrolitter dataset with the purpose of defining a EU beach litter baseline. Aggregated regional median litter abundances (2015–2016) obtained by the authors are provided in Table 4 to illustrate regional differences.

Table 4 Abundance of total beach litter items (median of items/100 m) in the four EU regional seas (based on aggregated beach litter data 2015–2016) (Source: Hanke et al., 2019)

Region	Number of surveys	Abundance (median number items/100 m)
Baltic Sea	498	40
NEA	585	233
Mediterranean Sea	346	274
Black Sea	41	106

5.2.1.1.1. Baltic Sea

In the earliest assessments of litter in the Baltic Sea region, a lack of comparable data was identified as a major gap to address marine litter (HELCOM, 2009). Information was dispersed and collected with different approaches and HELCOM prepared recommendations for harmonisation, including a survey form for reporting marine litter. Many of the beaches in the Baltic Sea are managed and cleaned, and therefore do not meet the criteria for the OSPAR selection of reference beaches (Schernewski et al., 2018).

Currently, beach litter is assessed as a core indicator under HELCOM, although the monitoring on a regional scale is still under development. The EU Marine Beach Litter Baseline (Hanke et al., 2019) found that Latvia presented higher abundances of plastic litter items, although in general the Baltic Sea was dominated by litter (2012–2016) averaging 40 items /100 m of beach. Data collected as part of the SPICE report found that the highest litter densities (>200 litter items / 100 m of beach) occurred in the Gulf of Finland, Bothnian Sea, and Northern Baltic Proper (HELCOM, 2018a). Beach characteristics, such as coastline shape, direction of water currents and winds appear to influence locations where litter accumulates, although human activities and level of beach cleaning likely plays a role in the observed abundances. Plastics were the most frequently identified item, with user-plastics relating to eating, drinking or smoking included in the 10 most frequent items across all beach classifications (Urban, Peri-urban, Rural). Industrial litter items (packaging, sheeting, strapping bands, masking tape) and derelict fishing gear were also reported. In a recent assessment of four years of data collection, tourism on the Polish coast was identified to heavily contribute (81.7 %) to beach macrolitter values, with cigarette butts and filters consisting of 53 % of the top ten litter categories. However, the Southern Baltic coast was reported to have a good status based on a threshold value defined at 13 items /100 m (Zalewska et al., 2021).

For data available on national/sub-regional scales, please refer to Table 5.

Table 5 National and sub-regional data identified for macrolitter on shorelines and beaches of the Baltic Sea

Location (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Lithuania (2015–2016)	OSPAR	4	7,117	Artificial polymer materials	72.9 % (70.8–75.1)	Balčiūnas and Blažauskas, 2014
Isle of Rügen (2015)	OSPAR	4	Total: 1115 304 (88.96) /100 m	Artificial polymer materials	83 %	Hengstmann et al., 2017
Lithuania and Germany (2011–2015)	OSPAR	35	138–340 items/survey (LT) 7–407 items/survey (DE)	Artificial polymer materials	63.8 %	Schernewski et al., 2018
Curonian Spit, Russia/Lithuania (2018)	RAKE	6	Total: 432 items Mean: 3.2 items/m^2	Artificial polymer materials	84 %	Chubarenko et al., 2020
Polish coast (2015–2019)	/	15	Total: 85,086	Artificial polymer materials	68.5 %	Zalewska et al., 2021
Swedish coast	RAKE	7	Mean: 0.18 – 1.46/m^2	Artificial polymer materials	22.2 – 80.6 %	Haseler et al., 2020
Danish coast	RAKE	4	Mean: 00.4 – 0.28	Artificial polymer materials	27.1 – 46.6 %	Haseler et al., 2020
Finish coast	RAKE	5	Mean: 0.08 – 1.90	Artificial polymer materials	24.5 – 64.4 %	Haseler et al., 2020

5.2.1.1.2. North East Atlantic Ocean

Beaches in the NEA cover the coastlines on mainland Europe from Portugal in the South to Norway and Iceland in the North, as well as the Azores, Madeira, Canary Islands, UK, Ireland, Faroe Islands and the West coast of Sweden. In the EU Marine Beach Litter Baseline (Hanke et al., 2019) total abundance (2015+2016) was reported as 233 items / 100 m beach for the NEA. With France consistently reporting higher abundance values (~ 2,000 items/survey), items of which were mostly dominated by user plastics including food and beverage containers and other service items (cutlery, straws, stirrers, etc.).

Recent research into the spatial size and distribution of litter on coastal dunes has been conducted using drones on the Portuguese coast which revealed that smaller litter items tended to be trapped by the foredune grass, whereas the largest items were mostly found on the back dune. Litter also varied corresponding to swash, elevation, wind speed and direction (Andriolo et al., 2020; 2021). Utilising drones or UAS (Unmanned Aerial Systems) has been shown to be fast, easily reproducible and cost-effective, showing the potential for new opportunities to improve and/or support marine litter monitoring programmes, as well as the integration into broader coastal environmental monitoring programmes considering morphological changes. Similar experiences with aerial imagery under the context of MSFD monitoring obligations have been presented for Malta. A considerable difference between the two monitored locations was observed (30 vs 578 items) which was suggested to be a consequence of different wave and wind exposure, coastal current dynamics and topography, as well as human activities at the sites (Deidun et al., 2018).

In an investigation of 42 beaches (Azores), gravel beaches tended to show the higher density of litter when compared to rocky and sandy beaches. Similarly, beaches with the highest litter density coincided with the prevailing wind direction. There was some variability with seasonal monitoring and litter input (Ríos et al., 2018).

With the copious amounts of data being generated under the obligations of OSPAR beach litter monitoring, an appropriate approach for data handling has been critical. Schulz et al. (2017) developed tailor made software ("Litter Analyst") and applied it to seven beaches in the North Sea to investigate trends in abundance between 2009–2014. The study identified that trend analysis can most efficiently be performed at the beach or national level, although the application of regional aggregation reduced the number of significant trends. Thus, no general patterns in trends in litter abundance were reported.

In a more recent study, the same team applied power analyses methods for reduction analysis of beach litter to the time series of 14 OSPAR beaches (Schulz et al., 2019). It identified that a 40–50 % reduction can easily be detected with < 12 surveys.

For data reported for national/sub-regional scales, please refer to Table 6 and Table 7.

Table 6 National and sub-regional data identified for macrolitter on shorelines and beaches of the North East Atlantic Ocean

Location (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
North Sea (1992–2011)	OSPAR	8	/	Plastic/Styrofoam/rubber	52.7–91.3 %	Schulz et al., 2015
North Sea (2009–2014)	OSPAR	7	Median: -84–421 per beach	Nets and ropes	25–40 %	Schulz et al., 2017
North Sea and Iberian Coast (2012–2017)	OSPAR	14	Mean abundance: 758 /100 m	Plastic fragments (large, 2.5–50 cm; small > 2.5 mm)	/	Schulz et al., 2019
Azores Archipelago	OSPAR	42	31,439 Average: 0.62/m^2	Artificial polymer materials (plastic fragments)	87 % (67 %)	Rios et al., 2018
Portugal, Morocco	NOAA	8	10,023 9.35/m^2	Artificial polymer materials	57–100 %	Velez et al., 2019
Faial Island, Azores	Transects	2	Total: 28,261 0–1.94 items /m^2	Artificial polymer materials	93.14 %	Pieper et al., 2015
Azores Archipelago (2012–2018)	MSFD TGML	2	116,649	Artificial polymer materials	95.35 %	Pieper et al., 2019
Madeira Archipelago	OSPAR	4 (macro) + 5 (meso)	52 types of litter items >51 kg (26 kg Polystyrene)	Polystyrene	>80 %	Alvarez et al., 2020

Table 7 Litter abundance at beaches in the North-East Atlantic Ocean. Date is displayed as items/100 m survey for Total Abundance (TA), SUP (single-use plastics) and FISH (fisheries items). Values taken from Hanke et al. (2019)

Country	Period	FISH	SUP	TA
Belgium	2015–2016	24	40	100
Germany	2015–2016	23	13	81
Denmark	2015–2016	89	66	236
Spain – Bay of Biscay and the Iberian Coast	2015–2016	72	102	288
Spain – Macaronesia	2015–2016	10	58	136
France – Bay of Biscay and the Iberian Coast	2015–2016	118	570	2430
France- Celtic Seas	2015–2016	96	79	323
France- G. North Sea, Kattegat + English Channel	2015–2016	170	220	622
UK – Celtic Seas	*2015–2016*	*39*	*50*	*193*
U – G. North Sea, Kattegat + English Channel	*2015–2016*	*22*	*128*	*385*
Ireland- Celtic Seas	2015–2016	39	19	73
Netherlands – G. North Sea, Kattegat + English Channel	2015–2016	105	46	229
Portugal	2015–2016	24	190	330
Sweden – *G. North Sea, Kattegat + English Channel*	2015–2016	40	40	149

5.2.1.1.3. Mediterranean Sea

For the Mediterranean Sea, comprehensive data on beach litter from several studies from 2007 to 2019 was compiled by EMODnet (2021) (Table 8). The distribution and numbers of beach surveys differs throughout the year growing from 18–40 in 2007/2010 to over 500 surveys included in 2019. The general trend is a declining number of items found in the later years from over 1,000 items per 100 m of beach to 325 items in 2019. The later numbers are relatively similar despite a large increase in the number of surveys and a larger total length of beach included.

Table 8 Litter abundance at beaches in the Mediterranean based on 2874 surveys, of which 74 were excluded (no survey length available, length < 10 meter, too limited data in 2020)

Year	Surveys	Items total	Length total meters	Mean items/100 m	Median items/100 m
2007	44	159,610	5,900	2,705	2,281
2010	18	41,166	2,400	1,715	1,772
2011	86	177,727	11,550	1,538	1,370
2012	109	266,437	14,600	1,824	1,682
2013	125	26,673	55,460	48	66
2014	159	55,087	68,382	80	88
2015	374	188,171	67,101	280	383
2016	473	195,080	29,480	661	427
2017	495	185,414	33,102	560	427
2018	463	156,753	32,728	479	448
2019	528	328,129	100,819	325	344

Source: EMODnet, 2021

5.2.1.1.4. Black Sea

Data from the Black Sea are scarce, but a few studies have been reported for Romanian and Bulgarian beaches. Two studies report total numbers of 13–19,000 items from 8–9 beaches resulting in an average of 0.058–0.134 items/m^2. In the latest study by Simeonova et al. (2017), marine litter surveys were conducted on 8 beaches along the Bulgarian Black Sea coastline over 4 seasons in 2015–2016 using the OSPAR protocol. The most abundant items were artificial polymer materials >84 %. Seasonal differences were seen showing larger numbers of items in the summer, most likely reflecting more intense usage of the beaches for recreation.

A Romanian study (Stoica et al., 2020) reported a total of 3,916 items on the four beaches which were influenced by rivers with densities varying from 0.105 to 2.039 items per m^2 (Table 9). Here, the litter abundances varied between the sampling sites, which might be attributed to river discharges, beach or human activities.

In the EU Marine Beach Litter Baseline (Hanke et al., 2019) 198 items per 100 m of beach were reported for Bulgarian beaches, while a total of 14 items per 100 m of beach were reported for Romania based on 31 and 10 surveys for 2015– 2016, respectively (Table 10).

Table 9 National and sub-regional data identified for macrolitter on shorelines and beaches of the Black Sea

Location (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Black Sea (2019) Romania/Türkiye	MSFD TGML	4	3,916 (0.105–2.039 items/m^2)	Artificial polymer materials	65–94 %	Stoica et al., 2020
Black Sea (2015–16) Bulgaria	OSPAR	8	19,805 (0.058–0.134 items/m^2)	Artificial polymer materials	> 84 %	Simeonova et al., 2017
Black Sea (2014–17) Bulgaria	MLW	9	13,150 (---)	Artificial polymer materials	> 80 %	Muresan et al., 2017
South-West Black Sea	Transects		0.085–5.058 items/m^2	Plastic fragments	53 %	Topçu et al. 2013
South-East Black Sea	Transects	9	0.16 ± 0.02 items/m^2	Plastic and Styrofoam	> 85 %	Terzi and Seyhan, 2017
Southern Black Sea	MSFD TGML	1	1.512 ± 0.578 items/m^2	Artificial polymer materials (mixed packaging)	95.6 % (41 %)	Öztekin et al. 2020
South-East Black Sea	OSPAR	1	1.22–4.17 items/m^2	Foam, Plastic/polystyrene fragments	32 %	Aytan et al. 2020a

Table 10 Litter abundance at beaches on the Black Sea. Date is displayed as items/100 m survey for Total Abundance (TA), SUP (single-use plastics) and FISH (fisheries items). Values taken from Hanke et al. (2019)

Country	Period	FISH	SUP	TA
Bulgaria	2015–2016	4	128	198
Romania	2015–2016	0	10	14

5.2.1.2. Microlitter in beach sediment

Current recommended beach monitoring methods for macrolitter are not appropriate for microlitter. They overlook most of meso- (5–25 mm) and large microlitter (1–5 mm), with some evidence suggesting 70 % of items identified on beaches using similar methods are 2–25 mm in size (Haseler et al., 2020). Therefore, an alternative approach is required to identify microlitter on shorelines. Many researchers have developed their own methodological approaches to identify occurrence, abundance and potential sources of microlitter and a comparison of methods has been provided by Hasler et al. (2017). For the purpose of this report both meso and microlitter are discussed as microlitter. Presented in this section are a summary of available literature.

5.2.1.2.1. Baltic Sea

Microlitter sampling has been carried out in the Baltic Sea using several different methods for research purposes. Coordinated monitoring is still under development. Of the research available for beaches and shorelines the earliest studies date back to 2014 from Germany. The environmental sampling has been performed mainly for research purposes, but some pilot monitoring activities are also ongoing in several Baltic Sea countries. Summaries of the available literature have been updated under the FanpLESStic project (2017–2019).

As the number of studies focusing on microlitter, in particularly microplastics, is rapidly increasing in the literature, this section focuses on the data available since 2015. Studies have identified microlitter on beaches from Denmark, Russia, Germany, Poland and Lithuania (Table 11). Where different methods are applied, the results of microlitter studies have been shown to vary greatly (Haseler et al. 2017; Kataržytė et al., 2020), which suggests further considerations of methodological approaches are needed before recommendations for further microlitter monitoring programmes can be ratified. For example, when applying a sand rake method to Baltic Sea beaches a total of 9,345 litter items were identified of which 2,489 were microlitter, 4,040 were mesolitter, 2,816 were macrolitter (Haseler et al., 2020). Artificial polymers were the most abundant category (53 %) followed by cigarette butts (15 %).

Some studies have focused on identifying which sources could be contributing to the microlitter, with harbour, and industrial activities and tourism a likely source for the German Baltic coast (Stolte et al., 2015). A correlation between microlitter concentrations, population density and coastal infrastructure was observed in Poland, but no link was found to concentrations in the national park (Urban-Malinga, et al., 2020).

Table 11 National and sub-regional data identified for microlitter on beaches and shorelines in the Baltic Sea (Dw: dry weight)

Country (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
German Baltic Coast (2014)	n.a.	11	0–7/kg 2–11 fibres/kg	Fibres (> 63 µm)	/	Stolte et al., 2015
Kallingrad, Russia (2015–2016)	n.a.	13	1.3–36.3 items/kg 370–7,330 mg/m^2	Foamed plastics	n.a.	Esiukova, 2017
Gdansk Bay (2014)	n.a.	3	25–53/kg Mean: 39	Polyester	27 %	Graca et al., 2017
Lithuania (2015)	n.a.	1	700 (296)	Microplastic	/	Lots et al., 2017
Isle of Rügen (2015)	OSPAR, (sampling transect)	4 (57 samples)	Median: 88.10 /kg dw 2,862/m^2	Fibres	/	Hengstmann et al., 2018
Curonian Spit, Russia/Lithuania (2018)	SFM	6	3,155 (1308)/m^2	Fibres	74.3 %	Chubarenko et al., 2020
Lithuania and Germany (2011–2018)	OSPAR, RAKE, FAM	9 – LT 18– DE	0.18 (0.40) /m^{2-} LT 0.018 (0.07) /m^2- DE	Cigarette butts	18.9 %-LT 12.4 %-DE	Ktaržytė et al., 2020
Baltic Sea (9 countries) (2017–2019)	RAKE	197 surveys	0.24 microlitter/m^2 0.39 meso-litter/m^2	Artificial polymer materials	53 %	Haseler et al., 2020
Poland (2015)	n.a	12	76–295 items/ kg dw	Fibres and plastic fragments	49–81 %	Urban-Malinga et al., 2020
Kiel Fjord (2016)	n.a.	3	1.8–30.27 items/kg dw	Fibres and fragments	n.a	Schroder et al., 2021

5.2.1.2.2. North-East Atlantic Ocean

Microlitter has been identified on numerous beaches in the NEA (Table 12). The level of coordinated monitoring is generally limited, thus the methods applied between studies and countries are often incomparable. Many of these studies focus on microplastics. The “Programme of microplastics monitoring in Spanish beaches” was initiated by CEDEX (Centre for Public Work Studies and Experimentation, Spanish Ministry of Development) in autumn 2016 and is part of the routine monitoring programme established under the MSFD. Three studies have been published which utilise the methods recommended by the TGML (Galgani et al., 2013) which should yield comparable results; however, they use different reporting unites (Table 12).

Much of the scientific research focuses on microplastic in beach sediment samples. Some studies have noticed spatial trends. For example, resin pellets become the dominant litter category close to industrial areas, whereas fragments and foams are found in higher concentrations near fishing ports in Portugal (Antunes et al., 2018).

Table 12 National and sub-regional data identified for microlitter on beaches and shorelines in the North-East Atlantic Ocean (DW: dry weight; MSFD: Marine Strategy Framework Directive; TGML: Technical Group on Marine Litter; PET: polyethylene terephthalate)

Country (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Portugal (2011–2013)	n.a.	11	Total: 162	Artificial polymer materials (microplastic)	99 % (68 %)	Antunes et al., 2018
Portugal, Morocco (2013)	Transect, 30m (n = 3 quadrats)	8	Average 335.5/m^2	Fragments	-	Velez et al., 2019
Aveiro, Portugal (2018)	Transect (33 samples)	1	Median: 100 items/kg (15–320 items/kg	Microplastics (Polyethylene)	30 %	Chouchene et al., 2021
Madeira Archipelago (2017)	MSFD TGML	5 (meso and micro)	< 0,2 mm: 306–902 items/L > 1 mm: 8–26 items/L	Artificial polymer materials	-	Alvarez et al., 2020
Canary Islands (2015–2016)	MSFD TGML	3 (261 samples)	1–5mm; max: 244.2 g/m^2 5–25 mm: max: 157.8 g/m^2	Fragments	-	Herrera et al., 2018
Lanzarote, Canary Islands (no date)	MSFD TGML	1	36.3 g/m^2 (8.5–103.4) Total: 9,149	Fragments (Polyethylene)	87 % (63 %)	Edo et al., 2019
Hauts-de-France (2017)	/	3	Total: 1,692 23.4 (18.9) – 69.3 (30.6) items/kg dw	Fibres Polyethylene	-	Doyen et al., 2019
Bay of Biscay (2015–2016)	/	60	67 (76) items/kg dw	Microplastic Fragments	84 %	Phuong et al., 2018a
Kattegat (2015)	/	5	Total: 210 2–55 items / 550g dw	Fragments	46.1 %	Hansen and Gross, 2019
Orkney, Scotland (2016)	/	13	730–2,300 items/kg dw	PET	45 %	Blumenroder et al., 2017
Coastal North-East Atlantic (2013–2014)	Shoreline and van veen grab	27	0–3,146 items/kg dw	Fibres and sphere	-	Maes et al., 2017
Norderney (2011)	/	3 sites 36 samples	59 (< 1 mm)	Plastic Fragments	-	Dekiff et al., 2014

*fibres were excluded

5.2.1.2.3. Mediterranean Sea

As with the other regional seas, microplastic investigations dominate studies on microlitter. Several studies have reported microplastics in beach sand or coastal and shoreline sediments in the Mediterranean Sea. The results from recent studies, summarised in Table 13, show a relatively large variation from 0 to 2,175 microplastic particles per kg dry sediment or sand. The highest levels were found in the Venice Lagoon, but no direct correlation was seen between rural or remote areas or beaches. For example, surprisingly low levels of microplastics were reported in a recent study in the Gulf of Trieste (Korez et al., 2019) while much larger amounts were found in 2014 (Korez et al., 2019) and 2016 (Renzi et al., 2018). It is speculated that much of the variation is due to the use of different sampling and analytical methods. Here there is still a large need for harmonisation and standardisation of analytical methods before a more detailed evaluation of results is possible. However, it can be noted that microplastics data are ambiguous in both coastal beaches and sediment in both urban, rural and protected areas of the Mediterranean.

Table 13 National and sub-regional data identified for microlitter on beaches and shorelines in the Mediterranean (FTIR: Fourier Transform Infrared)

Country (year)	Survey type	Area	Total number of items (item/kg dry sediment)	Most abundant item	Reference
Slovenia (2014)	Shoreline	Gulf of Trieste	133	Microplastic	Korez et al., 2019
Italy/Slovenia (2016)	Submerged sediments from shoreline	Northern Adriatic	137–703	Microplastics	Renzi et al., 2018
Slovenia (2017)	Shoreline sediment	Gulf of Trieste	0.5–1 (FTIR) 7.2–82.1 (Visual)	Microplastics	Korez et al., 2019
Croatia (2015	Shoreline sediment (3–10 m)	Northern Adriatic Sea	15 -392	Microplastics	Blašković et al., 2017
Italy (2012)	Shallow waters	Venice Lagoon	672 – 2,175	Microplastics	Vianello et al., 2013
Italy (2015–2017)	Shoreline sediment	Lido di Dante	1,512	Microplastics	Lots et al., 2017
Italy (2015)	Shoreline sediment	Central Adriatic Sea	0–75	Microplastics (filaments)	Mistri et al., 2017
Italy (2015–2016)	Submerged sandy shores and beaches	Thyrrenian Sea	186–679 62–466 45–1,069 72–191	Microplastics	Martinelle et al., 2018 and references herein.
France (2015–2017)	Shoreline sediment	Cassis	124	Microplastics	Lots et al., 2017
Greece (2015–2017)	Shoreline sediment	Pillion	242	Microplastics	Lots et al., 2017
Spain (2013)	Shoreline sediment	Balearic Islands	100–900	Microplastics	Alomar et al., 2016
Spain (2015–2017)	Shoreline sediment	Denia, Barcelona	156 148	Microplastics	Lots et al., 2017
Spain (2018)	Beaches Sediments	Tarragona Coast	5.5 – 89 0.7 – 42	Microplastics	Expósito et al., 2021

5.2.1.2.4. Black Sea

Microplastic concentrations in beach sediments sampled along the Bulgarian and Romanian Black Sea coast and in marine sediments varied and the highest concentrations were found at the Danube Delta coast (620 particles/ kg) with a mean coastal microplastic concentration of 98 particles/kg along the coast. Marine microplastic concentrations were lower in the Bulgarian Black Sea (mean 131 ± 52). The microplastics mainly consisted of fibres (> 90 %) with a small proportion of fragments (< 3 %). The exception was at a sampling site where mainly flakes (80 %) were found in sediments close to a recent fire. See Table 14.

Table 14 National and sub-regional data identified for microlitter on beaches and shorelines in the Black Sea

Country (year)	Survey type	Number of beaches	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Black Sea (2016–18)	Beach sediment/sand	3 areas	98—131 particles /kg (max 630)	Fibres	> 90 %	Pojar et al., 2021

5.2.2. Litter in European regional seas

5.2.2.1. Macrolitter in the sea surface and water column

Some of the first assessments of litter and plastic in the global oceans were based upon items floating on the ocean surface or immediately below. There are no established monitoring frameworks for floating macrolitter, although visual observations of litter have been recommended (e.g., aerial surveys, visual and fisheries observers, photographic surveys; TGML Guidance/Galgani et al., 2013; GESAMP 2019).

5.2.2.1.1. Baltic Sea

Only a single baseline study on floating litter in the Baltic Sea is available (Table 15). Higher densities of floating litter were observed near port cites but the overall abundance was low (Rothäusler et al., 2019). The same study found little seasonal variation, although more litter was observed during summer surveys. One suggestion for the low values may be linked to lower population densities or greater environmental awareness in the coastal communities.

Table 15 National and sub-regional data identified for macrolitter in the sea surface water column of the Baltic Sea

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Northern Baltic Sea (Finland/Sweden) (2012–2013)	Visual observations	8	27	Artificial polymer materials - Styrofoam -Bags	96 % -22 % -18 %	Rothäusler et al., 2019

5.2.2.1.2. North-East Atlantic Ocean

Only a few studies on floating litter observations are available for the NEA, some of which are presented in Table 16. The first, conducted in 2011, utilised ship visual surveys over a repeated transect along the Portuguese coast to count floating macrolitter. On average, authors reported 2.98 items/km^2, of which 0.46 items/km^2 were plastics (16 %). The authors noted that higher concentrations were potentially linked to the fishing and shipping activities in the region, especially in the North Sector of the Portuguese coast (Sá et al., 2016). A lower average abundance was reported following fisheries surveys in the Azores and Madeira islands, where an average of 1.39 items/km^2 was reported (Chambault et al., 2018).

Table 16 National and sub-regional data identified for macrolitter in the sea surface water column of the North-East Atlantic Ocean

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Portugal (2011)	Ship visual survey	3 repeated transects	Average: 2.98 items/km^2	Unidentified plastics	16 %	Sáa et al., 2016
Azores and Madeira (2015–2017)	Visual transects 10 mins each	2406	Total: 482 items 1.39 item/km^2	General user plastic	48 %	Chambault et al., 2018

5.2.2.1.3. Mediterranean Sea

Results from the MEDSEALITTER project covered a large part of the Mediterranean (< 20 000 km) including offshore observations from large ships of items larger than 20 cm. A decreasing gradient was found from river mouths, coastal areas to the open sea where 1–10 items per km^2 were observed. Another large-scale macrolitter mapping of the Mediterranean using both observations from the air and ships covering more than 27,000 km reported averages of 0.80 and 1.13 items larger than 30 cm. These results are summarised in Table 17 below.

Table 17 National and sub-regional data identified for macrolitter in the sea surface water column of the Mediterranean Sea

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Mediterranean (2013–2018)	Ship visual survey	7 repeated transects	Mean: 1–10 items/km^2	Unidentified plastics > 20 cm	NA	Antonella et al., 2020
Mediterranean (2012)	Air and ship survey	27,000 km	1.13 ± 3.3 items/km 0.80 ± 3.2 items/km	Unidentified plastics > 30 cm	68.5 % plastic bags, bottles, tarpaulins, palettes, inflatable beach toys	Lambert et al., 2020

5.2.2.1.4. Black Sea

A ship-based survey from 2014 in the North-Western Black Sea reported a litter density of 30.9 ± 7.4 litter items/km^2 with a maximum of 135.9 items/km^2, most of the items were of natural (wood) items (75 %) plastic was the most abundant type of anthropogenic litter (90 %) (Table 18). A more recent study that considered data from visual observations carried in 2017 and 2019 reveal high-densities of floating macrolitter in the Black Sea, particularly in the Eastern part of the basin and in the proximity of cities, which exhibited densities of litter of over 200 items/km^2 (González-Fernández et al., 2022).

Table 18 National and sub-regional data identified for macrolitter in the sea surface water column of the Black Sea

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
North-West Black Sea	Ship visual survey	30 transects 187 km	Mean: 30.9 ± 7.4 items/km^2	Fragments, bags, containers and packaging	89.1 %	Suaria et al., 2015
Türkiye, South-East Black Sea	Ship visual survey	7 transects 69 km	Mean: 980± 1,829 items/km^2	Plastic fragments	69.5 %	Aytan et al., 2019
Basin scale	Ship visual survey	302 transects, 4,761 km	Mean: 93.6 ± 128.3 items/km^2 Median: 38.6 items/km^2)	Plastic fragments	45.64 %	González-Fernández et al., 2022

5.2.2.2. Microlitter on the surface and in the water column

Monitoring microlitter in surface waters is currently not included as an indicator for OSPAR, International Council for the Exploration of the Sea (ICES) nor HELCOM. Floating Microplastics are included, however, as a Common Indicator in the Integrated Monitoring and Assessment Programme (IMAP) within the Barcelona Convention. The most used methodologies for collecting samples are the surface nets or trawls (including manta trawl). The historical use of plankton nets and the presence of small plastic items means data collected can be compared to already gathered time series data. However, as the knowledge of the limitations of sampling with a manta net have emerged scientists have begun using pump systems and other bulk sampling device (e.g. Niskin bottles) to avoid sample contamination, especially when the targeted microplastics are <1mm.

5.2.2.2.1. Baltic Sea

Microlitter on the surface and in the water column is currently being considered as a candidate indicator, and coordinated monitoring is still under development. Microlitter sampling has been carried out in the Baltic Sea using several different methods for research purposes, mostly targeting the sea surface using surface nets/trawls. Therefore, current studies do not, in their current form, provide enough information to make an evaluation of microlitter in the Baltic Sea (HELCOM 2018). Of the research available for surface waters some of the earliest sampling for microlitter in the Baltic Sea was performed along the Swedish coast (Noren, 2007). Much of the information from such investigations are focused on microplastics, thus the proportion of synthetic versus non-synthetic microlitter has not been assessed (Table 19).

As much of the work has focused on microplastics, the identification of potential sources and emissions have also been focused in this respect on microplastics. Tamminga et al. (2018) utilised both manta and bulk sampling in their study conducted in the Funen Archipelago and their results suggested that vessel traffic was likely the largest source of microplastics identified in the study.

Table 19 National and sub-regional data identified for microlitter on the surface and in the water column of the Baltic Sea

Country (year)	Sample type (mesh/sieve) (n =)	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Northern Baltic Proper (2007–2008)	Vertical tows (90 µm) and bulk	10^2–10^4 items/m³	n.r.	n.r.	Gorokhova, 2015
South Funen Archipelago, Belt Sea (2015)	Manta (n = 10) Bulk (n = 31)	Total: 137 Mean: 0.07 (0.02)/m³ Range: 0.05–0.09/m³	Fibres	n.r.	Tamminga et al., 2018
Gulf of Finland (2013)	Manta (> 333 µm)	Range: 0.3–2.1 items/m³	Microplastics	n.r.	Setälä et al., 2016
Gulf of Finland, n = 12 (2013)	Submersible Pump (100 µm)	Range: 0–8.2 items/m³	Microplastics	n.r.	Setälä et al., 2016
Gulf of Finland	Manta trawl	0.3–0.7 items/m³			Magnusson, 2014
Sweden	Plankton net 20 µm	300–1,300 fibres/m³ 100–7,000 particles/m³			Noren, 2009
Arkona Basin / Bornholm Basin	Manta (300µm)	0.0–8/m³ 0.0–35.0 fibres /m³			Noren et al., 2015
Arkona Basin / Bornholm Basin	Bulk (10µm)	0.0–35.0/m³ 0–1410 fibres /m³			Noren et al., 2015
Stockholm archipelago (2014)	Manta	Coastal: 4.2x10⁵/km² Offshore: 4.7x10⁵/km²	Polypropylene	53 %	Gewert et al., 2017
Helsinki archipelago, Gulf of Finland	Bulk	0.01–0.65 total fibres 0.5–9.4 synthetic particles	Fibres	/	Talvitie et al., 2015
Baltic Sea proper (2015–2016)	Niskin bottles (10–30 l, n = 95)	0.07–2.6 /l	Fibres	\	Bagaev et al., 2017
Baltic proper (2015–2016)	/	Mean: 0.40(58) items/L Max: 2.7 items/L	Fibres	77 %	Bagaev et al., 2018
German Baltic coast (2014)	n.a. (n = 3)	0–0.25 particles/L 0.43–5.0 fibres/ L	Fibres	/	Stolte et al., 2015

* Fibres were excluded

5.2.2.2.2. North-East Atlantic Ocean

The Bay of Biscay has been a particular focus of investigations into microlitter and microplastics (reviewed by Mendoza et al., 2020). Microplastic investigations emerged in 2014 (Lusher et al., 2014) which focused on subsurface water samples. The maximum abundance of microplastics in the Bay of Biscay was estimated at 1,678,532 items/km^2 (LEMA survey, Mendoza et al., 2020).

Trend analyses of microplastics were conducted on data from surveys of the French continental shelf (2013–2016), although no significant trend has been observed with ranges in values from 17,019 – 47,940 items/km^2 minimum values (Gerigny et al., 2018). See Table 20 below.

Table 20 National and sub-regional data identified for microlitter on the surface and subsurface waters of the North-East Atlantic Ocean

Country (year)	Survey type	No. of samples	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Bay of Biscay (2013+2014)	Manta (333µm)	41	Total: 1463 items (< 5 mm) 2013: 35,000/km^2 2014: 176,000 items/km^2	-	-	Gago et al., 2015
Bay of Biscay (2014)	Manta (335µm)	18	Mean: 0.24 (0.35) items/m^3 Mass: 0.3(0.60) items/m^3	Fragments (Polyethylene)	53 % (53–67 %)	Frere et al., 2017
Bay of Biscay (2017–2018)	Neuston (500µm)	44	2017: 17,502 items/km^2 2018: 210,477 items/km^2	-	-	Santos et al., 2019 (taken from Mendoza items et al., 2020)
Bay of Biscay (2013–2016)	Manta (335µm)	19	37,167 items/km^2 Range: 17,019 – 47,940 items/km^2	-	-	Gerigny et al., 2018 (taken from Mendoza et al., 2020)
Macaronesian region (2015–2018)	Manta (200µm)	45	15,283–1,007,872 items/km^2	Plastic fragments	34.9–57.3 %	Herrera et al., 2020
Galway Bay, Ireland	Manta (300µm)	20	Total: 1182 Mean: 0.56 (0.33) items /m^3	Fibres	86.1 %	Frias et al., 2020
SUBSURFACE WATER						
North-East Atlantic (2013–2014)	Subsurface pump	470	Mean: 2.46 items/m^3	Fibres	95.9 %	Lusher et al., 2014
North-East Atlantic (2015)	Subsurface pump	20	Range: 0–6.5 items/m^3	Fibres (rayon)	94 % (63)	Kanhai et al., 2017
Scotland (2014–2020)	Neuston catamaran	398	0–91,128 items/km^2	Fragments	50 %	Russell and Webster, 2021

Country (year)	Survey type	No. of samples	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Water Coastal North-East Atlantic (2011)	Manta (333µm)	152	0–1.5 items/m^3 Total: 3,597	Fragments	-	Maes et al., 2017
Skagerrak/Kattegat, Baltic Sea and Gulf of Bothnia (2014)	Manta trawl	24	Median: 0.04items/m^3	Fibres (polyethylene)	-	Schönlau, et al., 2020
Skagerrak/Kattegat, Baltic Sea and Gulf of Bothnia (2014)	In situ filtration pump	11	Median: 0.10items/m^3	Fibres	-	Schönlau, et al., 2020
Gullmar fjord, Sweden (2017)	Trawl	10	0.18–0.92 items/m^3	Microplastics fragments	68 %	Karlsson et al., 2018
Gullmar fjord, Sweden (2017)	In situ filtration pump	6	0–0.4 items/m^3	Microplastics fragments	85 %	Karlsson et al., 2018

5.2.2.2.3. Mediterranean Sea

Several studies have been published on microplastics in the Mediterranean and a selection is given in Table 21. A dedicated literature review has been undertaken by Cincinelli et al. (2019) and more recently by Simon-Sánchez et al. (2022). Most studies have traditionally used a manta trawl with a mesh size of 300 µm resulting in levels from several 100,000 to over 1,000,000 microplastics in the South Adriatic Sea. The quality of the different studies varies largely in terms of confirmation of the microplastics found often lacking chemical confirmation. This is especially the case for fibres which could be synthetic or natural. Another drawback is that smaller size fractions are not covered and there are indications that these fractions (> 500 µm) (Suaria et al. 2016) are most abundant. Limited harmonised data is available to be able to compare different regions in the Mediterranean but in every part of the Mediterranean more than 100,000 microplastics are found per square kilometre (0.1 item/m^2).

Table 21 National and sub-regional data identified for microlitter in the surface and subsurface waters of the Mediterranean

Location	Environmental compartment	Date	Numer of samples	Sampling	Depth	Density (min-max)	References
North West Mediterranean Sea	Surface	2010	40	Manta Trawl 330 µm	Surface	115,000 / km²	Collignon et al., 2012
West Sardinia	Surface	2012	30	Manta Trawl 500 µm	Surface	150,000 items/ km²	Da Lucia et al., 2014
Mediterranean Sea	Surface	2015	39	Manta Trawl 200 µm	Surface	243,853 items/ km²	Cozar et al., 2015
Slovenia	Surface	2012–-2014	17	Manta Trawl 330 µm	Surface	471,900 items / km²	Palatinus et al., 2015
Italy/ North Adriatic	Surface	2014	11		Surface	63,175 items / km²	Mazziotti et al., 2015
Italy/South Adriatic	Surface	2013	29		Surface	1,050,000 items / km²	Suaria et al., 2015
North West Mediterranean Sea	Surface	2011–2012	41	Manta Trawl 330 µm	Surface	130,000/ km²	Faure et al., 2015
Türkiye/North-East Levantine	Surface	2017	14	Manta Trawl 333 µm	Surface	1,067,120/km²	Gündogdu, 2017

5.2.2.2.4. Black Sea

The first study of microplastics in surface waters from the Black Sea was published in 2016 (Aylan et al., 2016), which was recently followed by two more recent studies from 2019 (Totoiu et al., 2020, Tayyip et al., 2020) (Table 22). The two recent studies report levels lower than the first study from 2016, the main reason being that fibres are included in the earlier study without confirmation analysis. The later studies are performed using more advanced analysis and are more consistent.

Table 22 National and sub-regional data identified for microlitter in the surface and subsurface waters of the Black Sea

Location	Environmental compartment	Date	Number of samples	Sampling	Depth	Density (min-max)	References
South-Western Black Sea Romania Bulgaria	Floating Microplastics	2019	18	Manta Trawl 200 µm	Surface	6.35–78.9 2.75–99.45 items/m³	Țotoiu et al., 2020
Western Black Sea Romania	Floating Microplastics	2014–2015	12	Neuston Net 200 µm	Surface /Top Layer	1,100 items/m³ > 50 % fibres	Aytan et al., 2016
South Eastern Black Sea Türkiye	Floating Microplastics	2019	14	Manta Trawl 333 µm	Surface	1.78–40.03 items/m³	Tayyip et al., 2020

5.2.2.3. Macrolitter on the seafloor

The seafloor is a sink for marine litter which is why seafloor surveys are important to investigate accumulation trends or changes in abundance of litter items (GESAMP, 2019). Systematic collections of litter data have been developed within several regional seas' programmes, including HELCOM, OSPAR and UNEP/MAP. Much of these have been developed in response to the MSFD Criterion 10.1.2: *Trends in the amount of litter in the water column (including floating at the surface) and deposited on the seafloor, including analysis of its composition, spatial distribution and, where possible, source.* Galgani et al. (2021) presented an overview of seafloor litter data collected through bottom trawling assessments, showing variable trends in European seas, including those that are stable in the Mediterranean and North Sea (García-Rivera et al., 2018; Maes et al., 2018), increasing in the Baltic (Zablotski et al., 2019), and mixed trends in France (Gerigny et al., 2019). Decreases have been observed in the Alboran Sea and Adriatic (García-Rivera et al., 2018; Strafella et al., 2019).

5.2.2.3.1. Baltic Sea

Litter identified on the Baltic Sea seafloor is monitored in connection to fish trawling surveys, through the Baltic International Trawl Survey (BITS), but does not cover all parts of the Baltic Sea, such as shallow waters or complex substrates (HELCOM, 2018c). As an example, 58 % of hauls (n = 1,599) in 2012–2016 contained marine litter items (HELCOM 2018b). Plastics were the most common litter category in the Baltic Sea (30 % by number, 16 % by weight) whereas, the debris that dominated most sub-basins were natural materials (wood, natural fibres and paper) and plastic items. The report found that there was a weak but statistically significant increase in non-natural seafloor litter over the studied period (Table 23).

Table 23 National and sub-regional data identified for macrolitter on the seafloor of the Baltic Sea

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Polish Maritime Areas (2015–2016)	Bottom trawl	86 tows	Total: 334 Range: 0–2.23/ha Mean: 0.2	Artificial polymer materials	67 %	Urban-Malinga, et al., 2018
Baltic Sea (2013–2015)	Bottom Trawl	79	5.07/km^2	Artificial polymer materials	66 %	Kammann et al., 2018
Baltic Sea (2012–2017)	Bottom trawl	2377 tows 53 cruises	Total: 6,828 items	Natural products (Artificial polymer materials)	42 % (35 %)	Zablotski and Kraak, 2019.

5.2.2.3.2. North-East Atlantic Ocean

OSPAR developed an indicator which focuses on using litter caught during fisheries surveys to assess the relative distribution of litter on the seafloor. The most recent assessment of seafloor litter was undertaken in 2017 as part of the OSPAR Intermediate Assessment of the NEA (OSPAR, 2017). Data between 2012–2016 was accessed utilising the ICES databases. Much of the seafloor litter data was obtained from the IBTS Working Group, which coordinates fishery-independent multi-species bottom trawl surveys within the ICES area. Plastics made up a large proportion of the litter items reported in 2014, specifically, 68 % for the Greater North Sea, 58 % for the Celtic Sea and 98 % for the Eastern Bay of Biscay.

As some of the surveys utilised different approaches, the Intermediate Assessment concluded that it is not possible to directly compare results from the Greater North Sea and Celtic Seas, which used a Grande Ouverture Verticale (GOV) trawl, to results from the Iberian Coast and Gulf of Cadiz, which were sampled with an otter trawl. Furthermore, it indicated that there is moderate confidence in the methodology and low to moderate confidence in the data. Subsequent data has been presented in the recent literature which is summarised in Table 24.

Table 24 National and sub-regional data identified for macrolitter on the seafloor of the North-East Atlantic Ocean

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
North Sea (2013–2015)	Bottom Trawl	95	16.8/km^2	Artificial polymer materials	83 %	Kammann et al., 2018
North-East Atlantic (1992–2017)	Bottom Trawl	39 surveys 2461 trawls	Max 1,835 items/km^2	Artificial polymer materials	65–94 % (2011 only)	Maes et al., 2018

5.2.2.3.3. Mediterranean Sea

Several studies used trawling to determine the amounts of macrolitter on the seafloor of the Mediterranean Sea (Table 25). Levels were both reported as number of items/km^2 and kg/km^2. The number of items varied from 13 items to more than 1,000 items/ km^2, depending on the area sampled. The items consisted predominantly of plastic materials (60–80 %). On a weight basis, plastics were also the most abundant litter item followed by glass items. Large variation was seen from 0 to 42 kg/km^2 but no temporal trends or decline of marine litter was seen over a 15–year period (García-Rivera et al. 2018). For the French part of the Mediterranean (Gulf of Lion and Corsica) less than 200 items per km^2 were found in the period from 1994–2006, in the period from 2008 to 2017 the level increased to just under 300 items per km^2 with the highest levels in 2015 again consisting mainly of plastics.

Table 25 National and sub-regional data identified for macrolitter on the seafloor of the Mediterranean Sea

Country (year)	Survey type	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Adriatic Sea	Bottom Trawl	913 items/km^2	Artificial polymer materials	80 %	Pasquini et al., 2016
Greece	Bottom Trawl	72–437 items/km^2	Artificial polymer materials	80 %	Koutsodendris et al., 2008
Sardinia	Bottom Trawl	58.6 ± 5.7 items /km^2	Artificial polymer materials	60 %	Alvito et al., 2018
Greece	Bottom Trawl	1,211±594 items /km^2 641±579 items /km^2 416±379 items /km^2 24±28 items /km^2	Artificial polymer materials	80 %	Ioakeimidis et al., 2014
Türkiye	Bottom Trawl	13.3–651 items /km^2	Artificial polymer materials	72 %	Olguner et al., 2018
France (1994–2017)	Bottom Trawl	49.63–289.01 items/km^2	Artificial polymer materials	71 %	Gerigny et al., 2019
France (2013–2017)	Bottom Trawl	9.18– 1,942 kg/km^2	Artificial polymer materials		Gerigny et al., 2019
Adriatic Sea	Bottom Trawl	103 ± 42 kg/km^2	Artificial polymer materials	43 %	Strafella et al., 2019
Gulf of Alicante	Bottom Trawl	0–11.6 kg/km^2	Artificial polymer materials	68 %	García-Rivera et al., 2017
Balearic Island	Bottom Trawl	1.39 ± 0.13 kg/km^2	Artificial polymer materials	66 %	Alomar et al., 2020
Spain	Bottom Trawl	9.8 ± 42.9 kg/km^2	Artificial polymer materials	29 %	García-Rivera et al., 2018
France	Bottom Trawl				Galgani et al., 2000

5.2.2.3.4. Black Sea

The seafloor levels in studies from the Black Sea vary largely from 1 to 20,000 items per km², the highest number of items were reported in 2013 (Moncheva et al., 2015), while significantly lower amounts were reported in subsequent studies in 2019 (Table 26).

Table 26 National and sub-regional data identified for macrolitter on the seafloor of the Black Sea

Country (year)	Survey type	Number of surveys	Total number of items	Most abundant item	Proportion of most abundant item	Reference
SW Black Sea, Türkiye (2010)	Bottom Trawl	14	128–1,320 items km⁻² (mean: 541 items /km²)	Artificial polymer materials	89.9 %	Topçu and Öztürk 2010
Black Sea (2013) Bulgaria Romania Türkiye	Bottom Trawl	6	300–20,000 / km² 9,500 items /km² 20,000 items /km² 7,956 items /km²	Artificial polymer materials	68 %	Moncheva et al., 2015
Black Sea (2011–2014) (2019)	Bottom Trawl	73	1,068 items /km² 300 items /km²	Artificial polymer materials	74–96 %	Galatchi et al., 2020
Black Sea (2013) Constanta	Bottom Trawl	16	1–48 items /km²	Artificial polymer materials	45 %	Ioakeimidis et al., 2014
SE Black Sea Türkiye (2019)	Bottom Trawl	30	Mean: 261.61±89.42 items /km²	Artificial polymer materials	67 %	Kasapoğlu et al. 2020
SW Black Sea Türkiye (2019)	Bottom Trawl	14	30–390 items /km²	Artificial polymer materials	72 %	Uzer et al., 2020

5.2.2.4. Microlitter on the seafloor

Microlitter studies focus on microplastics, with more and more methods ensuring the particles are confirmed as polymeric. AMAP recently released guidelines for monitoring microlitter and microplastics in benthic surface sediments and OSPAR and HELCOM are currently developing recommendations for seafloor microlitter as candidate indicators. Therefore, much of the information collected comes from uncoordinated scientific investigations.

5.2.2.4.1. Baltic Sea

Microlitter sampling has been carried out in the Baltic Sea using several different methods for research purposes with coordinated monitoring still under development. Selected results are presented in Table 27. Of the research available for benthic seafloor samples, many of the methods applied vary which hampers comparisons between investigations. For example, box corers, size fractionation and multistep digestion with (partial) chemical confirmation of particles has been carried out in Denmark (e.g. Strand et al., 2019). Box corers and Van Veen grabs have been used for surveys from Germany applying different density separation and chemical or enzymatic digestion, supported by (partial) chemical confirmation of synthetic materials.

Table 27 National and sub-regional data identified for microlitter on the seafloor of the Baltic Sea (DW: dry weight; WW: wet weight)

Country (year)	Sampling method	Number of samples	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Baltiysk Strait, Russia (2015)	Dredge	7	Average: 34 (10)/kg dw	Fibres	/	Zobkov and Esiukova, 2017
Danish waters (2015)	HAPS corer/ van Veen grab	12	202–2,511/kg dw 30–1,340/kg ww	Microplastic Fibres	/	Strand, et al., 2019
Gdansk Bay (2014)	/	6	0–27/kg dw	Fibres (polyester)	(50 %)	Graca et al., 2017

5.2.2.4.2. North-East Atlantic Ocean

Most of the sampling in the NEA has not been designated for any specific monitoring programme. Much of the work on microlitter has centred on the investigation of microplastics and other anthropogenic items by research scientists. Selected results are presented in Table 28.

Table 28 National and sub-regional data identified for microlitter on the seafloor of the North-East Atlantic Ocean (DW: dry weight)

Country (year)	Survey type	Number of stations	Total number of items	Most abundant item	Proportion of most abundant item	Reference
North Sea, Denmark (2015)	HAPS core	10	192–675 items/kg dw	Fibres	90–100 %	Strand and Tairova, 2016
North Sea (2013–2014)	van Veen	27	0–3,146 items/kg dw Average: 421 items/kg dw	Spheres	/	Maes et al., 2017
North Sea, UK (2017–2018)	van Veen grab	24	1921 6–532/kg dw Average: 80 items/kg	Microfibre	54 %	See et al., 2020
Galway Bay, Ireland	Sediment van Veen	27	/	Fibres	93 %	Pagter et al., 2018
Algarve, Portugal	Dive transect	10 transect, 27 samples	Total: 31	Rayan	25/31	Frias et al., 2016
Bay of Biscay (2014)	van Veen grab	18	0.97 ± 2.08 items/kg dw	Fragments	71 %	Frere et al., 2017
Bay of Biscay (2012)	van Veen grab	2	7.5 items per 50 ml of sediment; 150 items/ kg dw	Fibres	100 %	Sanchez-Vidal et al., 2018

Country (year)	Survey type	Number of stations	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Irish Continental Shelf (2014)	Cores	11	Total: 62 Mean: 7.7 (2.1) Galway Bay Mean: 6.3 (4.9) offshore.	Fibres	85 %	Martin et al., 2017

5.2.2.4.3. Mediterranean Sea

Studies on microplastics in the Mediterranean are difficult to compare due to the different analytical methods and size ranges analysed. A selection of recent studies is given in Table 29 showing that microplastics are abundant in the seafloor sediments but that levels vary from 0.4 to 900 microplastics and fibres are the majority of the microplastics found.

Table 29 National and sub-regional data identified for microlitter on the seafloor of the Mediterranean Sea (DW: dry weight)

Country (year)	Survey type	Number of stations	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Spain (2015) Spanish Mediterranean	Sediment	10	46 to 280 items/kg dw	Fibres	83 %	Filgueiras et al., 2019
Spain (2013) Mallorca/Cabrera	Sediment	3	100–900 items/kg dw	Fibres	60 %	Alomar et al., 2016
Italy (2017) Northern Tyrrhenian	Sediment	29	0.43–4.0 items/kg dw	Fibres	74 %	Mistri et al., 2020
Italy (2012) Northern Tyrrhenian	Sediment	3	62 ± 24 items/kg dw	Fibres	> 88 %	Cannas et al., 2017
Croatia (2015) North Adriatic	Sediment	6	3.4–84 items/kg dw	NA	NA	Blaškovic et al., 2017
Greece (2017) Samos	Sediment Core	3	1.1 ± 0.9 items/kg dw	Fibres	NA	De Ruijter et al., 2019

5.2.2.4.4. Black Sea

Only recently the first data on microplastics in sediments taken at different depths (22 – 2,131 m) throughout the Black Sea was published. In more than 80 % of the sediment samples microplastics were found, averaging 106 particles/kg and mostly consisting of polyethylene and polypropylene, followed by acrylate and acrylonitrile and polyamide fibres. Levels from the deep-sea areas were 10 times lower than the samples from coastal sediment from the North-Western shelf. These levels are in agreement with coastal sediments from the coast where 131 microplastics/ kg were found (Table 30).

Table 30 National and sub-regional data identified for microlitter on the seafloor of the Black Sea (DW: dry weight)

Country (year)	Survey type	Number of stations	Total number of items	Most abundant item	Proportion of most abundant item	Reference
Romania, Black Sea (2016–2018)	Coast and Marine Sediment	13	131 ± 2 Particles/kg dw	NA	NA	Pojar et al., 2021
Joint Open Sea Survey (2017)	Coast and Deep Sea Sediment	12	0 – 390 Particles /kg dw. Average 106.7 particles /kg dw	Fibres	NA	Cincinelli et al., 2021
Türkiye, SE Black Sea	Marine Sediment	14	74.1 to 1,778.8 particles/m^2 (0.004–0.192 particles/ml)	Fibers	66.6 %	Aytan et al., 2020b

Box 1 Ghost-fishing gear

Derelict abandoned, lost and discarded fishing gear (ALDFG) have been reported throughout European waters. The amount of ALDFG in the marine environment reflects the rapid expansion of fishing efforts and fishing grounds, as well as the use of cheap, synthetic materials which are more durable and buoyant than their natural alternatives. When fishing gear is either accidentally lost or intentionally abandoned at sea, both situations result in it being no longer serviced or tended by fishermen. Although fishermen will often attempt to locate and retrieve lost gear due to the economic cost (Lively and Good, 2019). Derelict fishing gear has been identified as a profound stressor for both coastal and marine ecosystems (FAO, 2020).

Ghost fishing refers to the duration/action by which ALDFG continues to fish and trap marine animals, often leading to entanglement and death of the caught animals, smothering of marine habitats, obstructing in-use fishing gear and causing a navigation hazard. ALDFG without any potential to continue catching fish or other animals would not be called ghost gear (GESAMP, 2020). Species that are at risk of capture in ghost fishing nets, traps and pots include both market species, and bycatch, such as vulnerable species (including 46 % of the species on the IUCN Red List of Threatened Species, i.e. turtles, whales, dolphins etc; FAO, 2020). Similarly, a global review on ghost gear interactions revealed that more than 5,400 individuals representing 40 species (mammals, reptiles and elasmobranchs) were either entangled in or associated with ghost nets (Stelfox et al. 2016). In the most recently available review of ALDFG, Gilman et al. (2021) assessed gear-specific relative risks, with ghost fishing identified as an adverse consequence from the derelict gear. The highest-risk gears were identified as set and fixed gillnet and trammel nets, drift gillnets, tuna purse seine with Fish Aggregating Devices (FADs), bottom trawl and pole-and-line with anchored FADs. When including estimates of adverse ecological and socioeconomic effects, set and fixed gillnets and trammel nets and drift gillnets had the highest scores for relative adverse outcomes.

As there is limited information on the magnitude of marine debris, global estimates of the amount of ghost fishing gear in the ocean are highly uncertain (e.g., 1.14 Mt of derelict gear leaked annually into the marine environment, EUNOMIA, 2016). This is further hampered by the loss of gear at depths, and where the consequences can go unobserved. Therefore, the impact of ghost fishing is difficult to quantify as ghost fished individuals either die, are consumed by predators or decompose without being recorded. One estimate of lost fishing panels from gillnets and entangling nets along the Black Sea coast of Türkiye calculated a log of 1,626.8 panels/year, which is 1.5 % of the overall panels in use (Dagtekin et al. 2018). ALDFG which is in the benthic region, can become entangled amongst rocks, which stress and damage sessile and suspension feeders, such as sponges and corals (Consoli et al., 2019; Angiolillo and Fortibuoni, 2020). As an example, 78 % of litter items identified during and remote operated vehicles survey in the Tyrrhenian Sea (Mediterranean Sea) were identified as derelict fishing gear, the majority of which were longlines. Of these debris, 29 % had entangled corals (Consoli et al., 2019). ALDFG made of plastic will degrade very slowly, remaining in the marine environment for decades if not removed, and becoming a source of microplastics. Thus, presenting an additional hazard of the risk of ingestion by marine organisms (OSPAR, 2020; Stolte et al., 2020).

5.2.3. Litter in marine biota

Marine litter can impact biota in several ways including ingestion and subsequent reduced feeding, injuries and lacerations caused by entanglement, the provision of new habitat which can facilitate the transport of invasive or alien species and the smothering of habitats. Marine birds can also use plastics for nest materials which also adds another element of risk of entanglement (e.g., Kühn et al., 2015; Kühn and van Franeker, 2020). Two of the criteria reported in the Commission Decision (2017/848/EU), associated with the MSFD, is related to the impact of litter on marine biota in terms of ingestion (D10C3) and entanglement or other injuries (D10C4), although the methodological approaches and requirements by country are not fully ratified. Understanding the impact of litter on biota is valuable to access the ecosystem scale impact of litter pollution. Several perspectives on the use of marine species and indicators for plastics pollution have been published including those for bivalves, fish, birds, mammals and turtles (e.g., Bonanno and Orlando-Bonaca, 2018; Li et al., 2019; Galgani et al., 2014; O'Hanlon et al., 2017; Matiddi et al., 2019). The recent EU-funded project INDICIT ([23]) aimed at developing standardized tools for monitoring the impacts of litter on marine fauna as a bio-indicator.

5.2.3.1. Macrolitter and megafauna

Macrolitter has the most visible impacts on marine megafauna (birds, mammals, reptiles). Interactions between megafauna and macrolitter can be grouped into entanglement and ingestion, with negative consequences often surmounting to the death of individuals.

5.2.3.1.1. Birds

Seabirds are commonly identified as a group of species impacted by marine litter (e.g. Kühn and van Franeker, 2020; Battisti et al., 2019; O'Hanlon et al., 2017). OSPAR developed an indicator of marine litter based on stomach content of the Northern fulmar (*Fulmarus glacialis*). These birds forage almost exclusively at the sea's surface, and they regularly ingest a variety of marine debris items. Fulmars do not regurgitate indigestible items. So, any items unable to be broken down and digested will remain in the stomach of the individual. Thus, fulmar stomach contents integrate litter abundance encountered during feeding over periods. The "*Coordinated Environmental Monitoring Programme (CEMP) Guidelines for Monitoring and Assessment of plastic particles in the stomachs of fulmars in the North Sea area*" was developed to give an indication of plastic impact on biota and a long-term goal that less than 10 % of fulmars would exceed a level of 0.1g of plastics in their stomachs (Ecological Quality Objective, EQO). An OSPAR assessment ([24]) covering the period between 2012 and 2016 found that 56 % of beached North Sea fulmars had more than 0.1g of plastics in their stomachs which exceeds the 10 % goal. Nevertheless, data suggests that the amounts of ingested plastics have significantly decreased over the 10 years period (2007–2016).

Research has also suggested that there is a North-South dimension related to the percentage of birds exceeding the 10 % limit: 86 % of birds from the English Channel, 60 % in the North Sea, 41 % in the Faroe Island, 28 % in Iceland and 23 % in Svalbard (Trevail et al., 2015). During the first assessment of plastic ingestion by seabirds in Ireland, 93 % of Northern Fulmars had ingested plastic debris and were over the 0.1g EQO threshold (Acampora et al., 2016). Data collected in the 1980s found that half of the plastics found in fulmars were from an industrial origin, whilst the other half was user plastics. Now, user plastics outnumber industrial plastics by a factor of 10 (Van Franeker et al., 2015). Fulmars are abundant in the North Sea, and NEA, but are less abundant and occur rarely in the Baltic Sea, suggesting that other species should be

[23] https://indicit.cefe.cnrs.fr/

[24] https://oap.ospar.org/en/ospar-assessments/committee-assessments/human-activities/marine-litter/plastic-particles-in-fulmar-stomachs-north-sea/ Accessed in July 2021

explored for their suitability as indicators for regions where fulmars are less abundant. During a baseline investigation of plastic ingestion in 15 species of seabirds from the Bay of Biscay, 16 % of individuals were found to contain plastics, with the common guillemot (*Uria aalge*) and Atlantic puffin (*Fratercula arctica*) suggested as candidate biomonitoring to assess impact in the region (Franco et al., 2019).

In a synthesis of the impact of plastic litter on seabirds from the NEA, 25 out of the 69 seabird species that commonly occur in the region had evidence of plastic ingestion (O'Hanlon et al., 2017), although the authors noted that the data were sparse (only 34 species were investigated for plastic ingestion) with small sample sizes, and robust comparisons were not possible.

Another (potential) indicator of interactions between birds and macrolitter is the utilisation of macrolitter as nesting material. Although research into the source and quantity of plastics in seabird nests is relatively rare (Thompson et al., 2020), the majority of macrolitter observations are in the form of ropes and fishing nets. As an example, a study of a kittiwake (*Rissa tridactyla*) colony in northwest Denmark found that the percentage of nests containing plastic increased from 39 % to 57 % (1992 – 2005) (Hartwig et al., 2007). Similarly, the nest of a pair of Northern gannets (*Morus bassanus*) in the Pelages Sanctuary (Mediterranean Sea) consisted exclusively of fishing gear from the local mussel farming – polypropylene (95 %) and polyethylene net fragments (5 %) (Merlino et al., 2018). The incorporation of litter by Northern gannets into their nets has been observed in virtually all of the colonies situated in the North Atlantic. 46 % of nests sampled contained debris, which were largely fibres and likely to originate from fishing activities (O'Hanlon et al., 2019). In Scotland, nests of five seabird species were assessed for marine litter, with plastics identified in 24.5 % to 80 % of nests across the five species (Thompson et al., 2020). More than 30 % of yellow-legged gull (*Larus michahellis*) nests on San Pietro Island, Italy contained marine litter with expanded polystyrene being the most frequently encountered item (31 %) (Battisti, 2020).

5.2.3.1.2. Mammals

Marine litter has been identified as one of the major threats for marine mammals in Europe (Panti et al., 2019). Evidence of impacts on marine mammals comes from a variety of published and unpublished sources including information from standing networks (Baulch and Perry, 2014). The number of cases of the impacts of marine litter on marine mammals have increased over the last five decades, likely due to the result of an increased awareness of the issue. As of 2018, 11 of the 14 families of cetaceans have been reported to interact with marine litter (Fossi et al., 2018). Although, the number of records is unlikely to represent the extent of impact on marine mammals. Rather, what has been observed has strong bias based on the availability of the different species and other factors such as differential rates of stranding and necropsy (Panti et al., 2019).

This highlights the importance for standardised approaches to aid us in understanding the impacts of litter on marine mammals. It is likely that entanglement is under reported, whereas ingestion can only be studied when mammals are accessible, having either been stranded or been euthanised and a necropsy conducted. Based on available data Baulch and Perry (2015) reported that ingestion rates varied from 0 % to 31 % of animals necropsied, with high geographic, intra- and inter-specific variations in rates. Very few countries and stranding organisations can perform necropsies on stranded animals.

There are various ways to detect marine litter ingestion in marine mammals. Few standard protocols for the recording of plastic are currently available, and therefore the amount and size of plastic reported differs between research groups. Other methods have been identified to understand interactions with plastics, including the analysis of plastic additive in blubber tissues, as a proxy for ingestion and analysis of biomarker responses to detect potential toxicological effects (Panti et al., 2019). Currently there are no coordinated assessments of marine mammals although the UNEP/MAP MED POL report published in 2015 identified that monitoring should include sensitive species, namely marine mammals.

Marine mammal ingestion shows a range of pathologies from no discernible impact to blockage of the digestive tract, suffocation and starvation. Whereas entanglement can result in drowning, injury and strangulation. Ingestion appears more common for marine mammals with 56.1 % of all cetacean species observed to ingest plastics compared to 39.8 % of cetacean species being reported as entangled (Kuhn and van Franeker, 2020). Whilst these numbers seem high, only 860 out of 19,486 individuals (4 %) contained plastic. In the Mediterranean, marine mammals are amongst the identified potential indicator species for marine debris, with five species presently identified to be affected by litter ingestion (*Physeter macrocephalus, Balaenoptera physalus, Tursiops truncatus, Grampus griseus* and *Stenella coerulealba;* Fossi et al., 2018). One particular study from Greece observed that 60 % of sperm whales in Greek seas had litter (plastic) in their stomachs (Alexiadou et al., 2019).

5.2.3.1.3. Turtles

When the impacts of litter on marine animals was considered under the context of the MSFD, turtles were identified as a potential indicator species (Galgani et al., 2014). Turtles have been found to ingest litter items including plastic mainly as a result of confusion between prey but also opportunistic foraging strategies. As an example, 83 % of loggerhead (*Caretta caretta*) in the Azores ingested plastics, with average concentrations of 15.8 items per individual (1.07 g per individual) (Pham et al., 2017), although the sizes identified were mostly microplastics 1–5mm in size. A similar study in Portugal found that 56.8 % of turtles had ingested plastics (>5mm), with 9.7 items per individual (Nicolau et al., 2016). It is possible that the high quantities of plastics ingestion in the Azores could be related to the proximity to the North Atlantic gyre, or due to the different methods applied, as only > 5mm items were recorded for the study in Portugal. Ingesting plastics and other marine litter items by turtles may cause internal injuries, malnutrition, obstructions in the digestive system, increase buoyancy and poor growth rates or reproductive outputs whereas entanglement may cause lacerations, drag and starvation (Nelms et al., 2106). However, understanding the cause of death requires a full necropsy. A review of the available literature published found that six of the seven marine turtle species have been repeatedly observed to ingest plastics (Kuhn and van Franeker, 2020). Of the 140 records, one third of the 7,879 turtles analysed contained plastics in their stomachs.

Regarding incidences of sea turtle entanglement in litter, Duncan et al. (2017) presented an in-depth global review which found 23 reports of sea turtle entanglement, which occurred across all species, life stages and ocean basins. In most instances entangled individuals were dead (90 %), with ghost gear contributing to most of the reports.

5.2.3.2. Microlitter and fauna

Microlitter is being increasingly reported across a wide array of species from European waters. To provide an extensive review is unfeasible in this current report. Thus, presented in this section are summaries of noteworthy reviews and publications from recent years. In general, much of the information available on micro and mesolitter has a focus on microplastics.

A global review of microplastic ingestion by vertebrates (mammals, seabirds, turtles and fish) identified 132 studies of which 77 came from the (entire) Atlantic, 35 from the Mediterranean and four from the Baltic Sea. In total 28.5 % of the studied individuals were found to contain microplastics (Ugwu et al., 2021). The consequences of microplastics presence and potential for bioaccumulation between species have been recently presented by Walkinshaw et al. (2020) and Miller et al. (2020).

5.2.3.2.1. Zooplankton

Zooplankton is a crucial link between primary producers and higher trophic levels, thus playing an important role in the marine food web. Ingestion of microlitter by zooplankton in their natural environment is reported (Desforges et al., 2015; Sun et al., 2017, 2018; Kosore et al., 2018; Md Amin et al., 2020; Taha et al., 2021; Aytan et al., 2022). Microlitter ingestion in the marine environment can affect the function and health of zooplankton and be moved to higher trophic levels via ingestion by predators.

5.2.3.2.2. Invertebrates

Invertebrates have been proposed as a potential indicator of microlitter in the marine environment (Li et al., 2018; Bonanno and Orlando-Bonaca, 2018; GESAMP 2019). For example, in their assessment of potential indicators for the Mediterranean region, Fossi et al. (2018) highlighted that most invertebrates could be considered as local scale indicators of the presence and impact of microlitter (mainly microplastics). Most of the existing literature reports ingestion by invertebrates in the context of their use for monitoring and therefore not as relevant for the purpose of assessing impact. Worth noting is the widespread occurrence or interaction reported across different species both water-filtering (e.g. Li et al., 2018; Phuong et al., 2018b; Rapp et al., 2021; Doyle et al., 2019; Hennicke et al., 2021) and deposit-filters (Fossi et al., 2018).

5.2.3.2.3. Fish

Most of the (global) studies of fish tend to focus on the whole gastro-intestinal tract (73 %), or the stomach (24 %), with the majority of particles identified being fibres (Ugwu et al., 2021). During an investigation of Atlantic horse mackerel (*Trachurus trachurus*) from the Sado Estuary, Portugal, 70 % of individuals presented microplastics with an average of 2.24 (2.05) items /0.018 (0.016) grams per individual (Pequeno et al., 2021) whereas the Atlantic chub mackerel (*Scomber colias*) only displayed a 55 % occurrence. In the Mediterranean Sea, the number of fish species with a documented record of litter ingestion reached 60 (Fossi et al., 2018; Bray et al., 2019). Taking the observation of microplastics presence a step further, studies have begun to consider the toxicological effects of ingested items on wild species. 49 % of 150 fish (*Dicentrarchus labrax*, *T. trachurus* and *S. colias*) from the NEA were found to contain microplastics within the gastrointestinal tract, gills and dorsal mussels, with significantly higher lipid peroxidation levels and brain acetylcholinesterase activity than fish without microplastics (Barboza et al., 2020). For more information on the commercial important species please refer to Box 2 or the substantial report compiled on behalf of FAO (Lusher et al., 2017).

Consequences of microplastics ingestion by fish can include (but are not necessarily limited to) intestinal blockage, physical damage, histopathological alterations in the intestines, behavioural changes, changes in lipid metabolism, and transfer to the liver (e.g., Jovanovic 2017; Santillo et al., 2017).

Box 2 Implications for seafood

As microlitter and microplastics are commonly reported in marine species, which has raised concerns for the impacts it can have on commercial important species, including those destined for human consumption (Lusher et al., 2017). In the first assessment of the status of knowledge on the occurrence and implications of microplastics for aquatic organisms and food safety, the Food and Agricultural Organisation (FAO) Technical Report identified that there was a growing body of evidence of the occurrence of microplastics in wild-caught and cultured fish and shellfish intended for human consumption. Based on the data available, the report concluded that with the current state of available knowledge, the presence of microplastics was confirmed within many species, with the effects of microplastics being studied in the laboratory and some studies showed the ability for nanoplastics to move across tissues. Evidence is lacking on the effect of microplastics on food security and food safety. More research was required to understand the ingestion and accumulation of smaller sized particles, which have the potential to move into the edible tissues.

As the gastrointestinal tract of most fish and crustacean species is not commonly eaten, when present only low numbers of particles are generally found (Gamarro et al., 2020), it is more probable that animals which are eaten whole, such as bivalves, could be the main source of microplastics when considering seafood. It appears that species lower in the trophic food web are more susceptible to microplastics ingestion or internalisation (Walkinshaw et al., 2020).

Concern of microplastics presence in seafood requires research to understand and report potential human health risks (Smith et al., 2018). Currently there is insufficient evidence to consider the risks to human health (Walkinshaw et al., 2020; Gamarro et al., 2020). Researchers have identified the requirement for more harmonised approaches to quantify microplastics and other anthropogenic items in seafood species to allow comparisons between different studies and regions (e.g., Dehaut et al., 2019).

5.3. Insights into beach litter in Europe from the citizen science initiative “Marine Litter Watch”

The Marine Litter Watch (MLW) is a citizen science initiative from the EEA to collect quantitative information on marine litter from beaches in and around Europe. The MLW database has been populated with beach litter data since 2013 by “communities”, which are organised volunteer groups of citizens, such as NGOs, civil society associations and other kinds of informal groups (see http://www.eea.europa.eu/themes/coast_sea/marine-litterwatch).
Besides sea beaches, data from river and lake beaches are also included in the database. The MLW database also includes official data collected by some of the EU Member States from the beaches of the four European regional seas (the Baltic Sea, the Black Sea, the Mediterranean Sea and the NEA).

As such, there are two types of data collection events in the MLW – differentiated as "Clean-up" and "Monitoring". Whilst the monitoring data are collected by experienced MLW communities, fully applying the methodology for monitoring marine litter on beaches following EU MSFD TGML guidance (Galgani et al., 2013), clean-up surveys may not take MLW methodology fully into account and are typified by a relatively simple protocol and decreased number of litter items categories ([25]).

In this section, the MLW monitoring data collected during the period between 2015 and 2021 are used. Specifically for this assessment, analyses of the incidence of litter items attributed to PPSI, in terms of abundance and share to total litter, in the EU and regional seas, are conducted and presented. Annual PPSI abundances on beaches are determined using the median number of litter items/100 m, as proposed by Hanke et al. (2019). Note that the PPSI figures obtained are likely underestimated, since only well-identified items (i.e. items categorised as plastic bottles, plastic bags, etc.) are accounted as PPSI, i.e. plastic fragments, even if resulting from the fragmentation of PPSI litter, are excluded.

Note that perceived trends arising from the analysis must be interpreted with caution, given the limited period covered by the MLW initiative, as well as the difference in surveying effort between the years. Furthermore, it is possible that influence of the Covid-19 pandemic may be captured in beach litter data for the years 2020–2022, whether in terms of monitoring effort, litter abundance and/or composition. This will need to be assessed in the future.

5.3.1. Abundance, share and trends in PPSI beach litter at European level

This section presents the combined MLW monitoring data for all EU regional seas, collected between 2015 and 2021, and thus provides insights into the wider situation regarding the occurrence of PPSI in beach litter at the European level.

Annual evolution of PPSI litter abundance in the EU beaches is presented in Figure 29. This analysis suggests an increase in the abundance of PPSI litter during the assessed period, from a median of 73 items/100 m in 2015 to 233 items/100 m in 2021. Temporal differences in the share of different types of litter items emerge from these data, where the proportion of PPSI to total litter increased, from 44 % in 2015 to 65 % in 2021 (Figure 30). Litter items attributed to PPSI represent approximately half of the total litter recorded in the EU and plastics are the most abundant litter group, accounting for about 80–90 % of all beach litter.

[25] https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch/get-started/how

Figure 29: Temporal variation of abundances of litter attributed to PPSI (bottom, in orange) (median number items/100 m) on EU beaches between 2015 and 2021 (based on MLW monitoring data)

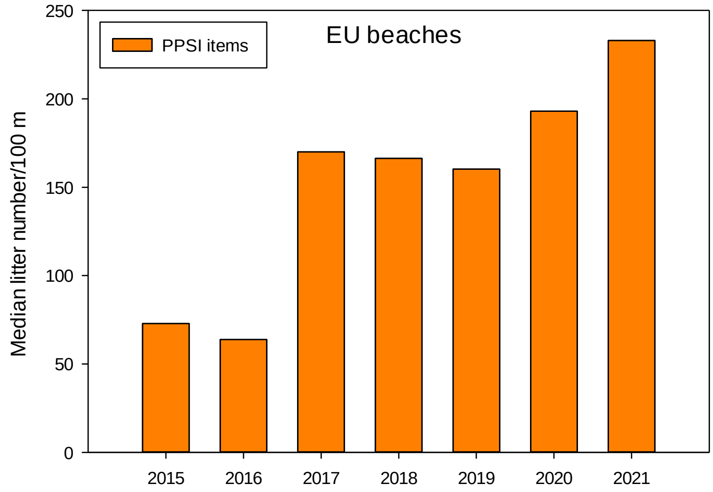
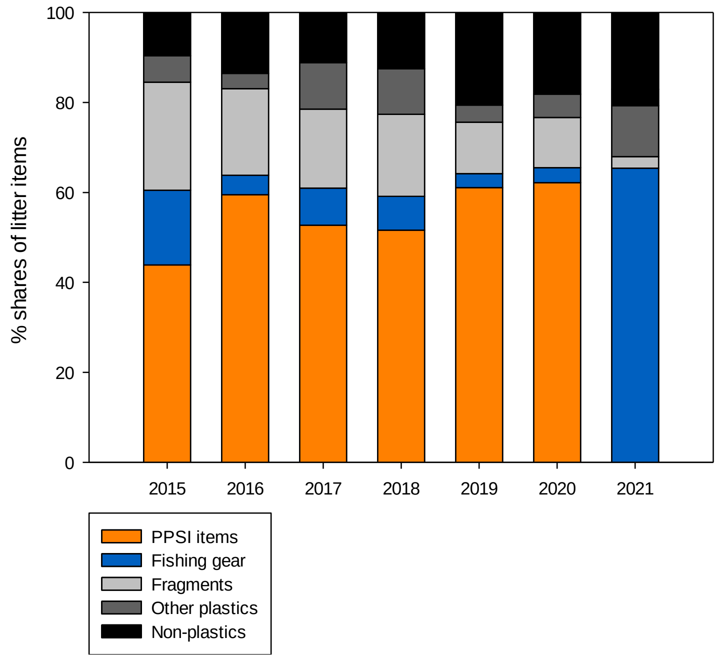


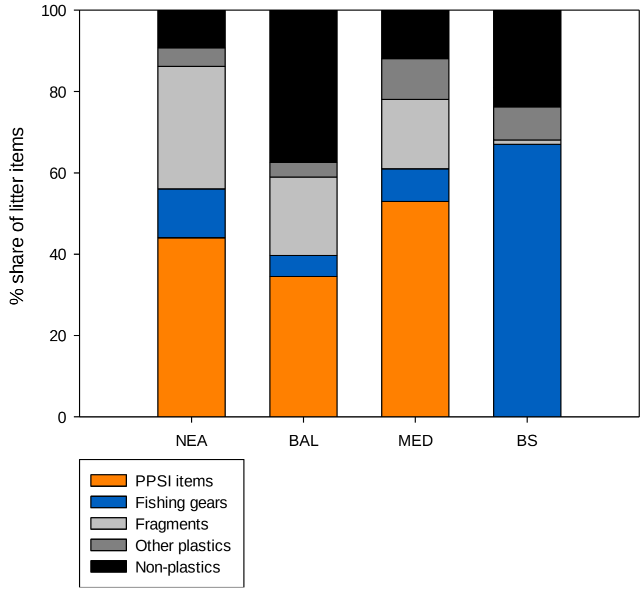
Figure 30: Annual share (%) of litter items attributed to PPSI, fishing gear, fragments, other plastics and non-plastic on European beaches, for the period 2015–2021 (based on MLW monitoring data) (PPSI: plastic packaging and small non-packaging plastic items)



5.3.2. Abundance, share and trends in PPSI beach litter across the four EU regional seas

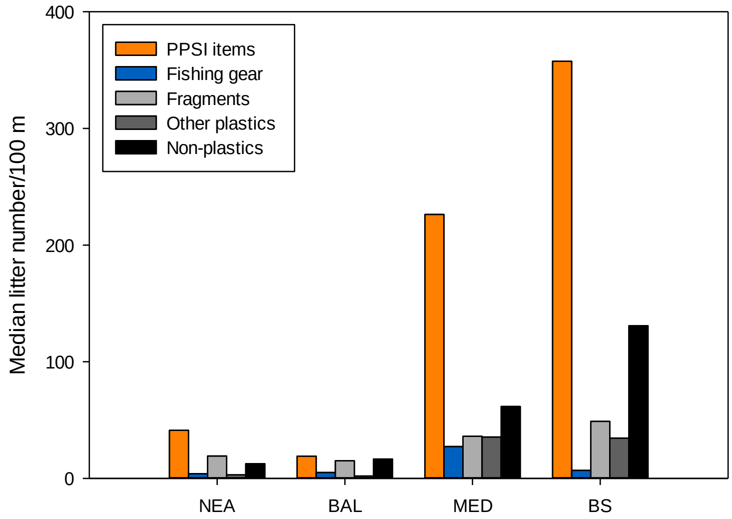
Clear differences in the composition of beach litter between the four seas of Europe emerged from the data analysis. PPSI is distinctly the most common litter category in the Black Sea and Mediterranean Sea, while being relatively less represented in the Baltic Sea (Figure 31). The relative contribution of PPSI to total litter items is higher in the more polluted regions (67 % in the Black Sea and 53 % in the Mediterranean Sea), than in the less polluted regions (44 % in the NEA and 34 % in the Baltic Sea).

Figure 31: Share (%) of items attributed to PPSI, fishing gear, fragments, other plastics and non-plastic in EU regional seas (MLW monitoring data, 2015–2021)



The aggregated incidence of each litter group across the four regional seas is depicted in Figure 32 and illustrates clear regional differences. Abundance of PPSI litter is highest in the Black Sea (median of 358 items/100 m), followed by the Mediterranean Sea (median of 226 items/100 m) and the NEA (median of 41 items/100 m), whilst the abundance of PPSI is lowest in the Baltic Sea (median of 19 items/100 m).

Figure 32: Abundance of litter items (median number items/100 m) attributed to PPSI, fishing gear, fragments, other plastics and non-plastic in European regional seas (aggregated MLW monitoring data 2015–2021) (PPSI: plastic packaging and small non-packaging plastic items; NEA: North-East Atlantic; BAL: Baltic Sea; MED: Mediterranean Sea; BS: Black Sea)

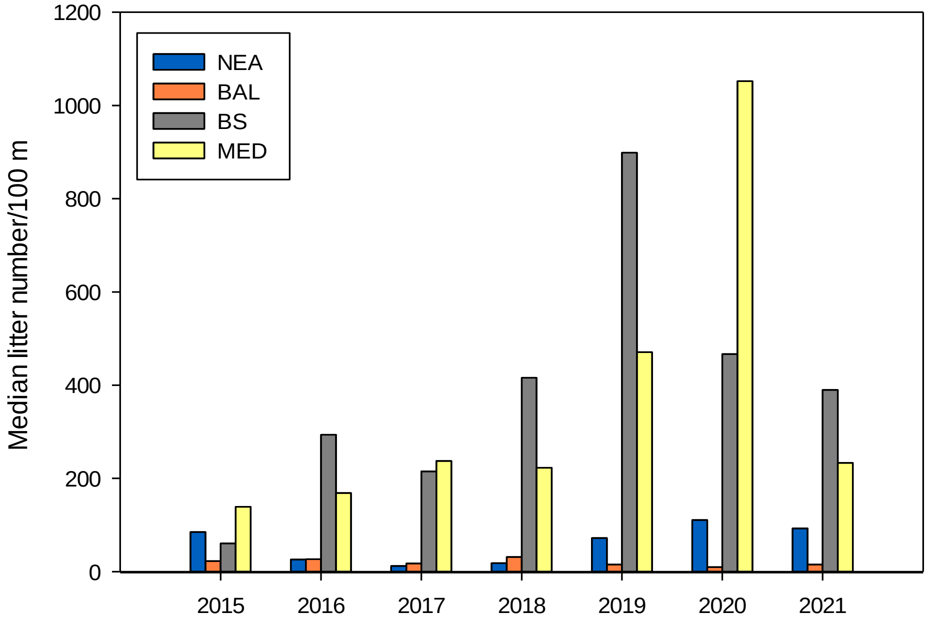


The abundance and share of PPSI items in total litter varies over time in the EU regional seas (Table 31 and Figure 33). Between 2015 and 2021, data suggest an increasing trend in PPSI amounts in all regional seas, except the Baltic Sea, reaching peak values in 2019 or 2020. In the NEA, however, the annual evolution is complex, and in the Baltic Sea a decrease in PPSI litter seems to have occurred over the analysed period.

Table 31 Annual abundance (median number items/100 m) of PPSI litter in Europe and the four regional seas (based on MLW monitoring data, 2015–2021)

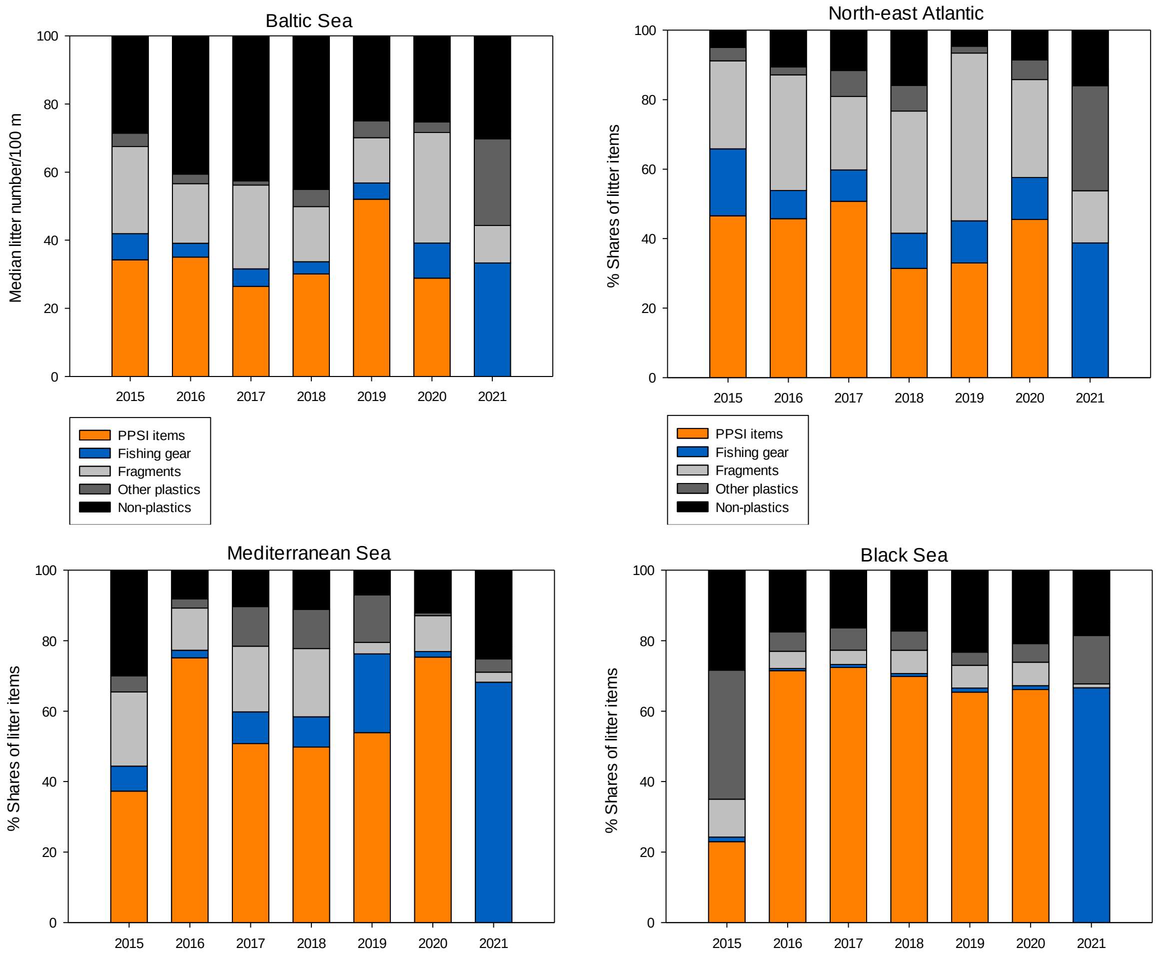
PPSI (items/100 m)	**NEA**	**BAL**	**MED**	**BS**
2015	85	23	139	60
2016	26	27	168	294
2017	12	18	237	215
2018	18	31	223	416
2019	72	15	471	899
2020	111	10	1052	467
2021	93	15	233	390

Figure 33: Temporal variation of annual abundance of litter items (median number items/100 m) attributed to PPSI litter in European regional seas between 2015 and 2021 (based on MLW monitoring data) (NEA: North-East Atlantic; BAL: Baltic Sea; BS: Black Sea; MED: Mediterranean Sea)



Finally, temporal variation in the share of different litter groups per regional sea is presented in Figure 34. The share of PPSI in total litter items varies between 37 % – 75 % in the Mediterranean Sea, 23 % – 72 % in the Black Sea, 31 % – 51 % in the NEA and 26 % – 52 % in the Baltic Sea.

Figure 34: Share (%) of items attributed to PPSI, fishing gear, fragments, other plastics and non-plastic in the four European regional seas between the period 2015 and 2021 (based on MLW monitoring data)



5.4. Indicator-based assessment on the status of marine litter pollution

A prototype multi-metric indicator-based assessment tool focusing on marine litter has been developed. The name of this tool is the 'Marine Litter Assessment Tool' abbreviated to MALT. Annex 5 explains the MALT tool principles in more detail. The data used have been described in section 5.1.1.1.

Although the MALT tool is designed to integrate multiple indicators, this preliminary assessment is based on the use of three indicators: (i) the count of beach litter items per 100 m; (ii) the count of seafloor litter items per km^2; and (iii) the count of floating microlitter particles per m^3 in surface water samples. It is preferable to apply indicators for which a published threshold value exists. In the case of the beach litter, the European threshold value defined by the TGML of 20 items per 100 m (van Loon et al., 2019) is used. For the seafloor litter count, no officially approved threshold values were found. As such, the 15^{th} percentile of the counts of seafloor litter in the assessment dataset is applied (corresponding to 15.4 items/km^2). This method is therefore analogous to the method used to derive the beach litter threshold. An alternative, less restrictive threshold value (230 items/km^2) is proposed by UNEP (2016) and tested in Malta (Borja *et al.* 2021). The effect of these alternative threshold values on the MALT assessment results, both on the seafloor litter indicator as well as the overall status are shown in Annex 6. For floating microlitter, a tentative threshold value of 10 items per m^3 was applied.

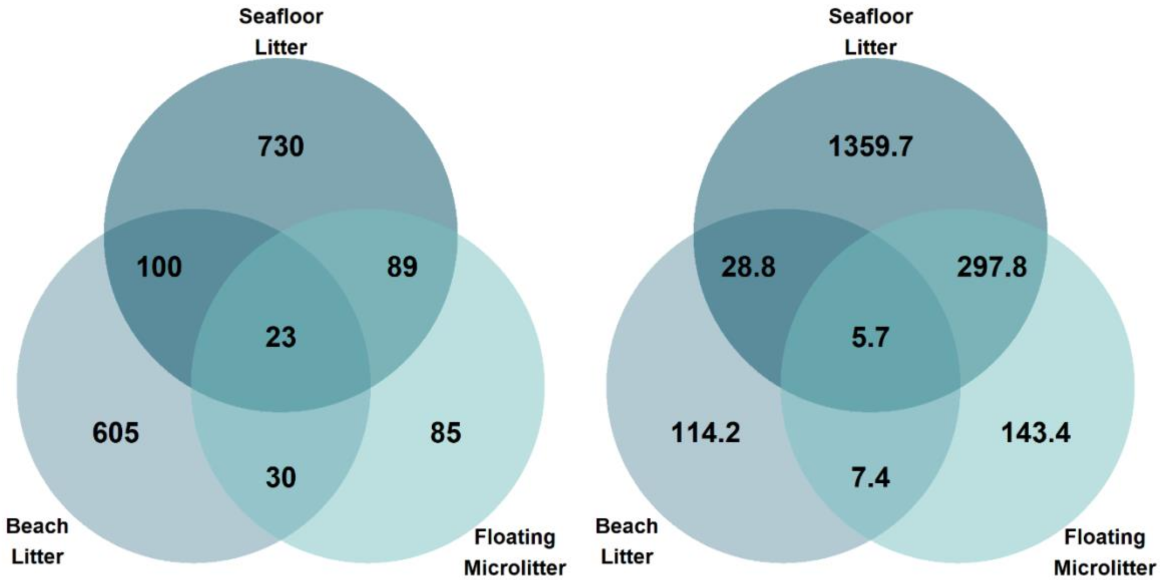
The litter counts corresponding to the minimum limit on the Ecological Quality Ratio (EQR) scale (corresponding to EQR = 0.0) were selected for each indicator by taking the 99^{th} percentiles of all the litter counts available. It should be noted that altering this limit will affect the distribution of results between the "problem" classes ("Moderate", "Poor" and "Bad") but does not affect the overall fraction of results assessed to be "problem" or "non-problem" areas, since this is determined by the Good/Moderate threshold value.

The potential weakening of confidence in the assessment which might result from the application of untested threshold values must be balanced with the desire to achieve the greatest possible assessment coverage in terms of available types of litter data. As better threshold values become available, these can easily be incorporated, replacing the values employed here. Also, as thresholds become available for other marine litter metrics or for more specific indicators e.g. within different categories of beach litter, these can be integrated into the MALT assessment procedure with minimal effort.

Recent EEA marine assessments (summarized in Reker et al., 2020) of hazardous substances, eutrophication, biodiversity, overall ecosystem health have all been based on the same EEA assessment grid, first developed by ICES for the assessment of hazardous substances. To maintain continuity between previous assessments and this present assessment of marine litter, the beach litter, seafloor litter and water column microlitter counts were matched to the same assessment grid. It should be noted that even though the beach litter indicator employed is a count per unit length of beach, the use of this 2-dimensional assessment grid means that the results of the assessment are given in terms of *area* of assessment grid cells (km^2) where status was evaluated. Status is determined within each assessment grid cell.

Error! Reference source not found. Figure 35 shows the number of assessment units and the area assessed using each of the three indicators. In 730 assessment units (1,359,700 km^2), status was based on seafloor litter counts alone. For 605 assessment units (114,200 km^2) status was based only on beach litter counts. Assessments were made using all three indicators in 23 assessment units (5,700 km^2) both indicators were used.

Figure 35: Number of assessment grid cells (left) and area assessed [000's km2] (right) using each indicator

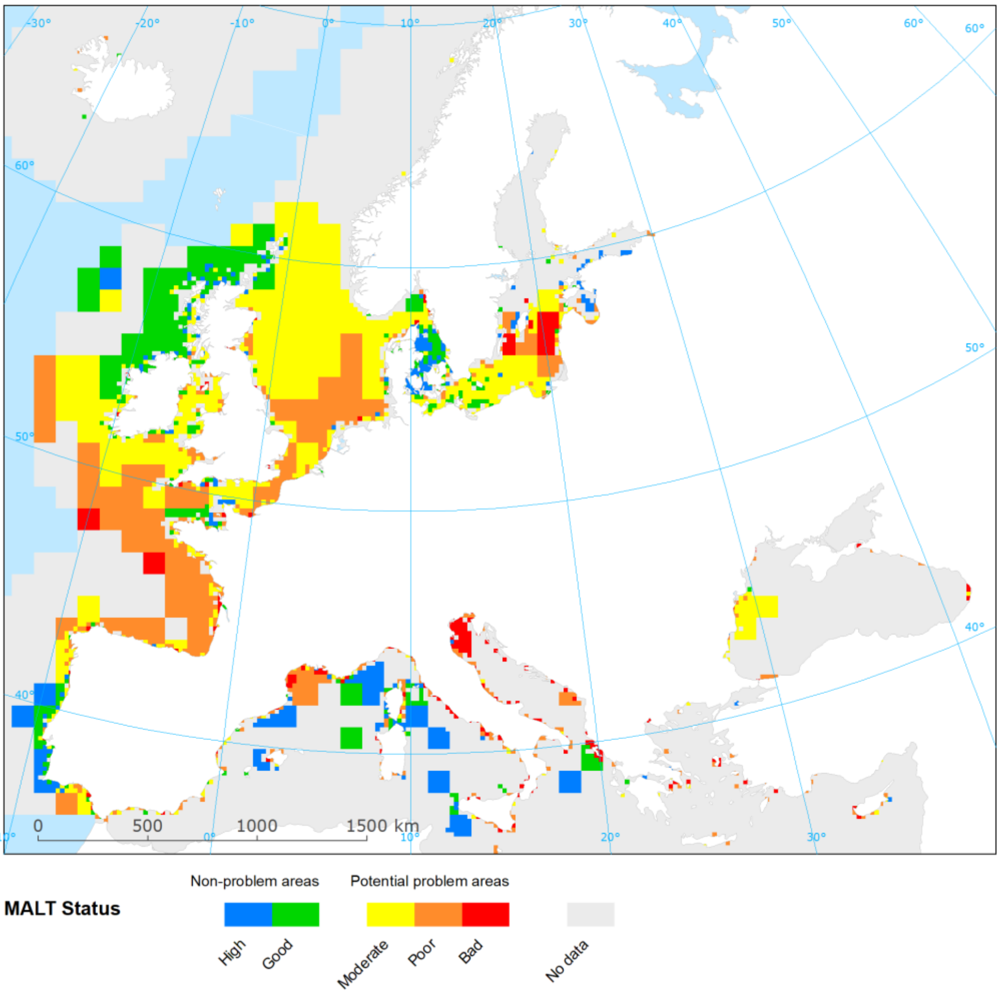


Where the item count exceeds the threshold (15 items per km^2 for seafloor litter and 20 items per 100 m for beach litter), an indicator is determined to have a status as a "problem area" otherwise the status is "non-problem area". The status classes for each of the indicators are further subdivided into 5 categories: "High", "Good", "Moderate", "Poor" or "Bad" by normalising the log-transformed count, $log_{10}(n)$ to a scale from 0 to 1, analogous to the EQR employed in other assessments. The resulting EQR score determines the status class for the preliminary assessment in each assessment unit (grid cell) (Table A5.1, in Annex 5). In assessment units where more than one indicator is available, overall status is determined according to the MALT tool aggregation scheme (Figure A5.1, in Annex 5) which follows the descriptor 10 criteria. Within the criteria, EQR is calculated as the average of EQR for individual indicators. For example, in an assessment unit where both Beach Litter and Seafloor Litter indicators are present, the EQR for C1 (Litter) is calculated as the average of EQR for the two indicators. Between criteria, the "one-out all-out" method means that the overall EQR is given by the criterion having the worst status. So, in an assessment unit having indicators for Seafloor Litter (C1 Litter) and Floating Microlitter (C2 Microlitter), the overall status is determined by the indicator having the worst status (lowest EQR value). In the 23 assessment units where all three indicators were available, EQR values were averaged within C1 (Beach Litter and Seafloor Litter) before taking the worst (lowest) EQR score between C1 and C2 (Floating Microlitter). In 142 assessment units where at least one C1 (Litter) indicator and Floating Microlitter indicator (C2) was applied, Floating Microlitter was *never* the determining indicator.

5.4.1. Status of European regional seas for marine litter

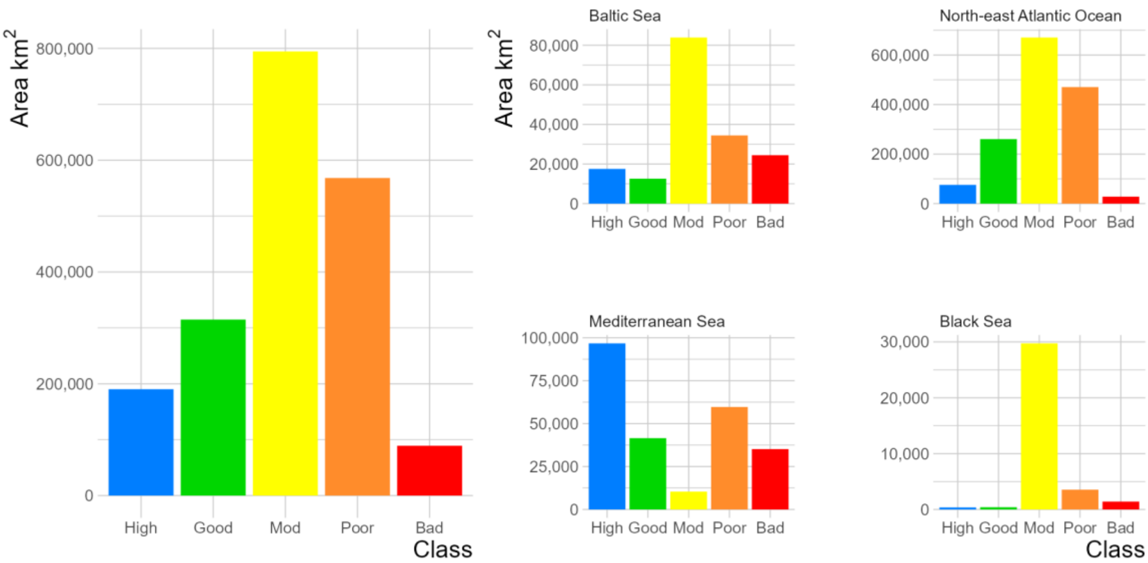
Figure 36 shows a map summarising the assessment results of marine litter for all four regional seas.

Figure 36: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in Europe's Seas (based on accessible data covering the period 2010–2021)



Of all the regions assessed, the Baltic Sea had the best coverage. Assessment results were calculated for grid cells covering 172,926 km^2 (43.4 %) of the 398,220 km^2 covered by assessment grid cells. Within the assessed cells, 17.4 % (30,130 km^2) had a "High" or "Good" status whilst 82.6 % (142,796 km^2) had a status of "problem area" (i.e. "Moderate", "Poor" or "Bad"). The NEA had a coverage of 22.0 % (1,505,214 of 6,849,267 km^2). This was the region having the second-best status and within the assessed area, 22.3 % (336,027 km^2) had a "High" or "Good" status. 77.7 % (1,169,186 km^2) were classified as having a "Moderate", "Poor" or "Bad" status. The Mediterranean Sea had a relatively poor coverage and grid cells covering 9.7 % (243,481 km^2) out of 2,520,934 km^2 were assessed. The region had the best assessed status, with 56.8 % (138,238 km^2) of the assessed area classified as having a "High" or "Good" status. This is due largely to the assessment of floating microlitter. "Moderate", "Poor" or "Bad" status was estimated in 43.2 % (105,243 km^2) of the assessed areas. Assessment coverage in the Black Sea was the poorest of all regions at 7.5 % (35,460 out of 475,054 km^2). Furthermore, the results of the assessment were poorest in this region with "High" or "Good" status in only 2.2 % (767 km^2) of the assessed area whilst 97.8 % (34,693 km^2) had a status of "Moderate", "Poor" or "Bad" (Figure 37).

Figure 37: Summary of preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in Europe's Seas for all areas (left) and for four regions



Considering the entire European Seas, 19.1 % (1,957,081 out of 10,243,474 km^2) of the grid cells were covered by the assessment. The fractions of the assessed area having a "High" or "Good", status was 25.8 % (505,163 km^2) whilst a "Moderate", "Poor" or "Bad" status accounted for 74.2 % (1,451,918 km^2).

In conclusion, the fraction by area of assessment units (19.1 %) where it was possible to determine status with regard to marine litter can be considered a reasonable proportion. The inclusion of litter counts in the assessment units where status is absent would improve the quality of the assessment. In particular, the coverage in the Mediterranean Sea and Black Sea regions is somewhat poorer than the other regions and resulted from the lack of accessibility to the data. Another important improvement required is the inclusion of further litter indicators in the MALT assessment.

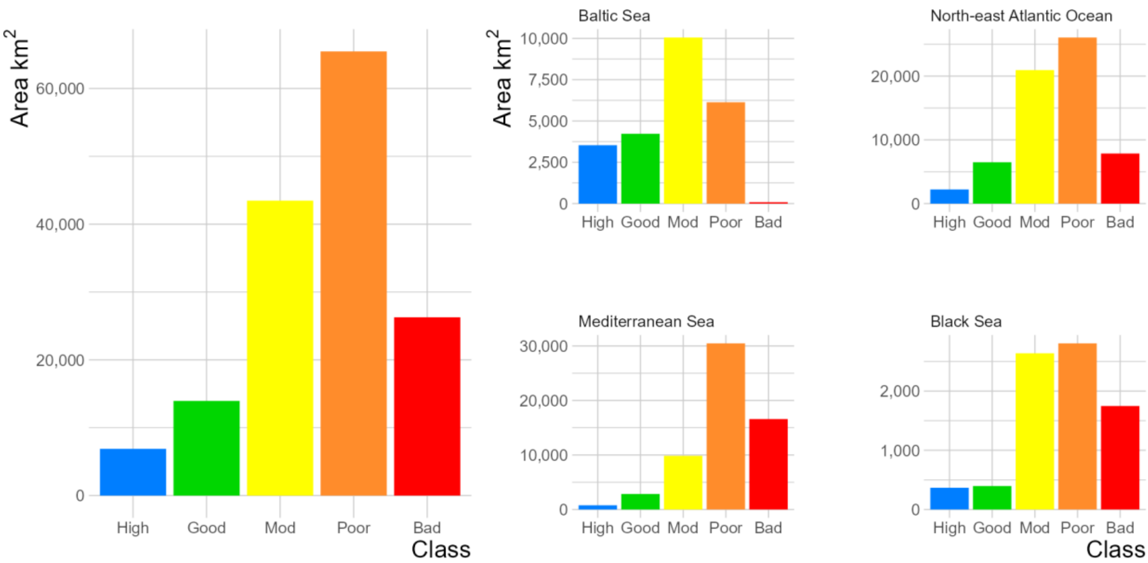
To address the question of development over time, an assessment was done for two separate assessments for the periods 2011–2013 and 2017–2019 (see section 5.4.3 and Annex 7).

5.4.2. Status of European coastlines for beach litter

In respect to beach litter, the summary of the classification of the status of coastal areas, in relation to a threshold adopted are presented in Figure 38. The assessment results covered a total of 25.5 % of the European coastal area (398,681 km^2 out of a total of 1,563,074 km^2 covered by assessment grid cells). For this indicator, the coverage across the four regional seas is more consistent, with 31.3 % for the Baltic Sea, 36.0 % for the NEA, 15.2 % for the Mediterranean Sea and 9.3 % for the Black Sea (see details in Table A5.3 in Annex 5).

Assuming that these areas are representative of the situation in each regional sea, the situation is worse in the Black Sea and Mediterranean Sea, with 92.5 % and 78.3 % of the areas assessed, respectively, classified as "potential problem areas" (i.e. "Moderate", "Poor" or "Bad" status). Less problematic but still poor are the Baltic Sea and NEA, where only 37.7 % and 35.7 % of the areas assessed, respectively, are classified with a "High" or "Good" status. Considering the overall European status, 74.2 % of the assessed coastal areas are "potential problem areas".

Figure 38: Summary of preliminary classification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in Europe for all coastal areas (left) and for the four regions

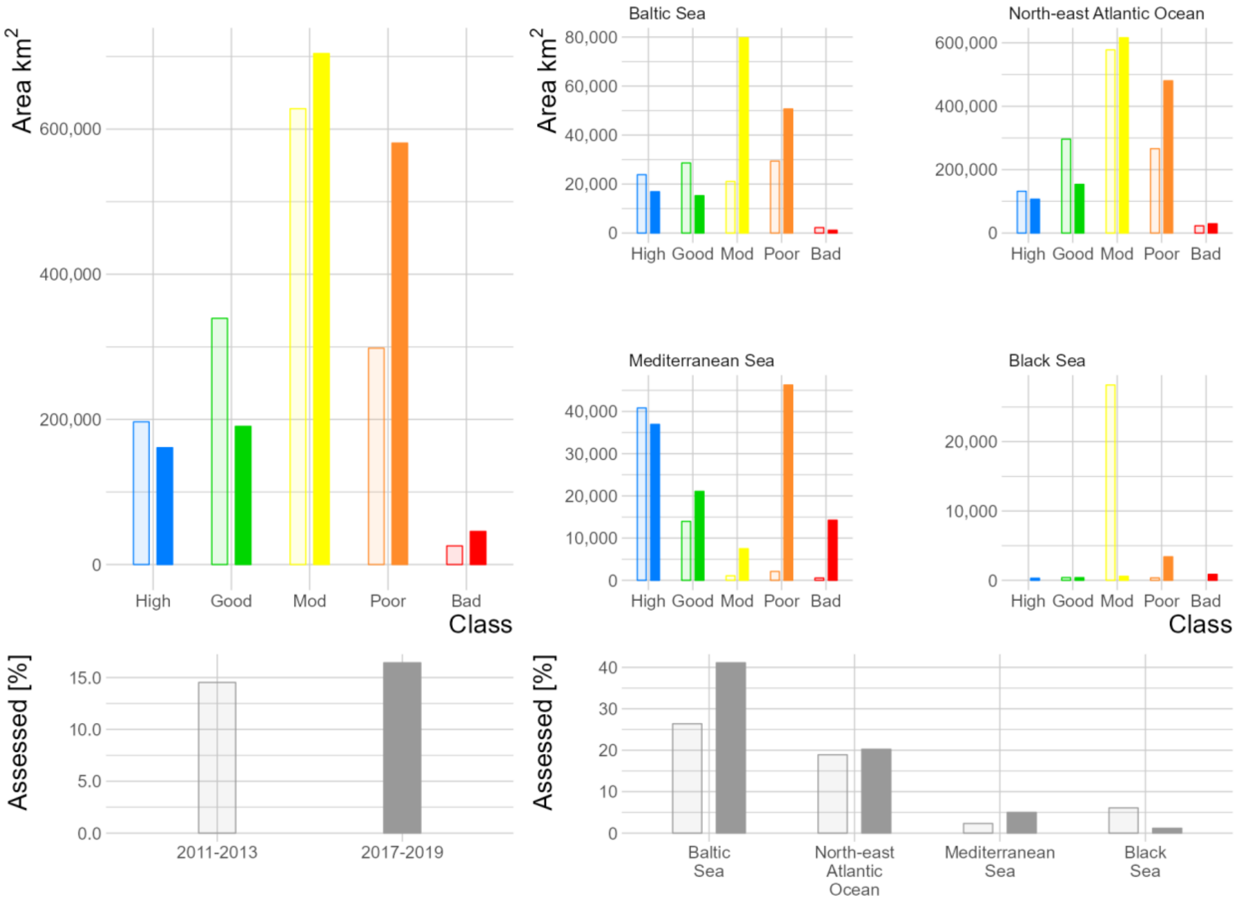


5.4.3. Changes in the status between two time periods (2011–2013 and 2017–2019)

When considering all the European regional seas and the thresholds used, the results of the MALT assessment indicate an increase in potentially problematic areas for the period of 2017–2019, when compared to 2011–2013 (from 64 % to 79 % of the total assessed area, respectively) (Figure 39 and Annex 7).

In relation to the NEA, where the proportion of the area assessed for the period 2011–2013 (18.9 %) is similar to 2017–2019 (20.2 %), we see a reduction in the fraction of the areas with a "high" and "good" status and an increase in the fraction of areas with a "poor" status. Assuming that the assessed area is representative, this suggests a worsening of the situation in the NEA region as a whole.

Figure 39: Summary of area (km2) of 'non-problem areas' and 'potential problem areas' with respect to marine litter in Europe's Seas for all areas (top-left) and for four regions (top-right) and percentage of total area assessed overall (bottom-left) and by region (bottom right) with results for the period 2011–2013 indicated by "hollow" bars and 2017–2019 indicated by filled bars



Comparisons between regions and periods must, however, be interpreted with caution, since the proportion of assessed areas are different. Following an intensification in data collection of marine litter in Europe, more data is available for the more recent period and covering a wider area (see table A7.1 in Annex 7). For example, datasets for beach litter for the period 2017–2019 are far more extensive and cover a larger proportion of the European coastline than for 2011–2013. Therefore, the results may reflect, at least partially, the fact that poorer quality areas were accounted for in the more recent period and not necessarily reflect a worsening of the overall situation. As more data become available, it will be possible to better infer on improvements in the situation and regional differences.

6. Integrated analysis

KEY MESSAGES

- Plastics have proliferated in our societies and global plastic production increased since the 1950s. The most extensive application of plastics is packaging, whose growth has accelerated as the world shifted from reusable to single-use containers and towards the prevalence of convenient but disposable items.
- Comparably in Europe, plastic production has continued to increase steadily in the last decade, as has the demand for plastic packaging. This, in turn, has led to an increase in the plastic packaging waste generated per capita. Our study indicates that in 2018, the total amount of PPSI (plastic packaging and small non-packaging plastic items) waste generated in the EEA 32 + UK reached 26.1 million tonnes, while in 2012 the region generated 22.9 million tonnes. Similarly, the per capita PPSI waste generated increased from 38.7 kg in 2012 to 42.9 kg in 2018.
- This means that until 2018, Europe was not on track to meet the policy goals of waste prevention nor achieving significant waste reduction (the priority step in the waste hierarchy, laid out in the Waste Framework Directive). At least in what concerns plastic packaging waste, this was certainly not the case, since amounts per capita for EU-27 have increased between 2011 and 2020, even at a faster rate than the Gross Domestic Product (GDP). Therefore, there is no evidence of decoupling between this pressure and economic growth.
- Efforts in improving collection and waste management have led to reduced shares in mismanaged PPSI waste in overall for the EEA 32 + UK and many individual countries. However, when looking at quantities, higher amounts of PPSI waste were mismanaged in 2018 than in 2012. Only a limited number of countries effectively reduced their amounts of mismanaged PPSI waste.
- Improvements in the proportion of adequately managed PPSI waste seem to be mainly driven by responses targeting the "downstream" and end-of-life stages of the plastics life cycle (i.e. waste management – collection, recycling, disposal). Contrastingly, we see a stepping-up in "upstream" stages (design, production, consumption), which have led to an intensification of the PPSI waste generated and, in turn, higher pressure in terms of PPSI waste that is mismanaged. Responses at both up and downstream levels are needed to transition to a Circular Economy. Still, during the period assessed, real transition in terms of PPSI waste reduction is not yet noticeable and remains relatively weak.
- Pressure at the coast from mismanaged PPSI waste is particularly intense in the Mediterranean and Black Seas, which collectively make up 90 % of the total mismanaged PPSI waste on the coast in Europe. This is most likely a combination of population density and intense tourism in these regions that leads to high amounts of PPSI waste generated, combined with weaker performances in terms of adequate waste management, which is prevalent in some countries. When assessing changes between 2012 and 2018, the results suggest that the total amount of PPSI waste mismanaged in coastal territories has increased in both the Mediterranean and Black Seas, while in the NEA and Baltic Sea it decreased slightly.
- Existing studies have estimated that 626 million floating litter items annually enter European Seas, corresponding to a load of 3,382 tonnes of litter per year. The Mediterranean Sea receives the largest share of floating litter (36 % of total riverine litter input in Europe), while the Baltic Sea contributes the least amount of floating litter (10 %).

KEY MESSAGES (cont.)

- An intensification in the pressure of PPSI waste generated, particularly in the mismanaged fraction, means that more of this plastic may end up in the environment and possibly the sea. In fact, we see that litter pollution is far from acceptable, with roughly 75 % of the areas assessed in European Seas classified as potential problem areas. When comparing the period around 2018 with 2012, our assessment suggests that the situation has not improved and may have even worsened.
- Specifically, on PPSI, field observations show the predominance of this fraction of waste in recorded litter from coastal and marine environments. Analyses indicate that the overall median annual number of PPSI increased between 2015 and 2021, particularly in the Mediterranean and the Black Sea. The evolution in PPSI abundance should continue to be assessed in the future, considering the potential impact of the Single-Use Plastics Directive in restricting and leading to better management of some of the items that compose PPSI applications.
- The levels of litter pollution, including PPSI litter in the four European regional seas, are in line with the regional differences found in the estimates of both mismanaged PPSI waste in coastal territories and the modelled riverine discharges of floating macrolitter from a previous study. The Baltic Sea region presents the lowest figures in mismanaged PPSI waste, riverine floating litter and beach litter. Contrastingly, the Mediterranean Sea and the Black Sea are the regions with the highest values.
- Waste prevention, the application of the waste hierarchy principles and plastic pollution reduction are part of the ambitions of the 8th Environmental Programme and the targets of the Zero Pollution Action Plan. This assessment provides evidence that as of 2018, Europe was generally not on track to meet these objectives and emphasises the importance of intensifying efforts on PPSI waste prevention, combined with continued improvements in waste management, including recycling, to reduce new inputs of plastic litter into the environment.

This chapter constitutes a synthesis of the previous chapters, where the main findings from the three analytical components (on sources, pathways and state of marine pollution) are highlighted and brought together. It uses the key assessment results to address crucial questions that may be relevant from a European policy perspective (section 6.1), as well as for evidence for appraising where we stand in relation to the policy objectives and targets (section 6.2).

6.1. Integrated assessment of marine litter along the DPSIR framework

6.1.1. Trends in key drivers

6.1.1.1. Plastic packaging production

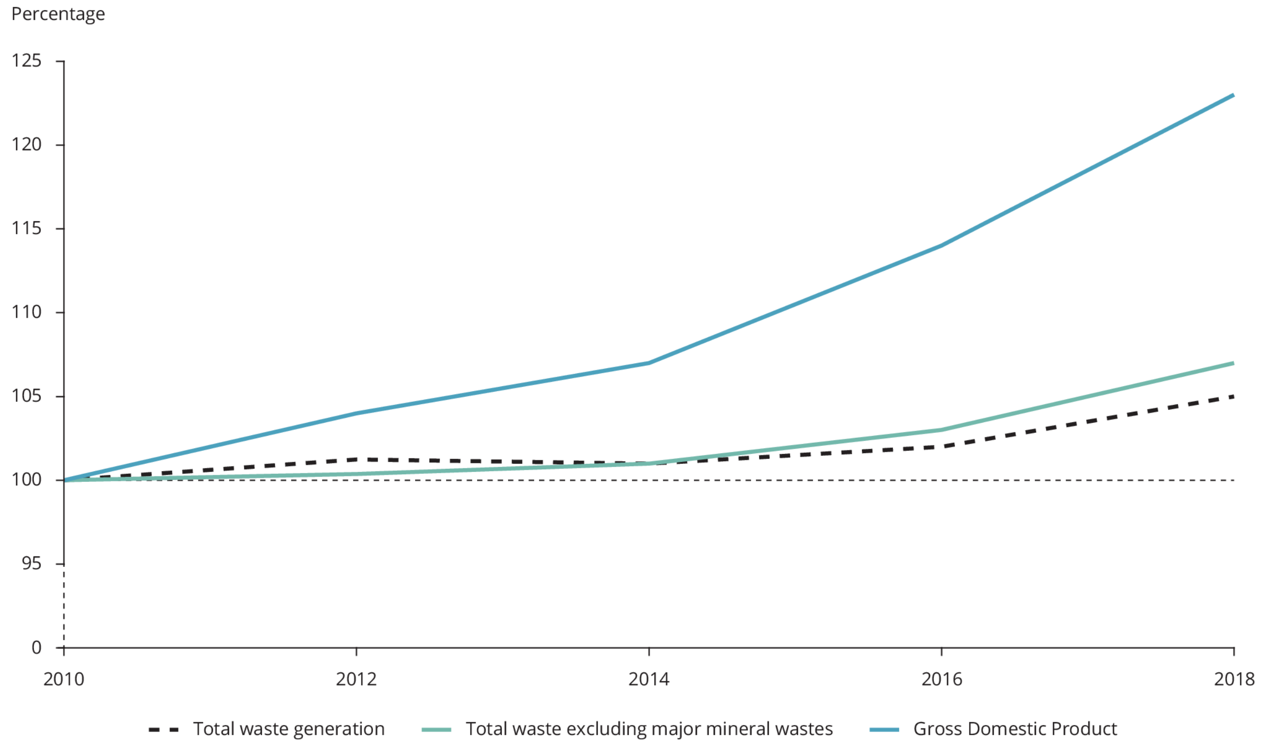
The development of our economies and the proliferation of plastics' applications in our societies are reflected in the increase in global plastics production since the 1950s. The largest plastic application is packaging, which has gradually replaced other materials, such as glass and paper. Its accelerated growth, however, is also driven by a systemic paradigm change, as the world shifted from reusable to single-use containers, from bulk to smaller packaged amounts of goods and other convenient but disposable plastic items, such as straws, stirrers, and cutlery.

As seen in section 2.1.1, approximately 40 % of the plastic produced in Europe from virgin resins (i.e. excluding recyclates) is converted into packaging. In terms of total amounts, both the total plastic production and the demand for plastic packaging in Europe have increased steadily. The estimated quantities converted to plastic packaging increased from 18.1 million tonnes in 2012, to 20.4 million tonnes in 2018. As such, within this period, higher amounts of plastic packaging from virgin sources have been injected into the European market.

6.1.1.2. *Is there evidence of a decoupling of plastic waste generation from economic growth?*

In relation to 2010, as of 2018, the total waste generation (excluding major mineral wastes) has increased 7 % overall in the EU-27 (Figure 40). According to the EEA (2021), since the European population has remained relatively stable, the main driver of increasing waste generation is economic growth, with GDP increasing 23 % between 2010 and 2018. Yet, the growing waste trend is not in line with the EU policy goal of significantly reducing waste generation.

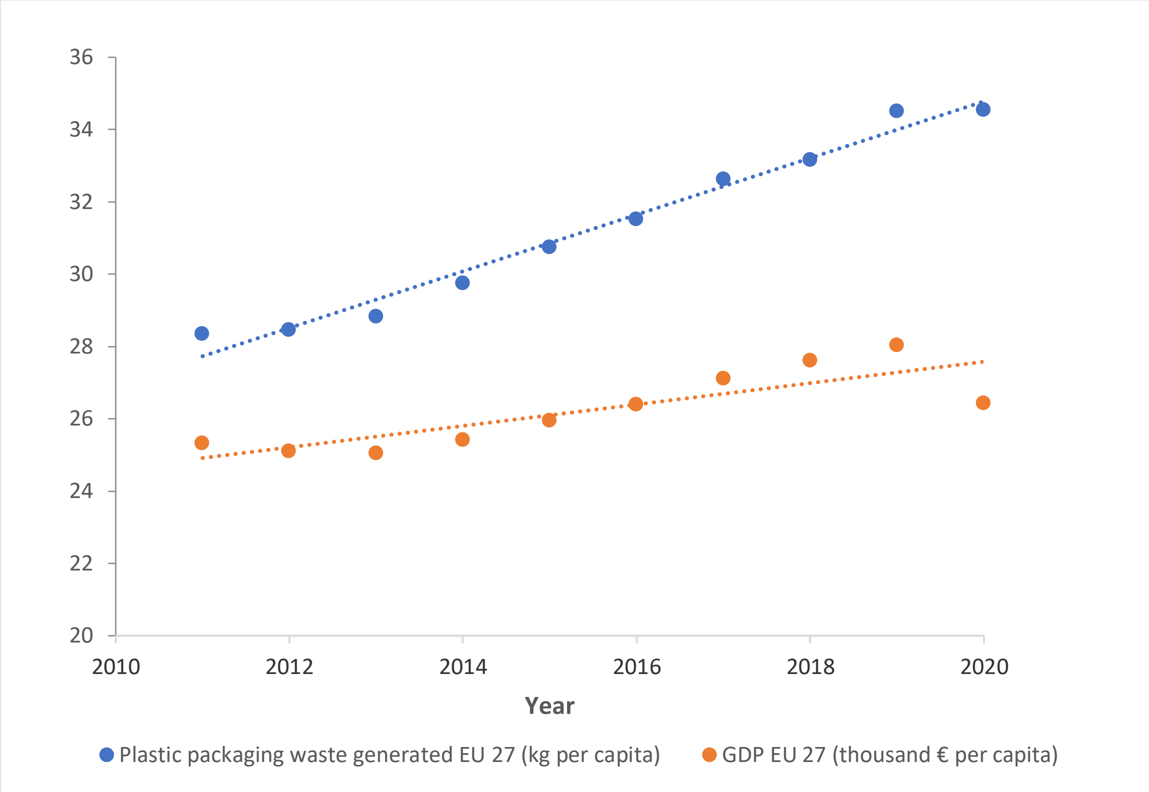
Figure 40: Waste generation and decoupling in the EU-27, between 2010 and 2018 (Source: EEA, 2021)([26])



Regarding plastic packaging, as seen above, the demand in Europe shows an increasing trend in the study period. As most of this packaging is not designed to be reused, it has a relatively short use lifecycle and thus will quickly become waste. As such, it is not surprising to see that the plastic fraction of waste, specifically plastic packaging, show a similar increasing trend in the EU-27 between 2011 and 2020 (
Figure **41**).

[26] https://www.eea.europa.eu/data-and-maps/indicators/waste-generation-5/assessment

Figure 41: Plastic packaging waste generated (kg per capita) (blue) and real Gross Domestic Product (GDP, thousand euro per capita) (orange) in the EU-27, between 2011 and 2020 (Source of data: Eurostat)



Contrary to the total waste generation (Figure 40, see also EEA, 2019) the growing trend in plastic packaging waste generation per capita seems to be increasing at a faster pace than the GDP (and Figure **41**). At least during the period considered, there is no evidence that the EU-27 is moving towards decoupling this specific pressure from economic growth. An absolute decoupling will only be achieved when an increase in GDP does not result in higher amounts of plastic waste generated. Whether it will ever be possible to achieve absolute decoupling when the goal of economic growth is so heavily dependent on the use of resources and material production and consumption remains debatable (e.g. Ward et al., 2016).

As presented in section 2.1.1, the demand for plastics for packaging increased steadily between 2012 and 2018, i.e. during the period covered in this assessment. Note, however, that more recent data for 2019 and 2020 indicate a reduction in this demand. Whether this effectively corresponds to an inversion of the trend and how it reflects on the generation of plastic packaging waste will need to be assessed in the future.

6.1.2. Reduction of pressures

6.1.2.1. Are we reducing our footprint in terms of plastic waste generated?

In terms of the generation of plastic waste, in the period assessed Europe is not on track to reduce this pressure. The total PPSI waste generated in the EEA 32 + UK was estimated at 26.09 million tonnes in 2018, 13 % higher than in 2012 (22.94 million tonnes). Similarly, the intensification of this pressure was also reflected in terms of per capita PPSI waste generated, with an average of 42.9kg in 2018, compared to 38.7kg in 2012. With very few exceptions, the amount of PPSI waste generated per capita was consistently higher in 2018 across countries. See further details in section 3.2.

6.1.2.2. Are we reducing the share of mismanaged plastic waste?

The share of mismanaged PPSI waste in relation to the total PPSI waste generated varies widely among EEA countries, ranging from 2 % to as high as 49 % (for 2018). Nevertheless, improvements in waste management have led to significant increases in the proportion of PPSI waste that is adequately managed in some countries, leading to a small improvement in the overall region. The aggregated share of mismanaged PPSI waste of the EEA 32 countries + UK was 12.6 % in 2012 and 11.5 % in 2018. In most countries, the fraction of mismanaged PPSI waste was already very high and has remained fairly unchanged.

6.1.2.3. Are we reducing the total amount of plastic waste that is mismanaged?

Overall, European countries are lagging on the capacity to adequately deal with increasing amounts of PPSI waste that is generated, which results from increased amounts of plastic being produced from virgin resins and injected into the market. Improvements in waste management, which in some countries have been significant in the last decade, are clearly reflected in smaller shares of PPSI waste that is mismanaged. However, these improvements were generally not sufficient to offset higher quantities of PPSI waste that was generated in 2018, when compared to 2012. Therefore, according to this study's estimates, in terms of absolute amounts more PPSI waste was mismanaged in 2018 than in 2012, largely due to limited upstream waste prevention measures.

6.1.2.4. What is the pressure of PPSI waste mismanaged in coastal territories?

The total estimated mismanaged PPSI waste on the coast (based on country-based estimates and as a function of the population in coastal NUTS3) has increased by 12 % overall for Europe in 2018 (1.64 million tonnes), compared to 2012 (1.47 million tonnes). This is also the case for the Mediterranean and Black Sea's coastal NUTS3 (Figure 43 and Figure 44). Only in the NEA and Baltic Sea regions, has the total aggregated PPSI waste mismanaged in coastal territories been lower in 2018, compared to 2012. As such, there seems to be some level of improvement in these two regions that lead to reductions in mismanaged PPSI waste, even if the PPSI waste generated has increased in all countries, except in the UK.

Nevertheless, it is striking to see that pressure on the coast is particularly intense in the Mediterranean and Black Seas, collectively making up 90 % of the total mismanaged PPSI waste in coastal territories in Europe in 2018 (
). This is most likely a combination of population density and intense tourism on the coast in these regions that leads to large amounts of PPSI waste generated (Figure 42), together with weaker performances in terms of adequate waste management that are prevalent in some countries (Figure 17, in section 3.2).

Figure 42: Estimated PPSI waste generated at the coastal regions (tonnes/year) in 2018 for the EEA 32 countries + UK. Values are calculated based on national per capita PPSI waste generated and population living within coastal NUTS3 (PPSI: plastic packaging and small non-packaging plastic items)

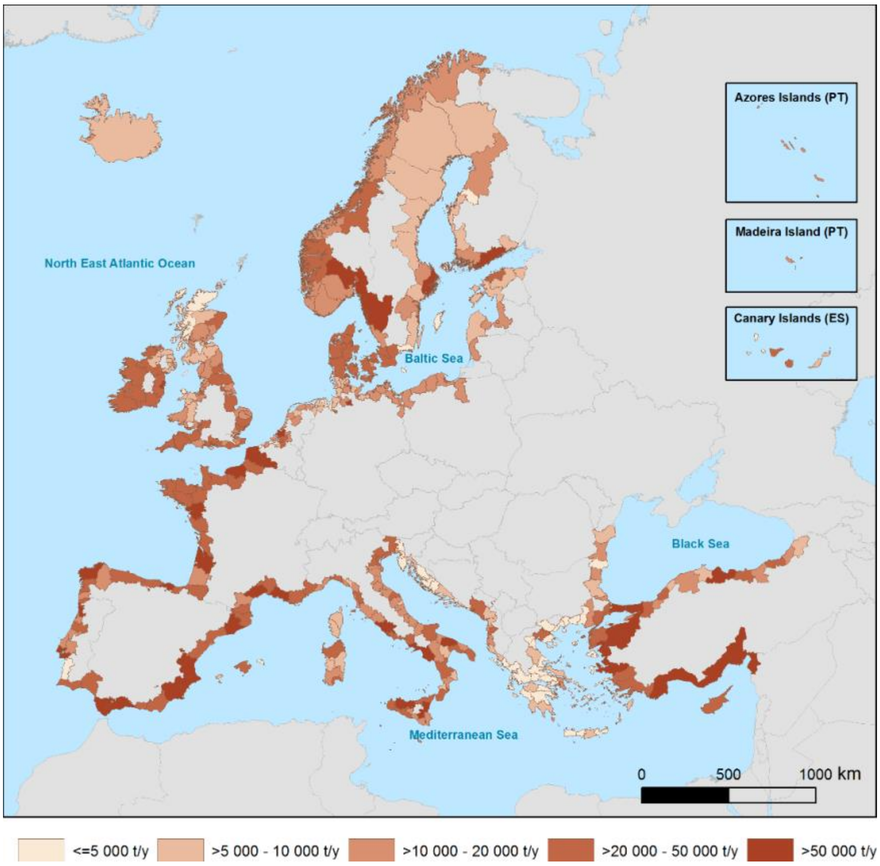


Figure 43: Estimated mismanaged PPSI waste (tonnes/year) in coastal territories in 2018 (left) and index of change in relation to 2012 (right) in the EEA 32 countries + UK. Values are calculated based on estimated national mismanaged PPSI waste per capita for the two years (PPSI: plastic packaging and small non-packaging plastic items)

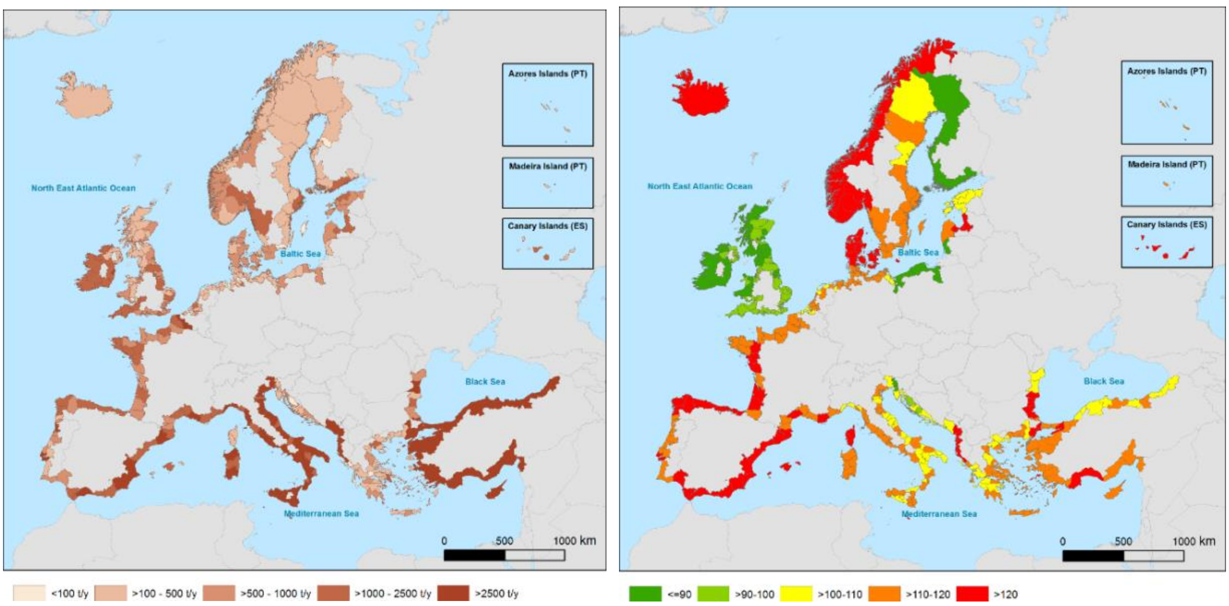


Figure 44: Total mismanaged PPSI waste (in thousands of tonnes per year) in coastal NUTS3 in 2012 and 2018, aggregated per European regional Sea: North-East Atlantic Ocean (NEA, include the Atlantic archipelagos of the Azores, Madeira and Canary Islands), Baltic Sea (BAL), Black Sea (BS) and Mediterranean Sea (MED) (PPSI: plastic packaging and small non-packaging plastic items)

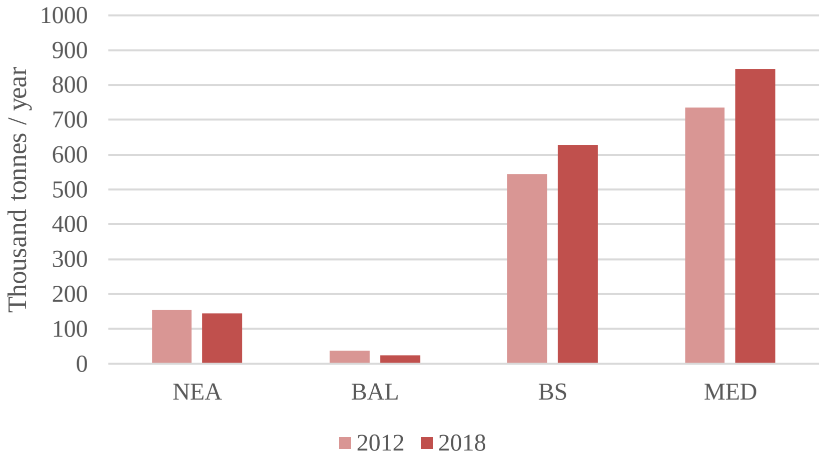
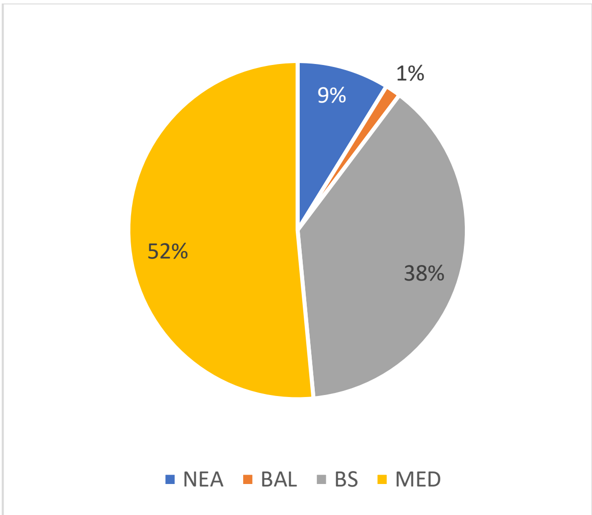


Figure 45: Share of mismanaged PPSI waste in 2018 in coastal NUTS3 per regional sea in relation to the total mismanaged PPSI in the European coastal (NUTS3) territories. North-East Atlantic Ocean (ATL), Baltic Sea (BAL), Black Sea (BS) and Mediterranean Sea (MED) (PPSI: plastic packaging and small non-packaging plastic items)



6.1.2.5. What is the pressure in terms of riverine litter emissions?

The only comprehensive study to date that estimates inputs of litter from rivers at the European scale, estimates that annually 626 million floating litter items enter the European Seas (ranging between 307 and 925 million items), corresponding to a load of 3,382 tonnes per year. Based on these estimations, the Mediterranean Sea receives the largest share of floating litter (36 % of total riverine litter input in Europe), followed by the Black Sea and NEA, while the Baltic Sea contributes with the least amount of floating litter (10 %). Note that the original study used different sources for their input data of mismanaged waste (see discussion in Annex 1) and as such these results cannot be directly correlated with our estimations of mismanaged PPSI waste. Nevertheless, both the riverine litter estimates and the assessment of mismanaged PPSI waste point towards similar regional differences (see 6.1.3.2 below for further info.).

6.1.3. Status of marine litter pollution in European regional seas

The assessment of the overall status covered 19 % of the area of European seas and the results indicate that roughly 75 % of the assessed areas are classified as potential problem areas. For coastal areas, specifically, two thirds of the total assessed area are considered as potential problem areas. Spatial differences emerge from the assessment, namely between regions, with the Black Sea and Mediterranean Sea presenting the worst results, where only 9 and 10 % of the coastal areas assessed, respectively, have a "Good" or "High" quality status. This is in line with the regional differences in terms of pressures, namely the coastal estimates of mismanaged PPSI waste, as well as the modelled estimates of riverine litter emissions into the sea presented in section 4.2.1. However, one should also note that these two regions, the Black Sea and the Mediterranean Sea, were also those with the poorest data coverage. Respectively 7.5 % and 9.7 % of total area was assessed whereas results in the NEA covered 22 % of the total area and in the Baltic Sea 43 %.

6.1.3.1. Are we improving the status of marine litter pollution?

Despite limitations in terms of data and spatial coverage in the assessment, taking subsets of the available data allowed comparison of a more recent period (2017–2019) with a previous (2011–2013). The MALT results from the two time periods suggest a worsening of the situation, with an increase in potential problem areas from 64 to 79 % of the total area assessed in the European coast and seas (see details in section 5.4.3). This may well be the case at least for the NEA, where the proportion of assessed areas is comparable between the two periods, and where the potential problem areas increased from 67 % to 81 %. Still, this remains to be further assessed, as more data becomes available. The Black Sea was the only region to show a reduction in the fractional extent of potential problem areas but since there was little overlap between the assessed areas in the two periods, this is somewhat uncertain.

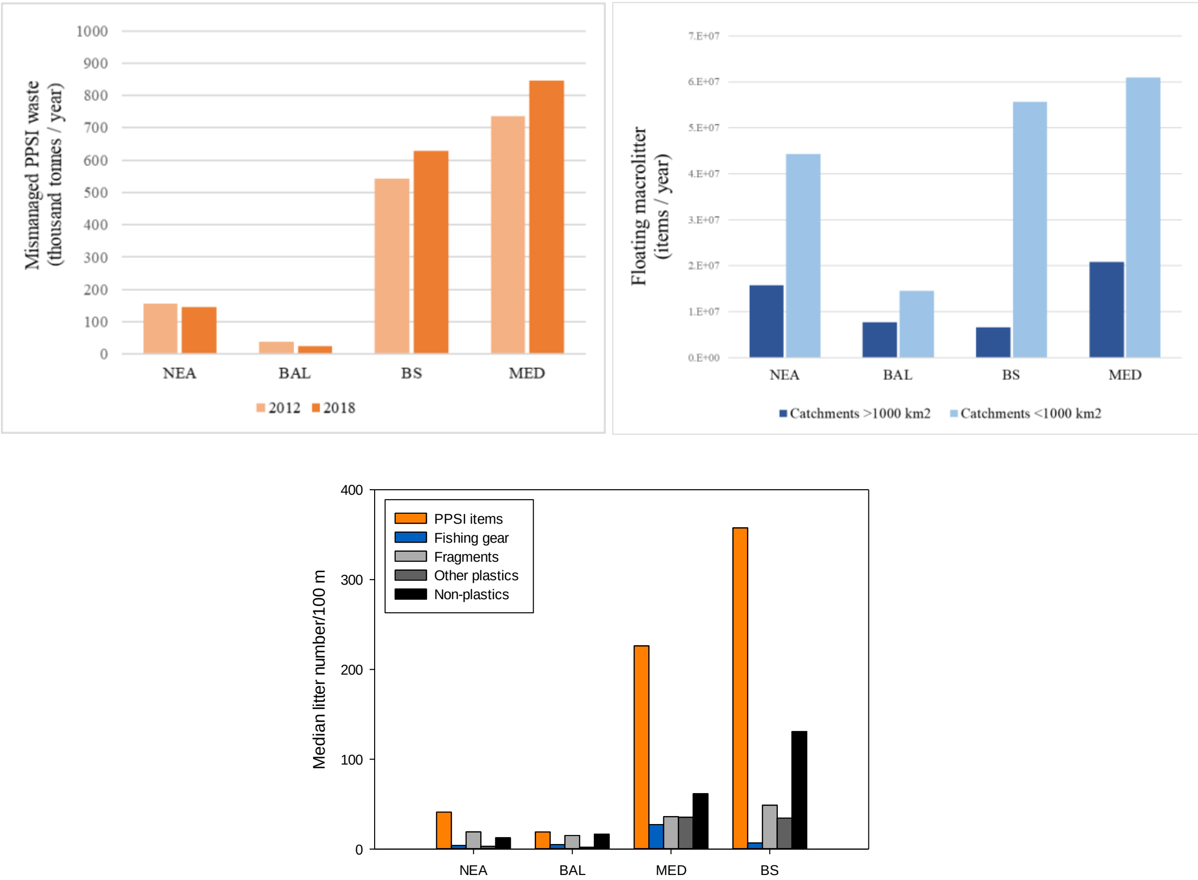
Though the overall status with regard to marine litter appears to worsen between the two periods, it is a positive conclusion that the spatial coverage of the assessment as a fraction of the total area of Europe's Seas increased overall from 14.5 % to 16.4 %.

A worsening of the situation in terms of marine litter would not be surprising, considering that generally the amounts of mismanaged PPSI waste in 2018 are higher than in 2012, and that a large fraction of litter found in European beaches corresponds to PPSI. In fact, as suggested by MLW monitoring data (section 0), the annual median number of litter items belonging to PPSI seems to be increasing between 2015 and 2021, overall for Europe and in all regional seas, except the Baltic Sea. With the recent implementation of the SUP Directive, future assessments may capture the impact of this policy, not only in terms of reductions of PPSI waste generated and mismanaged but also on the amounts of this category of litter recorded on beaches and in the sea.

6.1.3.2. Do regional differences in beach litter abundance reflect differences in performances of waste management and riverine litter inputs?

Comparing the abundance of PPSI recorded on beaches of the four European regional seas, the Baltic Sea presents the lowest values, followed by the NEA. This assessment shows that the Black Sea and the Mediterranean Sea are the most polluted in what concerns litter amounts and specifically PPSI items recorded on beaches. These results are in line with the regional differences found in the estimates of both mismanaged PPSI waste in coastal territories (NUTS3) (Figure 44) and the modelled riverine discharges of floating macrolitter by González-Fernández et al. (2021). This is illustrated by key results from the analytical components per regional sea, illustrated in Figure 46 below.

Figure 46: Top left: total mismanaged PPSI (plastic packaging and small non-packaging plastic waste) in coastal NUTS3 in 2012 and 2018 (based on authors' estimates); Top right: sum of median estimates of riverine floating macrolitter (based on modelled estimates by González-Fernández et al., 2021); Bottom: median number of beach litter of different groups (based on MLW monitoring data, 2015–2021) (BAL = Baltic Sea; NEA = North-East Atlantic Ocean; MED = Mediterranean Sea; BS = Black Sea)



6.1.4. *Summary of the assessment of marine litter from source to sea*

Table 32 provides a qualitative appraisal of the situation and the perceived change for Europe, summarising the key results from the assessment across the *drivers-pressures-state* causal chain. This highlights potential relationships between these three levels. Whenever possible, regional differences are emphasized. The appraisal of the situation is inherently subjective, particularly because there are no corresponding thresholds or targets. In what concerns the appraisal of the regional seas, this is partly done in a relative way, comparing it to the overall situation in Europe and/or other regions.

Table 32 Overview of appraised status on drivers, pressures and state of marine (plastic) litter in the marine environment in Europe for 2018 based on the results of this study. When possible, status is further defined for the Baltic Sea (BAL), North-East Atlantic Ocean (NEA), Mediterranean Sea (MED) and Black Sea (BS) and the change in relation to 2012 is evaluated (GDP: Gross Domestic Product; PPSI: Plastic packaging and small non-packaging plastic items; NEA: North East Atlantic Ocean; MLW: Marine Litter Watch)

Theme	**Status 2018** (colour) and **perceived change** in relation to **2012** (↘↗)					Justification
	Europe	BAL	NEA	MED	BS	
DRIVERS						
Plastic packaging production (EU-27 + UK, NO, CH, total amount)	Increasing trend					Packaging is the largest demand fraction for plastic production (40 %) and is increasing steadily between 2012 and 2018. Note, however, that in 2019 and 2020 there is an inversion in the trend. **See section 2.1.1**
Decoupling of plastic packaging waste generation from GDP (EU-27)	↘					Between 2011 and 2020, plastic packaging waste generated (per capita) increased at a faster pace than the GDP (per capita), suggesting that the EU-27 is not moving towards decoupling this pressure from economic growth. **See section 6.1.1.2**
REDUCTION OF PRESSURES						
PPSI waste generated per capita (EEA 32 + UK, national, per capita)	↘	↘	↘	↘	↘	PPSI waste generated both in total amounts and per capita in Europe was higher in 2018 than 2012. With a few exceptions, this is also the case for most individual countries. In general countries bordering the NEA and Mediterranean Sea have a higher PPSI waste generation per capita than the average for Europe (42.9 kg in 2018), while countries bordering the Black Sea have lower values. **See section 3.2.2**
Share of mismanaged PPSI waste in relation to the total PPSI generated (EEA 32 + UK, national, % total amount)	↗					Share of mismanaged PPSI waste in relation to the PPSI waste generated varies widely between countries (2 – 49 %) but usually this fraction is already low and has remained fairly unchanged in relation to 2012. Eastern countries in general tend to have slightly higher shares of mismanaged PPSI waste. Countries around the Baltic and the Mediterranean Seas present a mix of situations in terms of changes. Nevertheless, improvements in waste collection and sanitary disposal have been significant in some countries, leading to clear reductions in the share of mismanaged PPSI waste. **See section 3.3**

Theme	Status 2018 (colour) and perceived change in relation to 2012 (↘↗)					Justification
	Europe	BAL	NEA	MED	BS	
Mismanaged plastic PPSI waste per capita (EEA 32 + UK, national, per capita)	↘			↘		Mismanaged PPSI waste per capita and change in relation to 2012 also shows wide variations among countries. Overall, in Europe, mismanaged PPSI waste per capita has increased slightly but several countries managed to reduce these rates. Situation in most regional seas presents a mix picture, except for Mediterranean countries that consistently show higher mismanaged PPSI waste per capita in 2018 than in 2012. **See section 3.3**
Total mismanaged PPSI waste (EEA 32 + UK, national, total amount)	↘		↘	↘		In Europe, it is estimated over 3 million tonnes of mismanaged PPSI waste in 2018, slightly higher than in 2012. Even if there were improvements in waste management, these were not sufficient to offset higher amounts of PPSI waste generated. Situation in most regional seas presents a mix picture, except in the NEA and Mediterranean Sea, where estimated mismanaged PPSI waste in 2018 is higher than 2012 in most of the countries. **See section 3.3**
Pressure mismanaged PPSI waste at the coast (EEA 32 + UK, sub-national, total amount)		↗	↗	↘	↘	The total estimated mismanaged PPSI waste in European coastal territories is generally higher in 2018, and in particular in the Mediterranean and Black Sea regions, which together make up 90 % of the total mismanaged PPSI waste on the European coast. Exceptions are the NEA and Baltic Sea coastal territories, where mismanaged PPSI waste estimated for 2018 was slightly lower than estimated for 2012. **See section 6.1.2.4**
Annual riverine floating litter discharged into the sea (no. of items/year)	?	?	?	?	?	Based on published studies that modelled emissions by rivers in Europe (González-Fernández et al., 2021), the Mediterranean Sea is receiving the largest share of floating litter (36 % of total riverine litter input in Europe), followed by the Black Sea and NEA. Modelled rivers discharging in the Baltic Sea contribute with the least amount of floating litter (10 %). However, rivers discharging in the Black Sea contribute the largest share relative to the number of emission points (63 %). **See section 4.2.1**

Theme	Status 2018 (colour) and perceived change in relation to 2012 (↘↗)					Justification
	Europe	BAL	NEA	MED	BS	
STATE OF POLLUTION IN THE MARINE ENVIRONMENT						
Overall status of the coast and marine waters (based on beach and seafloor indicators)	↘	?	↘	?	?	For the overall period 2010–2021 (combining seafloor and beach litter, and floating microlitter), MALT results indicate that almost 75 % of the marine and coastal areas assessed in Europe are classified as "potential problem areas", i.e. having a moderate, poor or bad status in terms of marine litter pollution. For the Baltic Sea, these corresponds to 83 % of the assessed areas, the NEA to 78 %, the Mediterranean Sea to 43 % and the Black Sea to 98 %, although for the last two the assessment is based on limited data points. Assuming the assessed areas as representative, results suggest a worsening of the overall situation and at least specifically in the NEA, when comparing the period of 2017–2019 with 2011–2013. Note that data used for the Mediterranean and Black Seas are limited. **See section 5.4.3 and Annex 5**
Status of offshore areas (based on floating microlitter and seafloor litter in 100x100 km grid marine cells, no. of items/particles)	?	?	?	?	?	There is currently no agreed threshold for seafloor litter and data used, especially for the Mediterranean and Black Seas which are very limited. Based on MALT, the Baltic Sea presents areas with a relatively poorer status than the NEA. The limited assessed areas for the Mediterranean are mostly classified as "poor" or "bad", while the ones in the Black Sea mostly classified as "moderate". **See section 5.4.3 and Annex 5**
Status of coastal areas (based on beach litter, floating microlitter and seafloor litter in 20x20 km grid coastal cells, no. of items/particles)	?	?	?	?	?	Overall, for Europe, data used in MALT allowed to assess 25 % of the total coastal grid cells, reaching roughly one third of the coastal areas of the Baltic and NEA, 15 % in the Mediterranean and 9 % in the Black Sea. For the period 2010–2021, over two thirds of the total area assessed (68 %) are classified as "potential problem areas", i.e. having a moderate, poor or bad status in terms of beach litter and in relation to the defined threshold. Comparatively, the Black Sea presents the worse situation with over 90 % of potential problem areas, the Mediterranean Sea with 78 % and the Baltic Sea and NEA with 62 and 64 %, respectively. **See section 5.4.3 and Annex 5**
Abundance of beach litter (based on median annual litter items per 100 m – 2015–2016)	?	?	?	?	?	Based on the assessment of a pan-European beach litter harmonised dataset (Hanke et al., 2019), the Baltic Sea shows the lowest levels of litter (40 items/100 m), followed by the Black Sea (106 items/100 m). The NEA and the Mediterranean Sea present the highest values (233 items/100 m and 274 items/100 m, respectively). Currently, no information on reliable trends in the amounts of beach litter in the four regional seas is available. **See section 5.2.1**

Theme	Status 2018 (colour) and perceived change in relation to 2012 (↘↗)					Justification
	Europe	BAL	NEA	MED	BS	
Abundance of PPSI in beach litter (based on median annual litter items per 100 m – MLW dataset 2015–2021)	↘ (orange)	↗ (orange)	? (orange)	↘ (red)	↘ (red)	PPSI is the most common litter category, particularly in the Black Sea and Mediterranean Sea, where its abundance is highest (358 items/100 m and 226 items/100 m, respectively). It is lowest in the NEA (41 items/100 m) and the Baltic Sea (19 items/100 m), whilst corresponding to 44 % and 34 % of total litter items, respectively. Data suggest an increasing trend in PPSI amounts in all regional seas, except the Baltic Sea, reaching peak values in 2019 or 2020. In the NEA, however, the annual evolution is complex, and in the Baltic Sea a decrease in PPSI litter seems to have occurred over the analysed period. **See section 5.3.1**
						Legend and colour code red – not acceptable/poor situation orange – reasonable situation but not sufficient green – satisfactory/good situation ↗ – situation in 2018 is perceived as better than in 2012 ↘ – situation in 2018 is perceived as worse than in 2012

6.2. Assessing the situation against EU policy objectives

Several objectives and targets have been defined in different EU policy instruments that relate to solid waste and marine litter. In Table 33 these are assessed based on indicators selected in this report. The perceived change between the two assessed years (2012 and 2018) are used as evidence to appraise the progress towards those objectives.

Prioritising waste prevention is one of the principles of the *waste hierarchy*, which application is encouraged in the Waste Framework Directive and in one of the six priority objectives of the 8th Environment Action Programme (8th EAP) (2021–2030). Another priority objective of the 8th EAP is the "zero-pollution" ambition. The ZPAP has several ambitious targets of considerably reducing waste generation and plastic litter at sea.

The results from this study suggest, however, that up until 2018, Europe was generally not on track to meet the defined policy objectives or targets, in particular in what concerns the reduction of plastic (packaging) waste and improvement of the situation regarding marine litter pollution. Hence, accomplishing the objectives for 2030 will require substantial efforts in preventing new inputs of plastic marine litter, which can only be achieved by the combined reduction of leakages to the environment (from littering behaviour and losses in waste management) and efforts to significantly reduce the generation of plastic waste in the first place.

Table 33 Policy objectives and targets set out by key European policies relevant to marine litter, the corresponding *Drivers-Pressures-State-Impact-Responses* (DPSIR) stage, the year defined to achieve the objectives (if applicable), the relevant indicators used in this assessment that can inform on progress towards the goals, and the perceived changes in 2018, as compared to 2012 or period around/between (GDP: Gross Domestic Product; PPSI: plastic packaging and small non-packaging plastic items)

Policy instrument	Objective/Target	DPSIR stage	Year	Relevant indicators used in this assessment	Perceived change (2018 compared to 2012 or trend over this period)
7th Environment Action Programme	*Strive towards an absolute decoupling of economic growth and environmental degradation*	Drivers Impacts	2020	GDP; plastic packaging waste generation	In what concerns plastic packaging waste generation between there is no evidence of decoupling with economic growth. This fraction of waste has increased and at a faster pace than GDP.
	Waste generation to decline absolutely and per capita	Pressure	2020	Total PPSI waste generated; PPSI waste generated per capita	PPSI waste generation per capita has generally increased

Policy instrument	Objective/Target	DPSIR stage	Year	Relevant indicators used in this assessment	Perceived change (2018 compared to 2012 or trend over this period)
8th Environment Action Programme	*Pursuing a zero-pollution ambition (…) in order to achieve a toxic-free environment*	**P**ressure **S**tate	2030	(see *Zero Pollution Action Plan* below)	
	Advancing towards a well-being economy (…) where (…) the waste hierarchy is applied	**R**esponses	2013	(see *waste hierarchy,* below)	
Zero Pollution Action Plan	*Reduce significantly total waste generation and by 50 % residual municipal waste*	**P**ressure	2030	Total PPSI waste generated	Total plastic waste generation has generally increased
	Reduce by 50 % plastic litter at sea and by 30 % microplastics released into the environment.	**S**tate	2030	Beach litter; Seafloor litter; Floating microlitter	Evidence suggests that the European marine environment is not becoming less polluted with litter. Annual median abundance of PPSI on European beaches seems to have increased (2015 – 2021)
Waste Framework Directive – waste hierarchy	Waste hierarchy: prioritise prevention and reuse	**R**esponses	n.a.	Total PPSI waste generated	PPSI waste generation has generally increased
	Recycling, recovery	**R**esponses	n.a.	Share of mismanaged PPSI waste	Share of mismanaged PPSI waste is generally decreasing
Marine Strategy Framework Directive	*Good Environmental Status* – Quantitative reduction of marine litter to a level that does not cause harm to the marine environment	**S**tate	2020	Quality status (combining beach litter; seafloor litter; floating microlitter)	Evidence suggests that the overall status of marine litter in Europe has not improved and might have gotten worse

7. Outlook on future assessments

Although this report constitutes an important step towards more integrated and holistic assessments of marine litter, it also provided the opportunity to reflect upon what could be done better. This section provides some general recommendations to improve future integrated assessments of plastic and litter pollution, from source to sea.

Recommendation 1: Enhance litter data collection across all the "source-to-sea" domains, including on pathways

- As also recognised in the Clean Europe Strategy[27], in order to characterize the nature of litter, identify its causes, define appropriate interventions and assess their effectiveness, it is fundamental to **measure and monitor litter and littering in all environmental compartments** where litter is a problem, including on land (both urban and rural) and aquatic environments;
- Rivers are crucial for understanding the relationship between *source* and *pathways* of litter flows. However, the methodological developments in riverine litter are in the early stages and there is a lack of observations in freshwater environments, when compared with the marine domain. A special focus must be attributed to **encourage riverine litter monitoring** and the development of **harmonised methodologies and protocols** for data collection;
- In addition, measuring litter (and microplastics) retained or discharged by **WWTPs represents an opportunity to assess and monitor specific sources of litter**, such as the inadequate disposal of waste through domestic toilets (e.g. cotton-bud sticks), secondary emissions of microplastics from urban effluents (e.g. washing-machines) and storm water drainage, in the case of countries that have combined sewerage systems;
- Although many positive steps were taken in recent years, legislative integration efforts are still in very early stages and there are still major gaps especially for the freshwater legislation, in relation to marine litter and plastic pollution. There are no provisions for achieving "good status" and monitoring waste/plastics in the Water Framework Directive. Besides, the Urban Wastewater Treatment Directive does not require any measures regarding microplastics accumulating in the sewage sludge or filtering of plastic items to prevent them from reaching rivers and the seas. The problem of litter cannot be solved by only regulating the sea and beaches. At its current level of integration, the EU acquis is missing one of three main pillars for the solution: **freshwater legislation must include strong measures, clear targets and the monitoring of litter indicators** (harmonised with the MSFD) for a complete and holistic legislative structure.

Recommendation 2: Make use of all the best data available and diverse sources of data, namely emerging technologies and citizen science, as well as modelling tools

- Particularly the Coastal and Marine Litter Assessment attempted to make use of (and would have benefited from) the best data available on marine litter. This included the datasets pertaining beach litter, as well as seafloor litter and floating microplastics. In reality, however, the assessment only used those data that were publicly accessible in EMODnet and existing datasets that would have provided a

[27] Clean Europe Network (CEN)

broader assessment coverage, e.g. in the Mediterranean Sea, these were not used. The authors expect the **assessment outputs can be further improved by accessing and incorporating additional data**;

- Earth observation technologies/remote sensing (satellites, planes, drones), videography and **emerging digital technologies** to process and analyse data (e.g. Artificial Intelligence (AI) and Machine Learning) are currently being explored to **develop applications for marine litter and plastic pollution**. These can be deployed not only in the marine/coastal domain but also in rivers, riverbanks and even on land (e.g. to locate and monitor dumpsites). AI is already used to successfully quantify and identify litter items from video images. **Broad spatial and temporal observations can provide much needed information** to help understand the dynamics of leakages and flows of litter, as well as future changes driven by responses.
- Not only there is the need to invest in relevant dataflows across the continuum *source-to-sea* but develop and apply **methodologies that can integrate these dataflows** and **highlight the causal relationships** between pressures and state of pollution. These methodologies can combine and integrate tools such as indicator-trend analysis, waste flow modelling, hydrological transport, discharges and hydrodynamics modelling.
- Analytical tools such as MALT that can assess the status of marine pollution in relation to policy goals can be particularly informative. This type of indicator-based assessment tool is dependent not only on the availability of observation data, but it is essential that **recognised threshold values** or **acceptable limits** are available, with which observations can be compared. Where these thresholds do not exist, work is necessary in order to ensure that they are developed on a sound scientific basis.
- Finally, other **spatial information** and **socio-economic indicators**, namely population density, tourism intensity and even the geo-location of potential point sources such as landfills, are important elements that can be factored in when assessing the intensity of pressures.

Recommendation 3:
Indicators across the different land-sea domains need to be comparable

- While the EU acquis is moving towards a more integrated structure for solutions, monitoring efforts should also follow in providing informative policy feedback. Efforts to harmonise methodological approaches for marine litter and the list of litter items have been catalysed by the TGML guidance. Efforts on harmonisation should be expanded to cover the origin and pathways of marine litter and therefore help building more **holistic assessments** on marine litter.
- Specifically, marine litter indicators and waste management indicators are often expressed in different units (marine litter tends to be expressed in **number of items** per area or volume, while waste is usually translated into **weight** or mass per year or per capita). Although assessment tools such as MALT are capable of integrating different types of indicators, this hinders the comparison and integration of the information resulting from these two domains. The use of simple counts of items prohibits the calculation of mass budgets which would enable a direct comparison between sources and sinks of litter. As suggested by Lebreton et al. (2017) marine litter studies should target to provide mass estimates to enable conservative budget assessments and compare those estimates with plastic production statistics. On the other hand, studies on waste generated and management could generate more detailed information on the composition of waste better aligned with pollution data collection (e.g. drink packaging, single-use plastic types) to enable the assessing of specific plastic applications along the whole waste-litter cycle.
- A concrete recommendation for an improved assessment is to correlate the mismanaged PPSI estimations of this study, which encompass specific plastic item categories, with the field observations of these same categories from riverine litter and beach litter monitoring. For example, a similar method as used by González-Fernández et al. (2021) but considering only the subset of data on plastic packaging + small items and using the per capita mismanaged PPSI waste obtained in this assessment (considered as more reliable as these originate from reported waste data by European countries) could

enable establishing **more robust and realist relations** between what is generated on land and what is discharged by rivers. Similarly, marine litter data could be disaggregated to provide an insight into the specific trends and spatial patterns distribution of this particular category of plastic. Correlations between these three domains, in a directly comparable way, could then be sought.

Recommendation 4:
Improve the understanding and quantification of leakages of plastic waste from land-based sources

- There is remarkably little knowledge and information about how, where and how much litter escapes the intended destination. This specifically relates to **littering** or inadequate disposal behaviour (and how much of this litter is recovered back into the waste system), **losses** from waste collection, as well as from non-sanitary landfills and illegal dumpsites. In the mismanaged PPSI waste assessment of this report, the estimates are affected by a high uncertainty due to a lack of reliable data on non-sanitary landfills, as well as on littering rates. These aspects are crucial – in fact they are central – to reliably estimate plastic waste leakages and inputs into the sea, as well as to being the focus of interventions to prevent plastic pollution at source.

Recommendation 5:
Improve estimations of mismanaged plastic and increase the granularity of material flow analysis

- Reliable estimations of MPW are not only crucial and significant to inform policy but these are often used as input to plastic emission studies, including those assessing riverine plastic emissions. As such, MPW data will determine the level of uncertainty and credibility of the outputs generated.
- There is naturally a trade-off between broad spatial coverage and spatial resolution. This assessment aimed at covering the full EEA32 + UK region, while analysing in detail the specific situation of each country. Nevertheless, there is the potential to further **increase the granularity of the estimations of MPW** by incorporating sub-national data on waste management, as well country-specific shares of plastic components in MSW.

Recommendation 6:
Riverine litter monitoring and research on transport processes need to be enhanced. Methodologies for data collection and reporting should be standardized

- Future research should investigate the role of factors determining **plastic transport in rivers** (van Calcar and van Emmerik, 2019). Since extensive monitoring of freshwater contamination, along with systematic sampling in the sediment and surface water of rivers is necessary to better understand seasonal inputs (Lebreton et al., 2017).
- Transversal barriers in rivers such as dams, weirs or hydropower plants among others have been reported to act as sinks for litter and information on their impact and operation is limited and difficult to assess on a large scale (Meijer et al., 2021; González-Fernández et al., 2021). There is a need for targeted modelling and observational studies to better address local conditions and the function of these transversal barriers in rivers.
- Determining the types of plastic is another task that is not always addressed in current studies on riverine litter and plastic emissions. The transport of plastics of **different types and sizes** should be differentiated in future assessments as it can lead to the source of the plastic and hence to the improvement of waste management and regulation (van Calcar and van Emmerik, 2019).

- Of equal importance is the need for new studies that include detailed metadata on river discharge and precipitation conditions prior to and during litter data collection. This would allow the display of the full variability of **floating litter fluxes** within a specific river, resulting in more accurate estimates of annual and interannual variations (González-Fernández et al., 2021).
- The level of uncertainty related to both measurements and models of plastic transport in riverine systems is still great (Lebreton et al., 2017). Methodologies and reported units should be better **standardized** as these vary widely across assessments, which hampers the **comparison** and ultimately the synthesis of data (Lebreton et al., 2017; United Nations Environment Programme, 2020). An internationally consistent methodology, including a consistent categorisation is required (Winton et al., 2020).
- Recently, the United Nations Environment Programme (UNEP) (2020), provided **methodological guidelines** to support the monitoring and assessment programmes of plastics in freshwater systems. It contains the most current procedures for monitoring and analysing of plastic content in rivers, lakes, reservoirs and water/wastewater treatment plants. The following guiding principles should be considered for the design phase of an environmental monitoring programme; (1) plastic monitoring should be integrated into existing monitoring programmes, (2) focus on relatively frequent and long-term monitoring at fewer locations, (3) simpler and cost-effective methods should be preferred. These guidelines can help to build up a consistent basis of monitoring data for future evaluations of riverine plastic litter emissions.

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CHAPTER 6

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Annex 1 Appraisal of input waste management data from other studies

Several global and regional studies make an attempt to quantify leakages of waste or plastic litter into the sea based on national rates of mismanaged waste. However, as discussed in detail by Edelson et al. (2021), limited reliability associated to the underlying waste management data lead to high uncertainties and significant differences in the national and global estimates among these studies.

As one of the most recent publications on European riverine litter discharges, González-Fernández et al. (2021) computed estimations of mismanaged waste (MW) for the European and non-European countries considered in their study. The fact that González-Fernández et al. (2021) provided estimates for floating riverine litter, based on an empirical regression model that computed overall mismanaged waste (i.e. not disaggregated by plastic packaging fraction), limits how far we can compare and integrate those riverine outputs with our estimates of mismanaged PPSI waste.

Furthermore, following a critical appraisal of the waste management data used by González-Fernández et al. (2021):

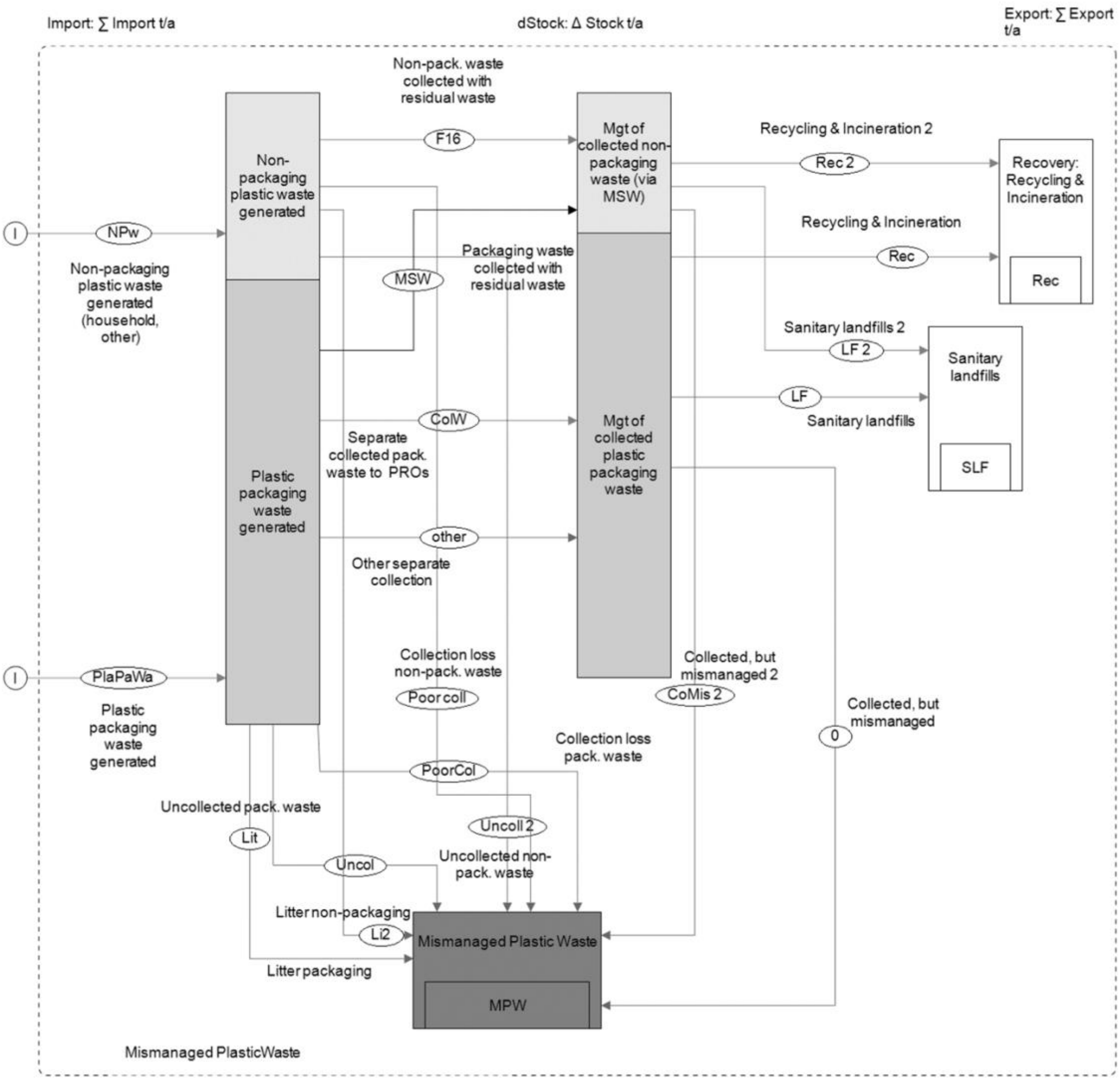
- González-Fernández et al. (2021) use MSW generation rates derived from the World Bank report "What a Waste" by Hoornweg and Bhada-Tata (2012)[28]. This is not only a more outdated dataset but they provide much higher MSW generation rates when compared to the MSW generation data rates from Eurostat (2021), as used in the present assessment. Furthermore, their numbers seem to include also municipal construction and demolition waste.
- Their estimates of MW seem to be overestimated, e.g. they come up with 28 kg/cap/year mismanaged MSW for Austria. Assuming a plastic fraction of 10 %, this would mean about 2.8 kg/cap/year mismanaged plastic waste, which is still about three times higher than what was found in this assessment (0.8 – 0.9 kg / cap), even if we only accounted for the PPSI waste fraction.
- They use some of the assumptions made in a widely cited paper by Jambeck et al. (2015), which assumes a littering rate of 2 % of plastic waste generated, which is, however, based on a US city specific number from 2008. This is clearly an important information gap. Nevertheless, in this assessment, for countries with similar waste management systems as Austria a default litter rate of 1 % was applied, based on a recent report by UBA-AT (2020), where the Austrian EPA tried to estimate the annual litter amounts in the country. For other countries, a littering rate of 2 % was used as default due to a lack of better data.

[28] Hoornweg, D. and Bhada-Tata, P., 2012, *What a Waste: A Global Review of Solid Waste Management*, World Bank 15, Washington DC

Annex 2 Detailed methodology, data quality assessment and uncertainty of the estimation of mismanaged PPSI Waste

A Material Flow Analysis (MFA) was performed for each country to quantify mismanaged PPSI waste (example in Annex 3). MFA is a systematic quantification of the flows and stocks of materials within a defined system in space and time, connecting the sources, the pathways and the sinks of a material (Brunner and Rechberger, 2016). It relies on a mass balance approach and allows for the consideration of data uncertainties. Based on publicly available data collected on the countries' management of plastic waste, the physical model of all relevant material flows was set up using the STAN free software (Cencic and Rechberger, 2008) (Figure A 2.1).

Figure A 2.1: Illustration of the qualitative material flow model to quantify mismanaged plastic waste as modelled with the STAN software[29]



[29] https://www.stan2web.net/. STAN (short for subSTance flow ANalysis) is a freeware that helps to perform material flow analysis according to the Austrian standard ÖNorm S 2096 (Material flow analysis – Application in waste management).

Data sources

- **Data on plastic production, demand segments and share of plastics in residual waste**: Plastics Europe (2013, 2019a, 2019b);
- **Data on plastic packaging placed on the market, plastic packaging waste generated, recovered and recycled** (as reported under the EU Packaging and Packaging Waste Directive)**:** Eurostat (2019, 2020, 2021a, 2021b). Plastic packaging data account for all packaging, whether it originates from industrial or commercial sources, offices, shops, services, households or any other entities;
- National Producer Responsibility Organisations and Extended Producer Responsibility Schemes or deposit schemes (country-specific example provided in Annex 3);
- **Waste collection coverage**: data on collection of MSW were based on country profiles on the management of municipal waste — Eionet Portal (europa.eu)[30] (EEA – Eionet, 2016) and assumed the same for PPSI waste;
- EEA/ETC/WMGE Early Warning Reports & current information received from the questionnaires in preparation of the next early warning report;
- **Data sources on littering**: UBA-AT 2020, Jambeck et al., 2015;
- **Data sources on the situation of landfills and illegal dumping**: EC database with information on infringement procedures (European Commission, 2021), media (e.g., Cypriumnews, 2019) and / or researchers (e.g., Kubásek, 2011) (country-specific, see Annex 3);
- **Landfilled postconsumer plastic waste:** Plastics Europe (2013, 2019).

For non-EU countries:

- **MSW generation and collection coverage in non-EU countries:** World Bank database (2018);
- **PPSI waste:** calculated based on the share of plastics in MSW based on World Bank data, using an average value of 12 % for high-income and upper middle-income countries and a share of 10 % for low-income countries (assuming 50 % uncertainty). 80 % of this are assumed to represent PPSI waste;
- For Türkiye, plastic waste imported in 2012 and 2018 was incorporated in the MFA (based on official data reported in TÜIK- Türkiye İstatistik Kurumu ([31]))
- **Population in NUTS3 regions**: Eurostat indicator "Population on 1 January – total", from the dataset “Population change – Demographic balance and crude rates at regional level (NUTS3) [demo_r_gind3]" by NUTS3 (see Section 6.1.2);
- **Population share in catchment areas**: EEA population grid 1x1 km (Hermann Peifer methodology), based on Landscan Global Population 2008 dataset; the dataset provides the basis for calculating the sum of population by 6.1.2 river catchments (see Section 4.2.1); and NUTS3 (see Section 6.1.2) for the NUTS3 units not covered by the Eurostat indicator: two NUTS3 regions of Estonia (Kesk-Eesti, Kirde-Eesti), five NUTS3 regions of Italy (Sassari, Nuoro, Cagliari, Oristano, Sud Sardegna), one NUTS3 region in Lithuania (Klaipėdos apskritis), four NUTS3 regions of the Netherlands (Noord-Friesland, Zuidwest-Friesland, Alkmaar en omgeving, Groot-Rijnmond), and eight NUTS3 regions of Norway (Troms og Finnmark, Oslo, Viken, Vestfold og Telemark, Agder, Rogaland, Vestland, Møre og Romsdal);

[30] https://www.eionet.europa.eu/etcs/etc-ce/products/country-profiles-on-the-management-of-municipal-waste
[31] https://data.tuik.gov.tr/Bulten/Index?p = Municipal-Waste-Statistics-2018-3066

- **Packaging covered:** all plastic packaging put on the market and plastic packaging waste generated in a country are covered, whether it originates from industrial or commercial sources, offices, shops, services, households or any other entities (Eurostat 2021b). The packaging data for each EU country were used as reported to Eurostat (2021b), while the small non-packaging plastic items were added with a 17:61 ratio[32] to obtain the total relevant amount of generated plastic waste;
- **Non-EU countries:** for non-EU countries who do not have to report on packaging waste, the known plastic share present in total MSW with 61 % assumed to be plastic packaging waste and 17 % small non-packaging plastic items was used to calculate the amounts of plastic packaging waste generated from land-based sources of marine plastic litter (Plastics Europe, 2019b). This was mainly important to quantify mismanaged PPSI waste in different regional sea areas, where countries like Russia and the Balkan states were included (see section 6.1.2), but also for EEA countries that do not report packaging waste numbers to Eurostat, namely Switzerland and Türkiye;
- **Uncertainties in reported data:** to account for reporting uncertainties (see further down), we cross-checked with the share of plastics in residual municipal waste, assumed that 61 % of these plastics represent packaging waste (Plastics Europe, 2019b) and added the separately collected plastic packaging waste. This calculated amount is then compared to the data reported to Eurostat and the difference is applied as an uncertainty range in the MFA inputs. In this context it is also important to understand the management of plastic packaging waste in each country, for instance, on how Extended Producer Responsibility Schemes (EPR) or deposit schemes work. Data on separate collection of plastic packaging waste is often published by national Producer Responsibility Organisations (EXPRA, 2014).

Data on plastic packaging for non-EU countries: A similar approach was followed to calculate PPSI waste generation relevant for land-based sources of marine litter for non-EU countries not reporting on packaging waste: the known plastic share present in total MSW with 61 % assumed to be plastic packaging waste and 17 % small non-packaging plastic items was used to calculate the amounts of plastic packaging waste generated (Plastics Europe, 2019b). Data on MSW collection coverage were mostly taken from the EEA country profiles on municipal waste management and assumed to be similar for packaging waste (EEA – Eionet, 2016). For non-EU countries data on MSW generation and uncollected waste was mainly taken from World Bank (2018).

Uncollected PPSI data: The share of uncollected PPSI waste in generated plastic waste is assumed to be equal to uncollected municipal waste in total generated municipal waste. This is most likely an overestimate, as the situation looks most likely better, at least for industrial/trade plastic packaging waste. Recycling rates for the latter, representing 36 % in overall plastic packaging waste, are higher compared to packaging from household sources, which implies also higher collection rates (EPRO, 2016).

Collection losses: Very limited information available about collection losses from waste infrastructure, e.g. overfloating waste bins, fly-off from trucks, transfer stations, a default of 1 % was assumed for all countries.

Post-collection mismanaged PPSI waste: for the amounts of plastic waste, which are collected but mismanaged a default range of 1 – 10 % was assumed for countries with open infringement procedures initiated by the European Commission with respect to poorly managed landfills and / or regarding active dumpsites (European Commission, 2021) or evidence from NGOs or other sources that there are some active illegal dumpsites.

[32] 61 % of total plastic waste is assumed to be plastic packaging waste and 17 % small non-packaging plastic items based on Plastics Europe (2019b).

Littering rates: Littering data are scarce. In this assessment, a default litter rate of 1 % was applied for countries with similar recycling rates as Austria, based on a recent report by UBA-AT (2020), where the Austrian EPA tried to estimate the annual litter amounts in Austria. For the rest the 2 % litter rate based on Jambeck et al. (2015) was used as the default due to a lack of better data.

Data gaps, assumptions and uncertainties

In addition to the assumptions made above, several others have been made that will be reflected in the uncertainty of the results:

- Average national numbers for waste generation, recycling, landfilling, littering and dumping are used, although there are regional differences within a country and also usually significant differences between rural and urban areas, e.g. with respect to waste management infrastructure, waste composition, awareness level etc.
- Country-specific data on land-based littering from the use-phase, for instance, is scarce, which is why Jambeck et al. (2015) is widely cited, assuming 2 % of generated waste being littered.
- Inherently, there are significant data gaps on illegal dumpsites and other waste crimes.
- Except for the EC's database on infringement procedures there is no quantitative information on the state and / or the potential leakage from European landfills.
- To the authors' knowledge, there is no robust quantitative data on losses during waste collection and transport for Europe.

Data on packaging and packaging waste

- As packaging waste is a major category of litter, it is important to understand the management and policies in each country. The uncertainties linked to the reporting of packaging waste can be very high, overruling other uncertainties linked to mismanaged PPSI waste estimates. They seem to be lower in countries with older Extended Producer Responsibility (EPR) schemes and better monitoring in place. Positive developments are visible over time, when comparing 2012 to 2018.
- According to the Producer Pays Principle, as anchored in the EU Packaging and Packaging Waste Directive, entities placing packaging materials on the market pay a fee to assure the environmentally sound disposal of packaging waste (Institute for European Environmental Policy, 2017).
- EPR schemes have very different operational, financial and legal set-ups, e.g. some cover both household and non-household sources (while others do not), with respect to financing there are collective vs individual schemes, some collect only specific plastic packaging, e.g. only flasks and bottles. Some countries have also deposit return schemes for certain plastic bottles in place.
- The EU Packaging and Packaging Waste Directive requires the reporting of packaging put on the market and packaging waste to Eurostat. Eurostat data are generally considered reliable, but the underreporting of packaging materials put on the market is a known issue as well as the overreporting of recycling rates for various reasons:
    - Free riding: online sales and cross border trade;
    - Use of a De Minimis threshold for reporting standards;
    - Reliance on inaccurate or incomplete industry data (Eurostat, 2020)
- Because of these underreporting issues, the uncertainties linked to the amounts of packaging waste can be very high, overruling other uncertainties linked to mismanaged PPSI waste. They seem to be lower in countries with older EPR schemes and better monitoring in place. Positive developments are visible over time, comparing 2012 to 2018.

Pedigree matrix used to assess the quality of data sources

During the data collection it was found that many data are linked to different types of uncertainties (e.g. from measurements or different degrees of reliability). To assess the quality of data sources the pedigree matrix by Weidema and SuhrWesnæs (1996) was used, allowing for the translation of different levels of data quality into uncertainties. Based on the scores of the data quality indicators the variance of the normal distribution can be calculated in addition to the uncertainty from measurement and was used for the modeling in STAN.

Annex 3 Results of the MFA for mismanaged PPSI waste for each country

Table A3.1 Results PPSI waste generated and mismanaged (kg/capita, based on the estimates of total PPSI waste generated and mismanaged resulting from the country-specific material flow analyses) in 2012 and 2018 for the European and non-European countries assessed. (PPSI: plastic packaging and small non-packaging plastic items)

Country		PPSI waste generated				Mismanaged PPSI waste						Population		Share of mismanaged PPSI waste (in relation to generated PPSI waste)		Share of uncollected PPSI (due to insufficient collection coverage)		Littering rate (use-phase)	Collection loss rate (e.g. overfloating bins)	Collected but mismanaged rate (due to poor landfills or strong informal sector)
ISO 2-digit	Name	2012 per capita [kg]	2018 per capita [kg]	2012 tonnes/year	2018 tonnes/year	2012 per capita [kg]	2018 per capita [kg]	2012 tonnes/year	uncertainty %	2018 tonnes/year	uncertainty %	2012	2018	2012	2018	2012	2018	1 % or 2 %	1%	0 % or 1%
AT	Austria	41.2	43.7	347642.00	386258.00	0.82	0.87	6953.00	24%	7725.00	24%	8,429,991	8,840,521	2.0%	2.0%	0	0	1%	1%	0%
BE	Belgium	34.2	38.9	379915.44	444316.93	0.74	0.78	8196.00	39%	8886.00	46%	11,106,932	11,427,054	2.2%	2.0%	0	0	1%	1%	0%
BG	Bulgaria	16.8	23.9	122941.00	168008.16	1.72	2.2	12571.00	153%	15591.0	56%	7,305,888	7,025,037	10.2%	9.3%	2%	1%	2%	1%	1-10%
CY	Cyprus	22.5	25.5	19467.66	22223.90	3.4	3.8	2910.0	253%	3322.0	190%	863,945	870,068	14.9%	14.9%	7%	7%	2%	1%	1-10%
CZ	Czech Republic	25.8	32.2	270713.14	342104.36	1.0	1.3	10747.0	45%	13582.0	80%	10,510,785	10,629,928	4.0%	4.0%	0	0	2%	1%	1%
DE	Germany	45.1	49.9	3628139.00	4138588.00	0.9	1.0	72563.0	71%	82772.0	62%	80,425,823	82,905,782	2.0%	2.0%	0	0	1%	1%	0%
DK	Denmark	42.0	53.4	234948.46	309308.24	0.8	1.1	4699.0	25%	6186.0	28%	5,591,572	5,793,636	2.0%	2.0%	0	0	1%	1%	0%
EE	Estonia	46.0	53.6	60868.00	70848.00	3.7	3.8	4869.0	37%	4959.0	25%	1,322,696	1,321,977	8.0%	7.0%	5%	4%	2%	1%	0
EL	Greece	21.4	24.1	236512.68	258485.90	1.8	2.0	19713.0	147%	21545.0	138%	11,045,011	10,732,882	8.3%	8.3%	0	0	2%	1%	1-10%
ES	Spain	35.7	45.2	1668409.46	2116986.73	1.5	1.9	69534.0	33%	88236.0	32%	46,773,055	46,797,754	4.2%	4.2%	0.02%	0.02%	2%	1%	1%
FI	Finland	27.7	31.4	149948.68	172987.31	0.8	0.6	4498.0	66%	3460.0	68%	5,413,971	5,515,525	3.0%	2.0%	0	0	2%	2% 1% (2018)	0
FR	France	39.0	44.9	2555212.00	3014412.00	1.2	1.3	76656.0	30%	90432.0	25%	65,438,667	67,101,930	3.0%	3.0%	0	0	2%	1%	0
HR	Croatia	14.5	20.1	61728.38	82321.56	1.8	1.9	7478.0	349%	7649.0	196%	4,269,062	4,090,870	12.1%	9.3%	4%	1%	2%	1%	1-10%
HU	Hungary	33.1	44.6	328590.45	435654.26	1.6	1.8	16298.0	44%	17295.0	21%	9,920,362	9,775,564	5.0%	4.0%	2009, 92 %		2%	1%	
IE	Ireland	46.9	69.4	215616.38	337677.74	7.7	3.2	35577.0	35%	15533.0	26%	4,599,533	4,867,316	16.5%	4.6%	13.5%		2%	1%	0
IT	Italy	44.1	48.5	2624508.00	2931468.00	8.7	9.5	516372.0	17%	576766.0	17%	59,539,717	60,421,760	19.7%	19.7%	12%+-0,0142	12+-0,0142	2%	1%	1-10%
LT	Lithuania	25.6	34.6	76353.74	97021.10	1.5	1.4	4581.0	45%	3881.0	24%	2,987,773	2,801,543	6.0%	4.0%	3%	1%	2%	1%	0%
LU	Luxembourg	58.5	54.5	31056.68	33128.66	1.2	1.1	621.0	50%	663.0	28%	530,946	607,950	2.0%	2.0%	0	0	1%	1%	0
LV	Latvia	23.3	29.0	47303.82	55791.69	3.0	3.8	6178.0	28%	7286.0	27%	2,034,319	1,927,174	13.1%	13.1%	5%	5%	2%	1%	1-10%
MT	Malta	33.0	40.7	13872.03	19708.11	3.7	4.5	1550.0	69%	2201.0	62%	420,028	484,630	11.2%	11.2%	3%	3%	2%	1%	1-10%
NL	Netherlands	35.0	38.8	587061.00	668917.00	0.7	0.8	11741.0	31%	13097.0	30%	16,754,962	17,231,624	2.0%	2.0%	0	0	1%	1%	0
PL	Poland	28.0	33.2	1064024.40	1259707.56	6.6	1.3	252910.0	31%	49988.0	22%	38,063,164	37,974,750	23.8%	4.0%	20%	0	2%	1%	1%
PT	Portugal	42.6	51.6	448021.00	530144.00	1.3	1.5	13441.0	30%	15904.0	32%	10,514,844	10,283,822	3.0%	3.0%			2%	1%	
RO	Romania	19.0	25.7	381195.72	500569.90	4.5	4.9	89409.0	25%	95019.0	27%	20,058,035	19,473,970	23.5%	19.0%	16%	13%	2%	1%	1-10%
SE	Sweden	28.7	30.9	273257.07	314549.59	0.6	0.6	5465.0	25%	6291.0	24%	9,519,374	10,175,214	2.0%	2.0%	0	0	1%	1%	
SI	Slovenia	27.9	30.5	57351.64	63160.86	1.1	0.9	2277.0	30%	1882.0	20%	2,057,159	2,073,894	4.0%	3.0%	0	0	2% 1% (2018)	1%	1%
SK	Slovakia	24.7	31.0	133720.73	168732.08	1.0	1.2	5309.0	24%	6699.0	22%	5,407,579	5,446,771	4.0%	4.0%	0	0	2%	1%	1%
UK	United Kingdom	51.3	45.4	3265986.61	3019719.00	2.0	1.8	129660.0	36%	119883.0	27%	63,700,215	66,460,344	4.0%	4.0%	0	0	2%	1%	1%
TR	Turkey	41.0	42.4	3078600.00	3453300.00	18.3	20.9	1491072.0	50%	1703760.0	50%	75,175,827	81,407,204	44.7%	49.3%	23%	12%	2%	1%	45%
NO	Norway	40.3	53.4	202115.25	283545.35	1.2	1.6	6063.0	36%	8506.0	20%	5,018,573	5,311,916	3.0%	3.0%	1%	1%	1%	1%	1%
IS	Iceland	45.8	60.8	14690.59	21450.11	1.4	1.8	441.0	38%	644.0	36%	320,716	352,721	3.0%	3.0%	0	0	2%	1%	0
CH	Switzerland	45.1	42.7	360778.00	363236.00	0.7	0.6	5412.0	62%	5449.0	73%	7,996,861	8,514,329	1.5%	1.5%	0	0	1%	0.50%	0
LI	Liechtenstein	25.3	27.0	927.28	1032.15	0.5	0.5	19.0	64%	21.0	35%	36,657	38,246	2.0%	2.0%	0	0	2%	1%	0
Others																				
AL	Albania	31.1	44.4	90240.00	127200.00	17.1	24.4	49632.0	50%	69960.0	50%	2,900,389	2,866,376	55.0%	55.0%					
AD	Andorra	52.2	54.7	4028.35	4128.00	25.0	26.2	1929.6	50%	1977.3	50%	77,181	75,486	47.9%	47.9%					
BA	Bosnia and Herzegovina	32.6	34.2	125088.00	119424.00	21.9	23.0	84189.3	50%	80377.2	50%	3,837,455	3,496,157	67.3%	67.3%					
BY	Belarus	38.1	43.3	360762.14	410880.00	2.7	3.1	25614.1	50%	29172.5	50%	9,464,495	9,483,499	7.1%	7.1%					
MC	Monaco	113.4	115.3	4132.90	4416.00	10.9	11.1	396.8	50%	423.9	50%	36,460	38,300	9.6%	9.6%					
MD	Moldova	65.0	89.7	231424.35	318496.00	55.1	76.0	195970.1	50%	269702.4	50%	3,559,519	3,549,196	84.7%	84.7%					
MK	North Macedonia	36.6	28.9	75456.00	60000.00	36.5	28.8	75244.7	50%	59832.0	50%	2,061,044	2,076,217	99.7%	99.7%					
ME	Montenegro	47.5	50.9	29472.00	31680.00	44.9	48.2	27874.6	50%	29962.9	50%	620,601	622,271	94.6%	94.6%					
RU	Russia	32.2	39.5	4632595.20	5760000.00	30.7	37.7	4424128.4	50%	5500800.0	50%	143,993,982	145,734,038	95.5%	95.5%					
RS	Serbia	34.9	30.7	251520.00	214080.00	34.7	30.5	250092.6	50%	212865.1	50%	7,199,077	6,982,604	99.4%	99.4%					
SM	San Marino	47.8	47.8	1598.48	1648.77	26.2	26.2	878.4	50%	906.0	50%	33,469	34,522	55.0%	55.0%					
UA	Ukraine	14.0	10.5	637600.00	443200.00	13.4	10.1	608917.6	50%	423262.7	50%	45,412,987	42,100,165	95.5%	95.5%					
XK	Kosovo	14.2	18.1	25520.00	32560.00	10.5	13.4	18908.4	50%	24124.5	50%	1,797,814	1,797,086	74.1%	74.1%					

Below, the details of the MFA to estimate PPSI for Bulgaria in 2012 and 2018 are provided as an example.

Figure A3.2: MFA for mismanaged PPSI waste in Bulgaria, 2012 (PPSI: plastic packaging and small non-packaging plastic items), using STAN free software

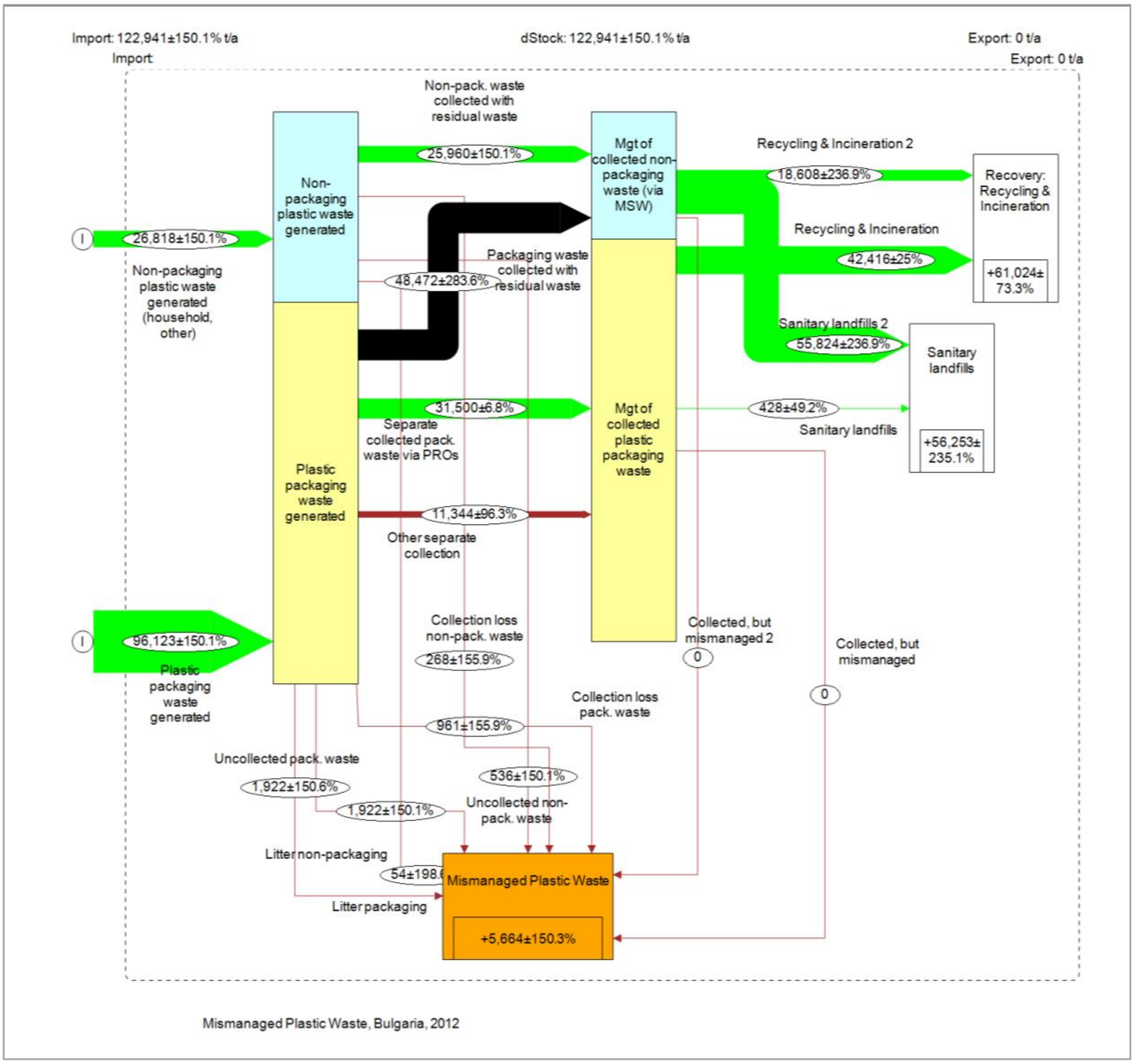


Figure A3.3: MFA for mismanaged PPSI waste in Bulgaria, 2018. (PPSI: plastic packaging and small non-packaging plastic items), using STAN free software

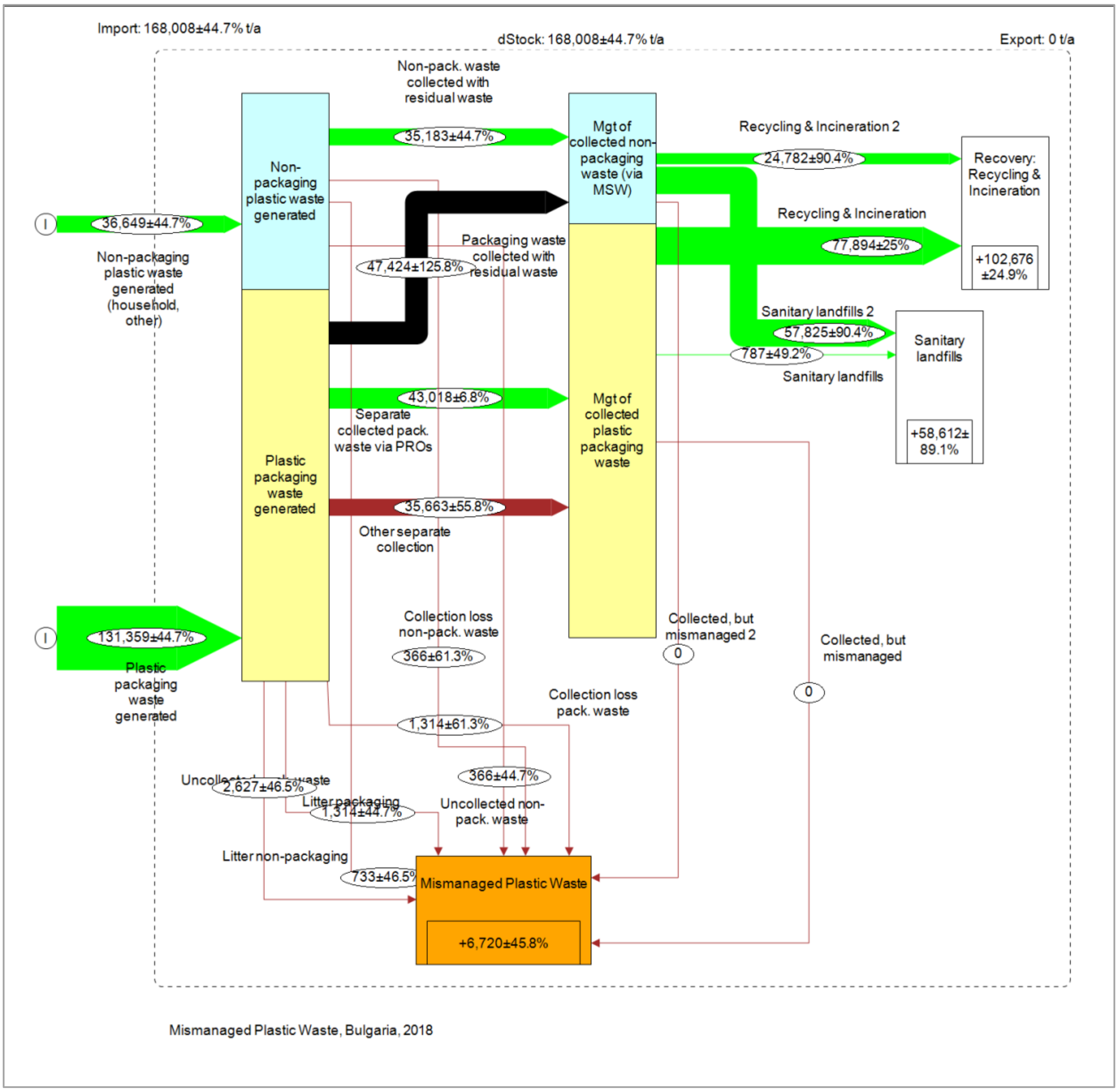


Table A3.2 Data to quantify mismanaged PPSI waste in Bulgaria (PPSI: plastic packaging and small non-packaging plastic items)

MFA Process (boxes) & Flows (arrows)	2012 Data & Assumptions for MFA model	2018 Data & Assumptions for MFA model	Data sources	2012 Uncertainties	2018 Uncertainties	Data quality (see below) Score 1 (best) – 5
Plastic packaging waste generated	**96 123 t (2012)**	**131 359 t (2018)**	**Plastic packaging waste generated (tonnes/year; kg/capita) (Eurostat)**	264 kt[33]	182 kt	I. Reliability: 2 II. Completeness: 1 III. Temporal correlation: 1 IV. Geographical correlation: 1 V. Further technological correlation: 1
Non-packaging plastic waste generated (household, other)	**27.9 % * Plastic pack waste**	**27.9 % * Plastic pack waste**	**Plastics Europe, 2012/2018, EU average (not country specific)** Plastic Waste generation by sector, 2012 /2018 4 % household items 13 % other (incl medical) 61 % packaging waste			I. Reliability: 2 II. Completeness: 2 III. Temporal correlation: 1 IV. Geographical correlation: 3 V. Further technological correlation: 2
Uncollected pack. waste **Uncollected non-pack. waste**	98 % Municipal waste collection coverage achieved in 2010 **2 % uncollected in 2013**	99 % (assume) Municipal waste collection coverage achieved after 2010 **1 % uncollected in 2018**	**Waste MSW collection coverage / collection rate** Municipal waste management. Factsheet for Bulgaria, 2013	0.0002	0.0001	I. Reliability: 3 II. Completeness: 3 III. Temporal correlation: 1 IV. Geographical correlation: 1 V. Further technological correlation: 3
Separate collected pack. waste via PROs	Assume 31 500 t (2012) 43kt/131 kt = 33 % transfer 2018 share to 2012 as according to Eunomia early warning not much has changed= 33 % * 96 kt = 31.5 kt	43018 t (2018)	**Plastic packaging waste collected by biggest PRO in Bulgaria, 2018** Ecopack Bulgaria , 2018 The biggest PRO Ecopack reports 18,003.87 tonnes of pla pack waste & market share of 41.85 % = 43018 t total separated collected plastic waste	2136	2918	I. Reliability: 3 / 2 II. Completeness: 3/3 III. Temporal correlation: 3/1 IV. Geographical correlation: 1 /1 V. Further technological correlation: 1/1
Collected packaging waste from other sources	Calculated		In Bulgaria curbside separate collection with very active informal sector (Early Warning Report)			
Packaging waste collected with residual waste	Calculated					
Non-pack. waste collected with residual waste collected	Calculated					
Litter packaging **Litter non packaging**	2 % of the total waste generated 2012: 0.0227 * **Plastic pack waste** 0.0227 * **Plastic non-pack waste**	2 % of the total waste generated 2018: 0.0227 * **Plastic pack waste** 0.0227 * **Plastic non-pack waste**	2 % = number from the US estimated in 2008, based on Jambeck 2015			I. Reliability: 2 II. Completeness: 5 III. Temporal correlation: 2 IV. Geographical correlation: 2 V. Further technological correlation: 3
Recycling & Incineration (pack. Waste)	Plastic packaging waste: **42 416 t /a (2012)**	Plastic packaging waste: **77 894 (2018)**	**Recovery / Recycling of plastic packaging waste** (EUROSTAT)	Uncertainty of 25 % applied, due to organic contamination [34]		I. Reliability: 1 II. Completeness: 1 III. Temporal correlation: 1 IV. Geographical correlation: 1 V. Further technological correlation: 1

33 Uncertainty factors with respect to data quality (Weidema 1996) + underreporting uncertainty (cf section 8.1.1)
34 "Naar een beter beleid voor verpakkingsafval in Vlaanderen – recover (2018)", Table 4

MFA Process (boxes) & Flows (arrows)	2012 Data & Assumptions for MFA model	2018 Data & Assumptions for MFA model	Data sources	2012 Uncertainties	2018 Uncertainties	Data quality (see below) Score 1 (best) – 5
Sanitary landfill 2	**Rest of pack waste which does not go into recovery/recycling** 1% of separately collected plastic pack. waste	**Rest of pack waste which does not go into recovery/recycling** 1% of separately collected plastic pack. waste	5 sanitary landfills meeting EU standards are under operation in Estonia, replacing 150 former, non-EU-conform landfill sites For separately collected pack waste we assume very little 1 % to be landfilled	0.0042		I. Reliability: 5 II. Completeness: 5 III. Temporal correlation: 5 IV. Geographical correlation: 5 V. Further technological correlation: 5
Sanitary landfill	75 % of post-consumer plastics to landfill	70 % of post-consumer plastics to landfill	**Plastics Europe 2013 / 2019** FINAL_web_version_Plastics_the_facts2019_14102019.pdf (plasticseurope.org) https://www.plasticseurope.org/application/files/7815/1689/9295/2013plastics_the_facts_PubOct2013.pdf			I. Reliability: 1 II. Completeness: 1 III. Temporal correlation: 1 IV. Geographical correlation: 1 V. Further technological correlation: 1
Recycling & Incineration 2 (non-pack. waste)	Calculated					
Collected, but mismanaged (pack. waste) **Collected, but mismanaged 2 (non - pack. waste)**	0		Municipal waste management. Factsheet for Bulgaria			I. Reliability: 1 II. Completeness: 1 III. Temporal correlation: 1 IV. Geographical correlation: 1 V. Further technological correlation: 1
Collection loss pack. waste [35] **Collection loss non pack. waste**	Assume 1 % of collected waste leaks into the environment e.g. overfloating bins, fly off from transfer stations (poorly collected)			0.0042		I. Reliability: 4 II. Completeness: 5 III. Temporal correlation: 5 IV. Geographical correlation: 5 V. Further technological correlation: 5
Overall mismanaged waste	Calculated			-		-

Table A3.3 Per capita mismanaged PPSI waste and share of mismanaged PPSI waste in overall waste (PPSI: plastic packaging and small non-packaging plastic items)

	Bulgaria			
	Kg /capita plastic (non) packaging waste			
	2012	**uncertainty**	**2018**	**uncertainty**
Generated	17	148 %	24	45 %
Mismanaged	0,8	150 %	1	46 %
EW	7,310,000		7,030,000	
Share of mismanaged waste in overall generated plastic waste	5 %		4 %	

[35] Based on collection service and frequency / how does the collection system work, i.e. door-to-door, bring points, are the bins leaking? Wind from transfer stations?

Annex 4 Characteristics of the main studies used for riverine litter emission estimations

Table A4.1 Characteristics of the two main studies used for riverine macrolitter emission estimations in Chapter 4

Category	Meijer et al. (2021)	González-Fernández et al. (2021)
Geographical scope	Global	Europe
Spatial reference	3x3-arc sec grid cells	European Catchments and Rivers Network System (ECRINS)
Reference year	2015	2016/2017
Model output variable	Tonnes of macroplastic emissions per year per river mouth [t×year^{-1}]	Number of floating macrolitter items per year [items×year^{-1}]
Model components	*Component 1* Probability P(E) for plastic waste, discarded on land, to be emitted into the ocean, including (a) mobilization on land, (b) transport from land to a river, and (c) transport from the river to the ocean. (a) Mobilization on land is based on monthly averaged wind speed and annual rainfall; (b) Transport from land to a river is based on distance to the nearest river and landscape roughness (land use and terrain slope); (c) Transport from the river to the ocean is based on distance to the ocean, Strahler stream order and annual river discharge. *Component 2* Total amount of generated mismanaged plastic waste mass (kg year^{-1}) within the grid cell	Total amount of generated mismanaged plastic waste mass (t×year^{-1}) generated in the upstream catchment

Category	Meijer et al. (2021)	González-Fernández et al. (2021)
Model formula	ME = ∑ MPW×P(E), with ME – total annual emission of plastic into the ocean from a river; MPW – mismanaged plastic waste mass; P(E) – probability for plastic waste to be emitted into the ocean.	log10 (FLM) = a + b×log10 (MW), with FLM – annual floating macrolitter loading; MW – mismanaged plastic waste mass.
Data source on mismanaged plastic waste	Lebreton & Andrady (2019)	Schmidt et al. (2017) based on Jambeck et al. (2015)
Details on model of mismanaged plastic waste	Geographical scope: global Spatial reference: 3x3-arc sec grid cells Reference year: 2015 Model components: - per capita municipal solid waste generation rate - plastic fraction in municipal solid waste - mismanaged waste fraction Data reference on waste generation rate: Waste Atlas (2016)[36]	Geographical scope: global Spatial reference: buffers within 50 km of the coastline Reference year: 2010 Model components: - per capita waste generation rate - percentage of plastic waste - percentage of mismanaged waste Data reference on waste generation rate: Hoornweg & Bhada-Tata (2012)
Model calibration	Calibrated against 52 field observation data points of monthly riverine macroplastic transport from 16 rivers (data collected between 2017 and 2020).	Calibrated against field observation data points of 38 rivers (698 monitoring sessions with a total of 398 h of observation) selected from the

[36] Waste Atlas, 2016, 'D-waste' (http://www.atlas.d-waste.com/) accessed 15 August 2021.

Category	Meijer et al. (2021)	González-Fernández et al. (2021)
	Best calibrated model shows R^2 = 0.71 between observed and modelled plastic litter emissions.	RIMMEL database (minimum six monitoring sessions per river; data collected from June 2016 to September 2017), complemented with three additional rivers offering comparable data from the literature. Relating mean-based FML to MW obtained a statistically significant logarithmic linear regression model (R^2 = 0.56).
Model validation	Validated against 84 field observation data points of monthly riverine macroplastic transport from 51 rivers (data collected between 2017 and 2020). Model predicted emission points ranged within a factor of 4 with a 68 % confidence interval and a factor of 10 with a 95 % confidence interval.	The model has not been validated.
Survey method for observational data	Observational data were collated from three different data sources. Observations were generally conducted from bridges near river mouths. During each measurement, all floating plastic items were counted for a certain duration, then normalized over time by expressing the data in floating plastic items per hour (items $hour^{-1}$). Items visible in the upper 10 cm of the water column were monitored.	Observational data were collected on the basis of a harmonized monitoring approach (González-Fernández & Hanke 2017). Observations took place from an elevated position (bridge, pontoon, pier or riverside), identifying surface and near-surface floating macrolitter flowing downstream in the respective river. Observers performed monitoring sessions for 30–60 min.
Size of macroplastic litter	> 0.5 cm	> 2.5 cm
Average mass per macroplastic	2 to 19 g	5.4 g
Strengths	- Model accounts for factors of litter mobilization and	- Study explicitly addresses the European

Category	Meijer et al. (2021)	González-Fernández et al. (2021)
	transport. - Model calibration obtained R^2 = 0.71. - Model has been validated with additional data. - Observed data consider conversion factor to account for plastics at deeper water layers, derived from net sampling at each river (if available). - Observed data consider monthly average river discharge to distribute plastic emissions over 12 months.	context. - Monitoring data used to calibrate the model have been derived on the basis of a standardised protocol. - A ranking of different types of floating litter items is provided, showing that 82 % are plastic items.
Weaknesses	- Global study not specifically addressing the European context. - No model estimates available for emission points >60°North (due to lack of global DEM). - Type and characteristics of the plastic item are not studied.	- Monitoring frequencies and durations differ between rivers used to calibrate the model. - Macroplastic litter item sizes < 2.5 cm are not considered. Only floating macroplastic litter is considered.

Annex 5 Prototype MALT assessment tool methodology and detailed results

The prototype Marine Litter Assessment Tool (MALT) is a multi-metric indicator-based status assessment tool, in the tradition of other assessment tools employed by the EEA and ETC-ICM in recent European assessments to determine status with regard to hazardous substances (CHASE+) (EEA 2019a), eutrophication (HEAT+) (EEA 2019b), biodiversity and ecosystem health (MESH+) (EEA 2020). MALT has been developed using the same principles as these other tools, allowing assessments to be made in a uniform manner given varying forms and availability of indicators.

Indicator definition

The tool works by calculating an Ecological Quality Ratio (EQR) within a Spatial Assessment Unit (SAU), as an aggregated score of normalised indicator values. All indicator values are normalised to a scale from 0 to 1, with five status classes at equal intervals. This allows indicators using different numerical scales to be compared in a consistent way.

Table A5.1 Ecological Quality Ratio (EQR) Status Classification

EQR Value	Class
0.0 ≤ EQR < 0.2	Bad
0.2 ≤ EQR < 0.4	Poor
0.4 ≤ EQR < 0.6	Moderate
0.6 ≤ EQR < 0.8	Good
0.8 ≤ EQR ≤ 1.0	High

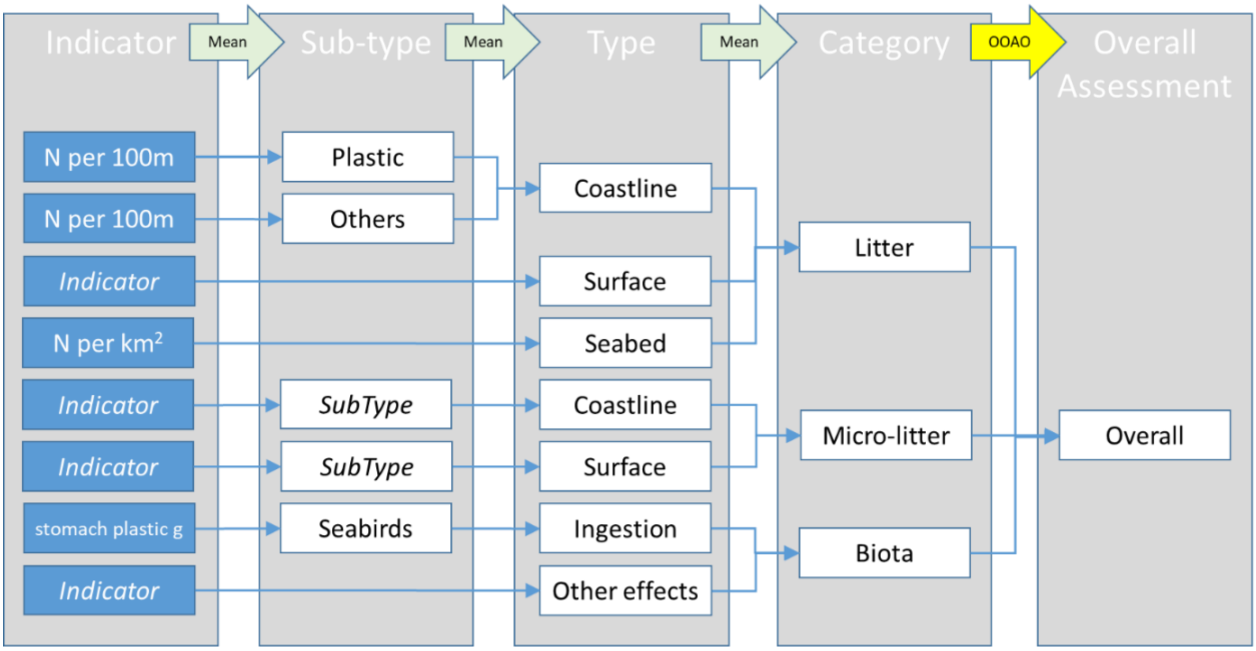
To normalise the observed value of the indicator parameter to the common EQR scale 3 values are required. The threshold value, determining the boundary between good and moderate status i.e. the value of the indicator corresponding to EQR = 0.6. For example, the value of 20 items per 100 m of beach. Additionally, the values of the indicator corresponding to the worst possible case (EQR = 0) and the value of the indicator corresponding to reference conditions. In the case of a count of items of litter, this could be 0 items.

Aggregation

The tool has a flexible structure within which indicators are aggregated at several levels. Within descriptor 10, there are two primary criteria (D10C1 Litter and D10C2 Micro-litter) and two secondary criteria (D10C3 Ingestion by animals and D10C4 Individuals adversely affected). The tool is structured with three indicator categories, the first two corresponding to C1 and C2 and a third category C3 corresponding to the two biota-related secondary criteria.

Primary Criteria C1 and C2 refer to three types of litter (or microlitter): (i) on the coastline, (ii) in the surface layer of the water column and (iii) on the seafloor. The tool allows for indicators to be aggregated within these indicator "Types" before being aggregated at Category (Criteria) level. Further subdivision of indicators into subtypes is possible e.g. using separate indicators for plastic and other materials when counting items on the coastline. At each aggregation level, the aggregated EQR is calculated as the mean of the EQR values of the included indicators. Finally, using a one-out all-out method (OOAO), the overall EQR is determined as the worst of the EQR values of the three categories Litter, Micro-litter and Biota. The aggregation steps are outlined below in figure A5.1.

Figure A5.1 – Indicator aggregation scheme for the MALT prototype tool



Where no Types or Sub-Types are specified, indicators are simply aggregated within the three categories Litter, microlitter and biota. The potential for aggregation at several levels is a flexible feature which may be useful where more diverse sources of ML monitoring data are to be gathered to give a single assessment.

Spatial assessment units

The MALT tool is intended to be applied using indicators mapped to the EEA assessment grid which was used as the spatial structure for the previous Europe-wide EEA assessments mentioned above. Development of this assessment grid is described in the online supplementary material to (EEA 2019b) grid. However, in principle the tool can be applied to any set of spatial assessment units (SAUs), with the only requirement being that all indicators are mapped consistently to the same set of SAUs. That is, indicators defined with different spatial resolutions and extents should be interpolated to a common set of spatial assessment units.

Table A5.2 Status class boundaries for the beach litter count, seafloor litter count and floating microlitter count indicators

EQR	Boundary	Beach litter		Seafloor litter		Floating microlitter	
		n per 100 m	$log_{10}(n)$	n per km²	$log_{10}(n)$	n per m³	$log_{10}(n)$
1.0	Upper limit EQR	1.0	0.00	1.0	0.00	0.001	-3.00
0.8	High/Good	4.5	0.65	3.9	0.59	0.1	-1.00
0.6	Good/Moderate	20	1.30	15.4	1.19	10	1.00
0.4	Moderate/Poor	127	2.10	57	1.75	46.4	1.67
0.2	Poor/Bad	807	2.91	207	2.32	215	2.33
0.0	Lower limit EQR	5129	3.71	759	2.88	100	3

Figure A5.2: Summary of preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in Europe for all coastal areas (left) and for 4 regions

MALT summaries for beach litter and seafloor litter

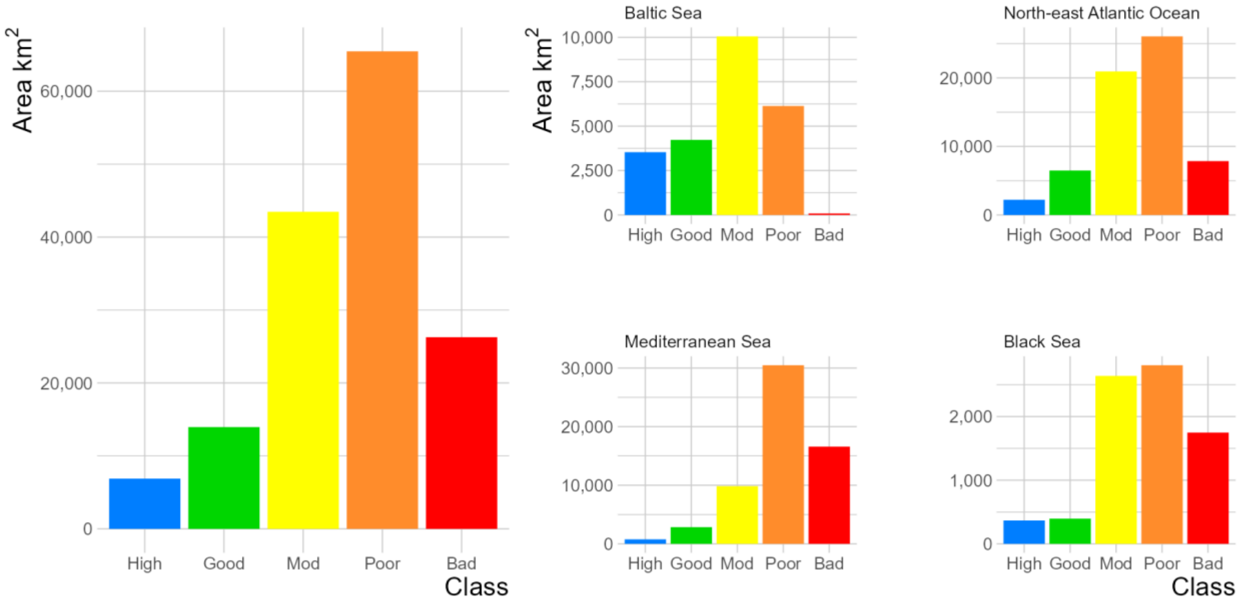


Figure A5.3: Summary of preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in Europe's Seas for all areas (left) and for 4 regions

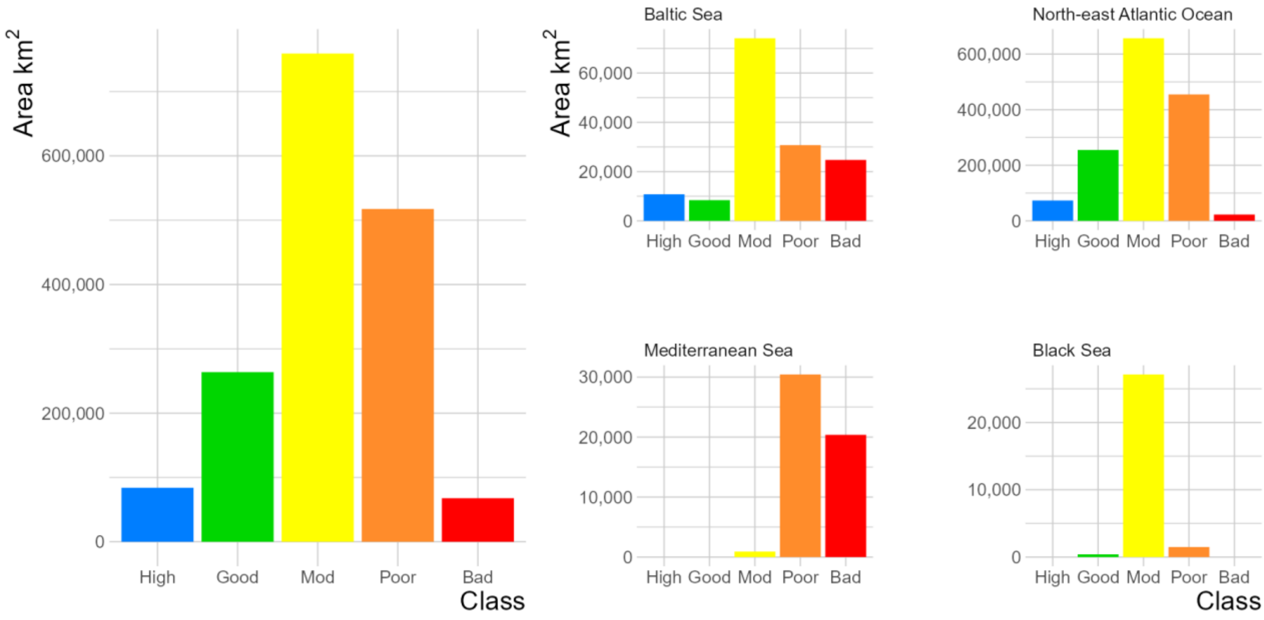


Figure A5.4: Summary of preliminary classification and identification of 'non-problem areas' and 'problem areas' with respect to floating microlitter in Europe's Seas for all areas (left) and for 4 regions.

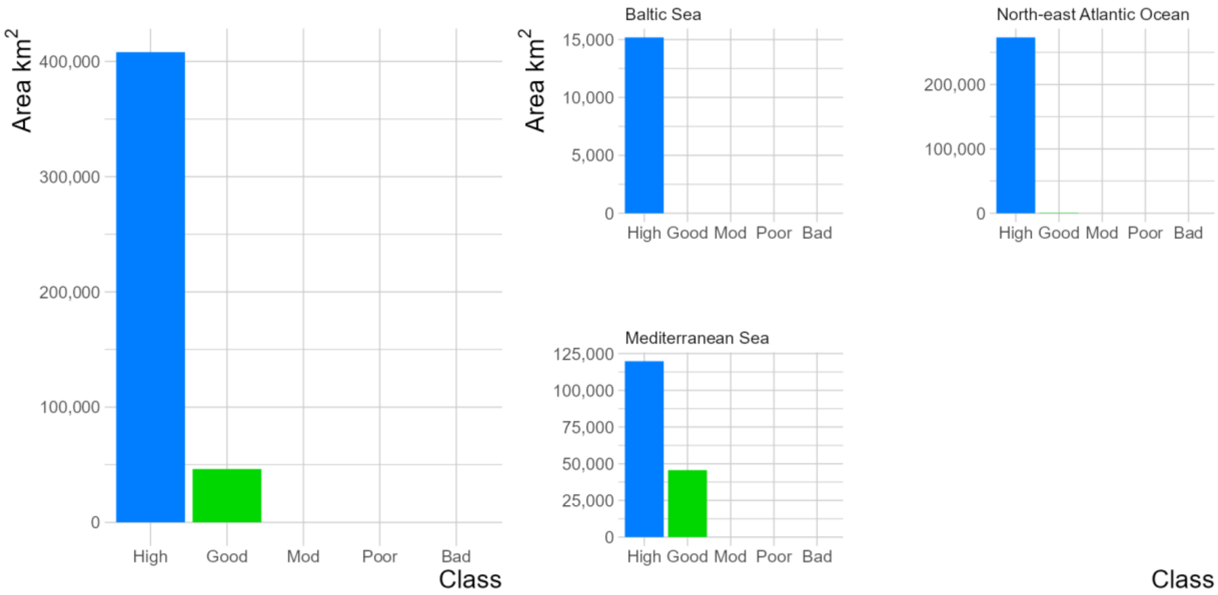
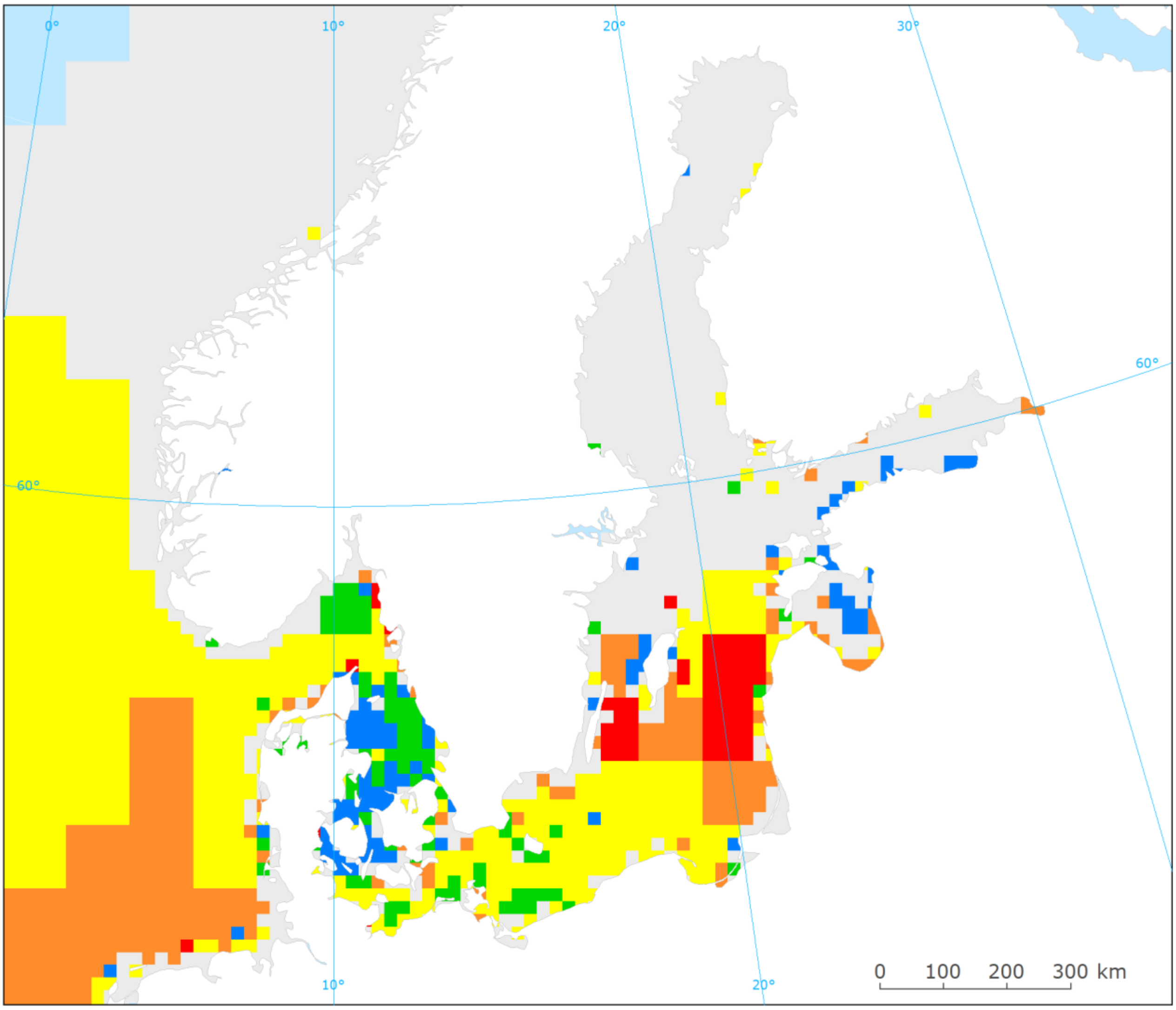


Table A5.3 Summary of assessment results by region for coastal and offshore assessment units

Region	Coastal/ Offshore	Total Area (km²)	Assessed area (km²)	Non-problem area (km²)	Potential problem area (km²)	Assessed Area %	Non-problem area (%)	Potential problem area (%)
Baltic Sea	Coastal	211,420	66,126	24,930	41,196	31.3	37.7	62.3
Baltic Sea	Offshore	186,800	106,800	5,200	101,600	57.2	4.9	95.1
Baltic Sea	**Total**	398,220	172,926	30,130	142,796	43.4	17.4	82.6
NE Atlantic	Coastal	640,467	230,814	82,427	148,386	36.0	35.7	64.3
NE Atlantic	Offshore	6,208,800	1,274,400	253,600	1,020,800	20.5	19.9	80.1
NE Atlantic	**Total**	6,849,267	1,505,214	336,027	1,169,186	22.0	22.3	77.7
Mediterranean	Coastal	601,334	91,481	19,838	71,643	15.2	21.7	78.3
Mediterranean	Offshore	1,919,600	152,000	118,400	33,600	7.9	77.9	22.1
Mediterranean	**Total**	2,520,934	243,481	138,238	105,243	9.7	56.8	43.2
Black Sea	Coastal	109,854	10,260	767	9,493	9.3	7.5	92.5
Black Sea	Offshore	365,200	25,200		25,200	6.9		100.0
Black Sea	**Total**	475,054	35,460	767	34,693	7.5	2.2	97.8
Europe's Seas	Coastal	1,563,074	398,681	127,963	270,718	25.5	32.1	67.9
Europe's Seas	Offshore	8,680,400	1,558,400	377,200	1,181,200	18.0	24.2	75.8

MALT integrated assessment status in European Regional Seas

Figure A5.5: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Baltic Sea



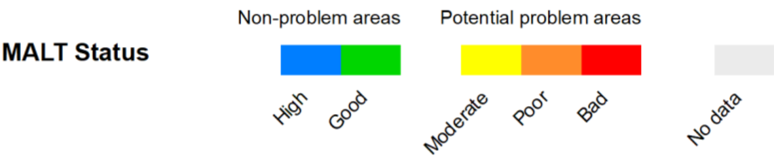


Figure A5.6: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the North Sea and Celtic Seas

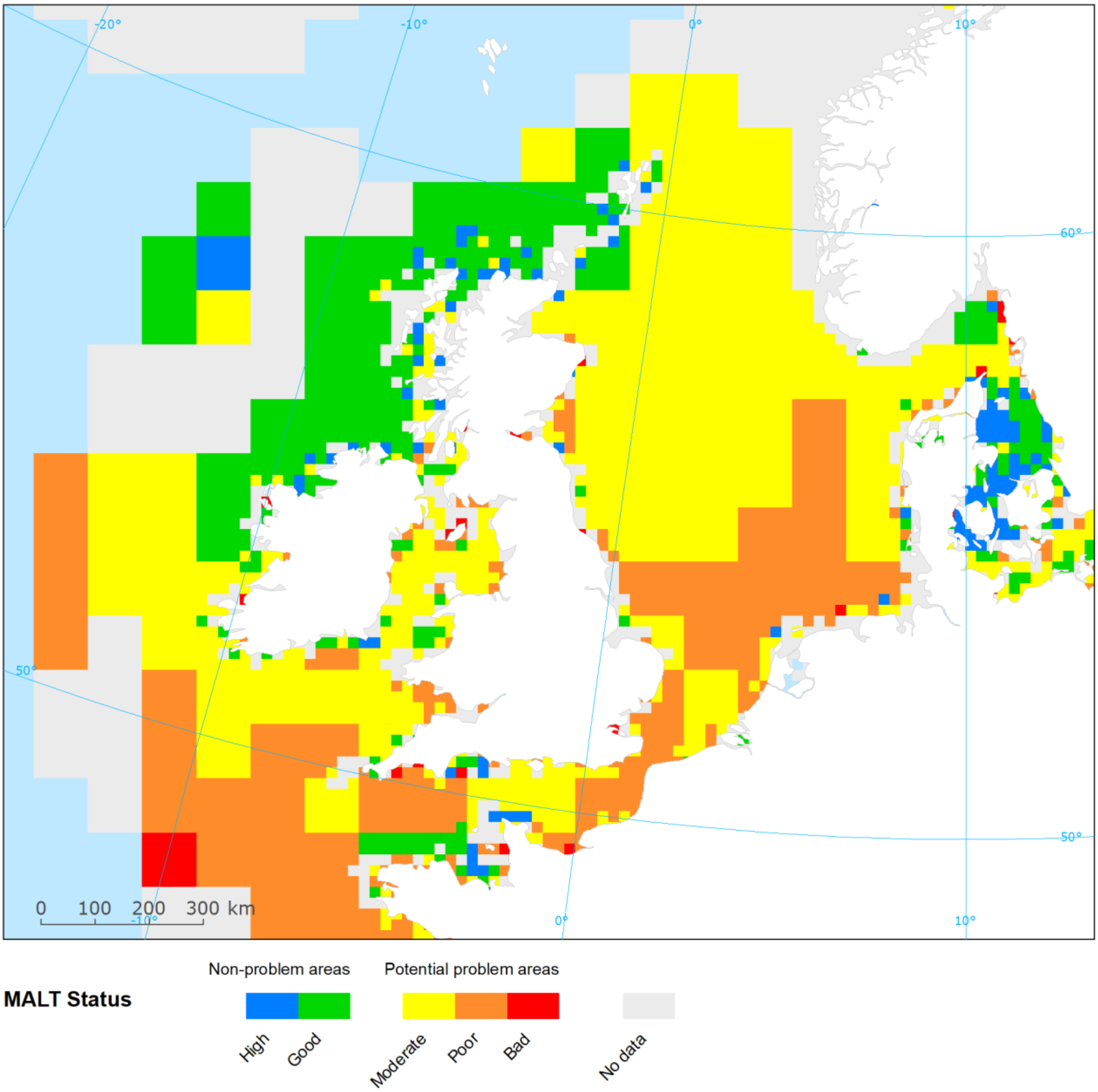


Figure A5.7: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

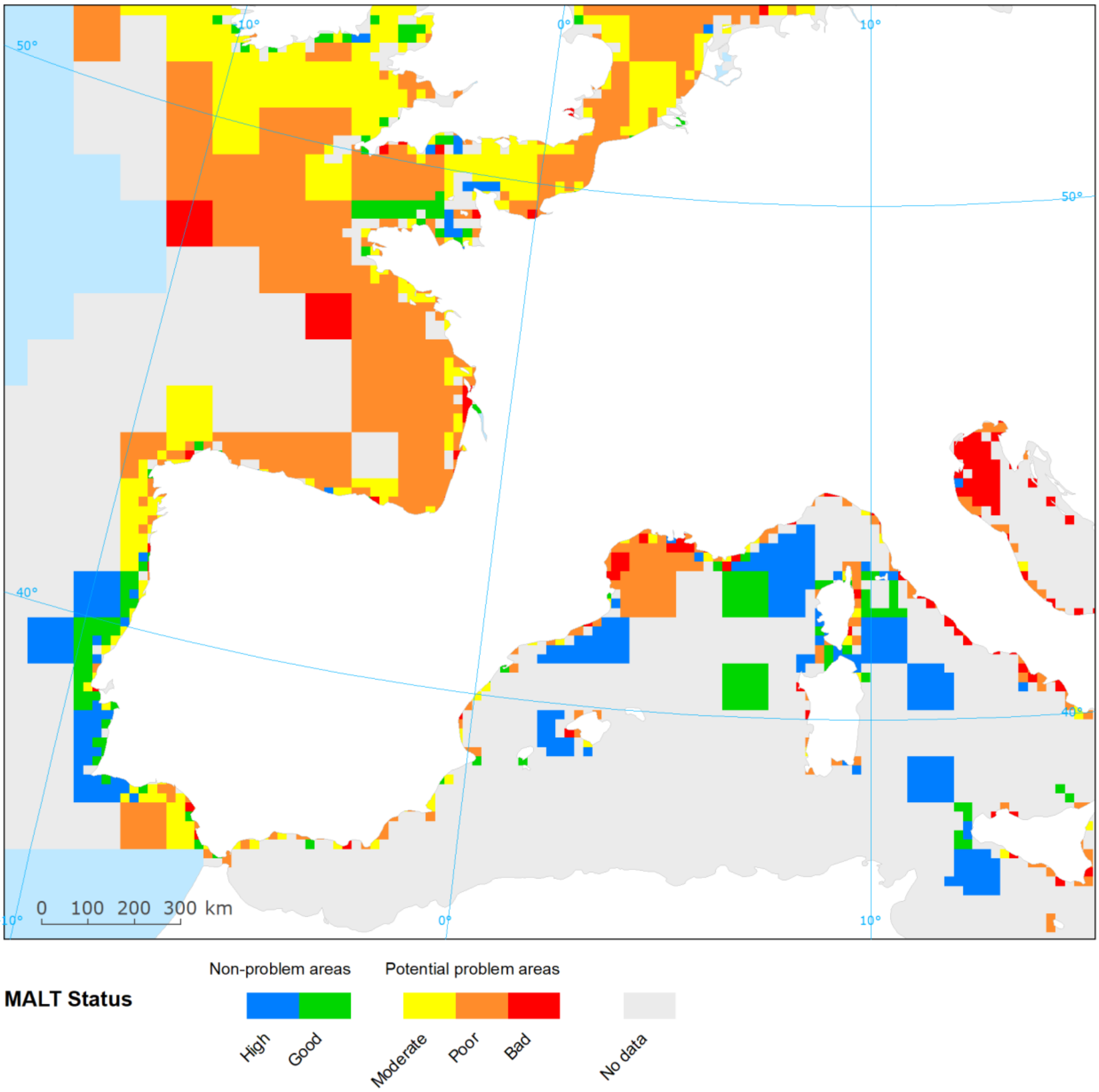


Figure A5.8: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Eastern Mediterranean Sea

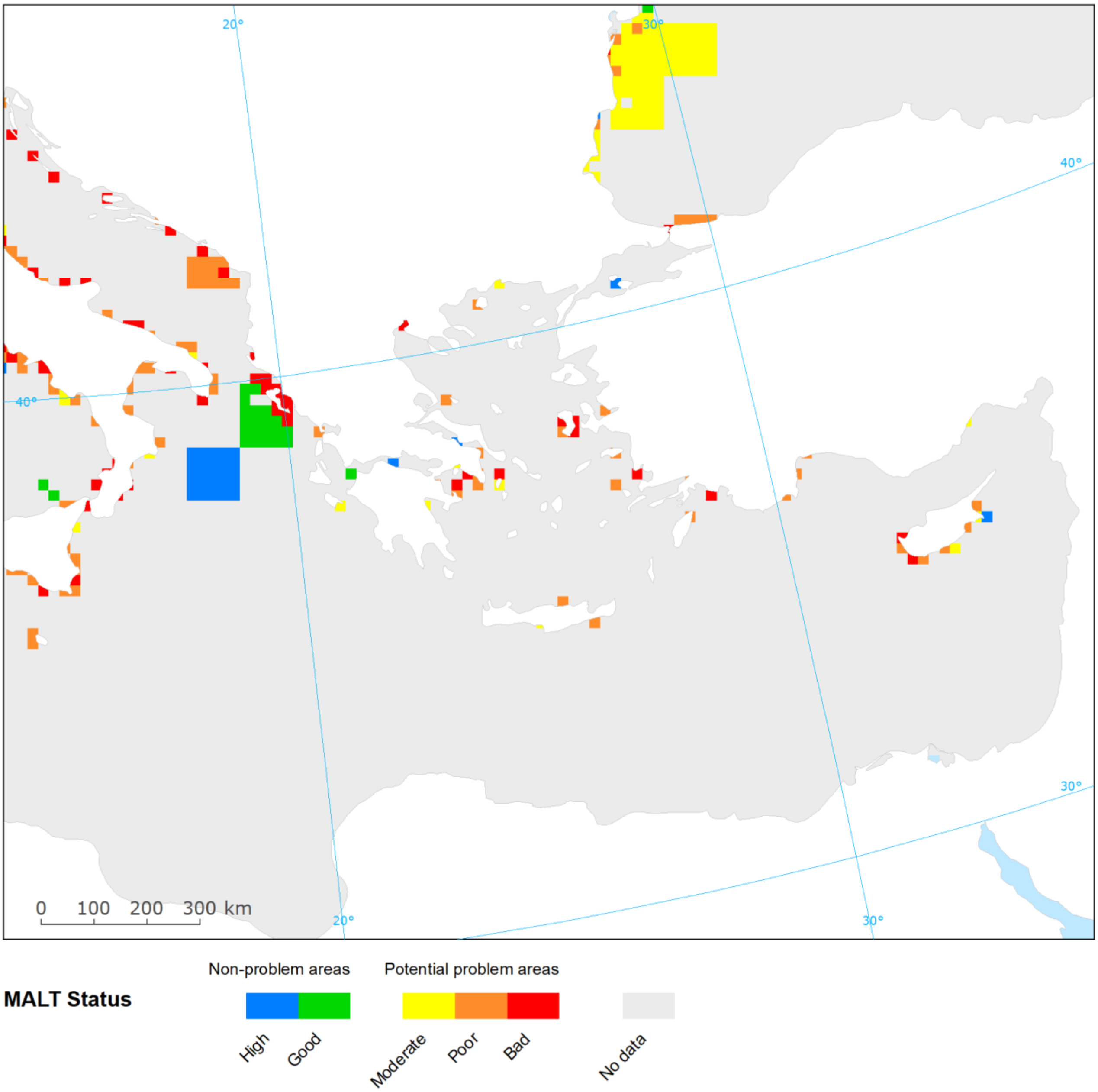
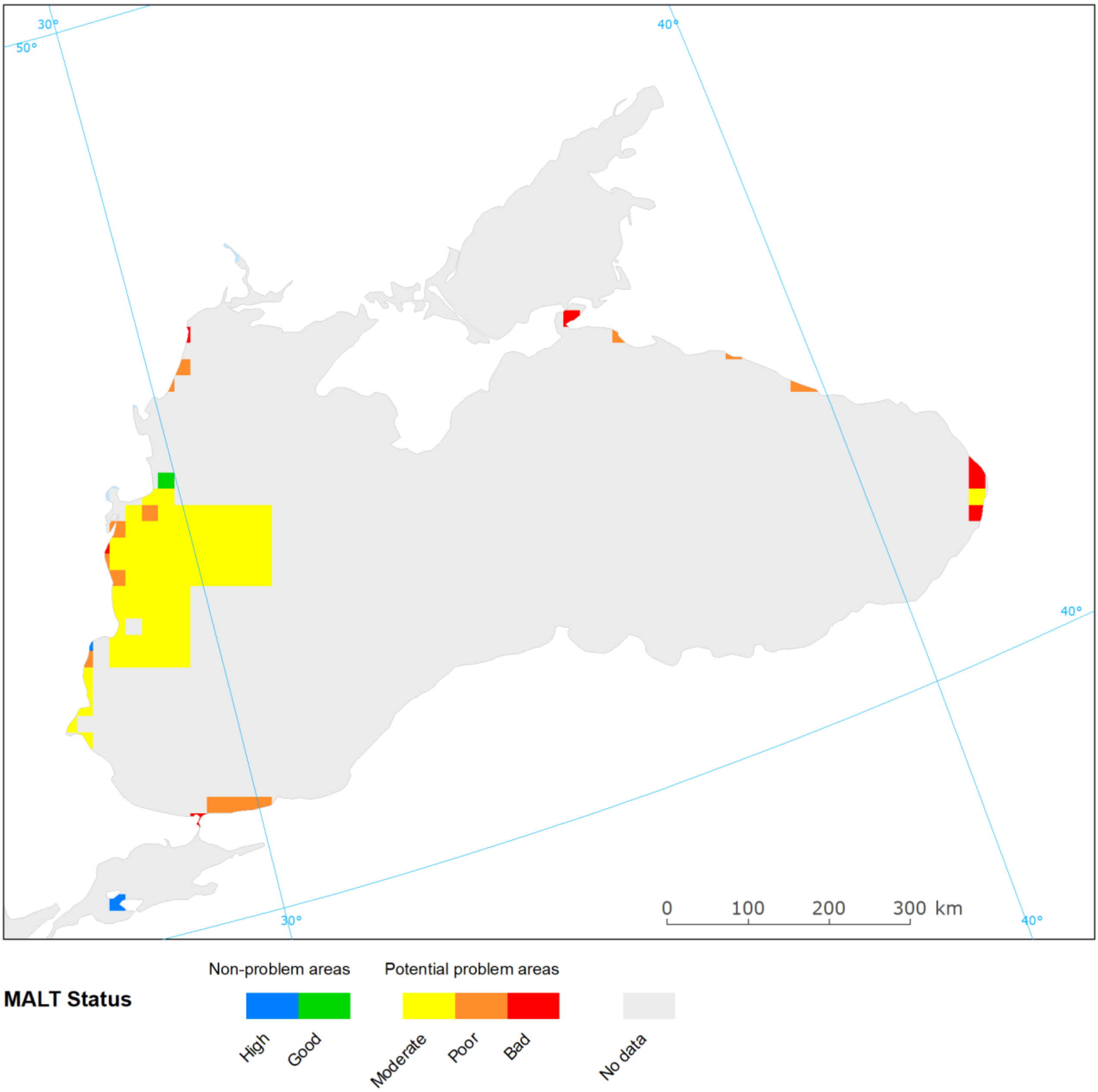


Figure A5.9: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Black Sea



MALT assessment of beach litter status in European Regional Seas

Figure A5.10: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in the Baltic Sea

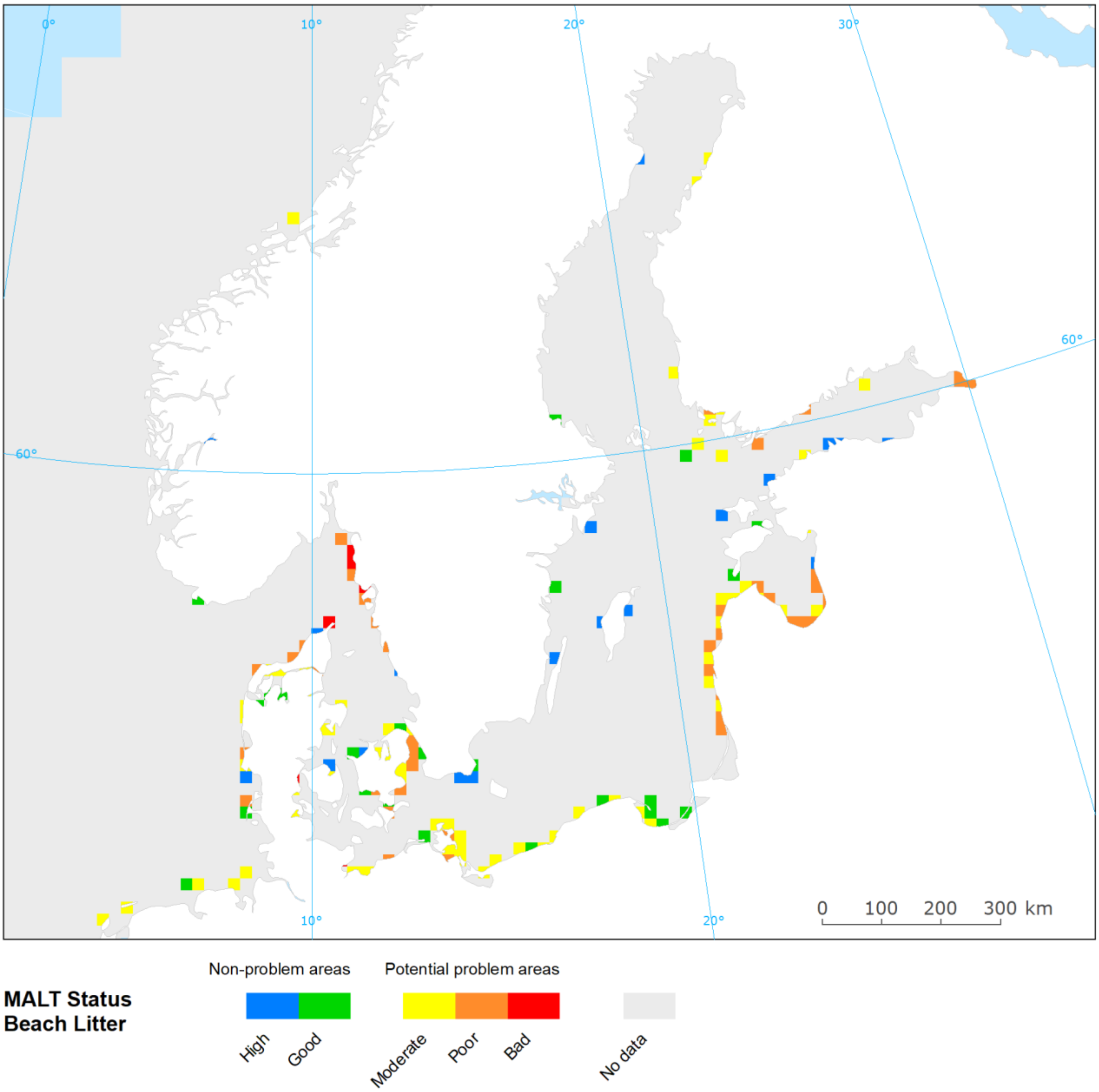


Figure A5.11: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in the North Sea and Celtic Seas

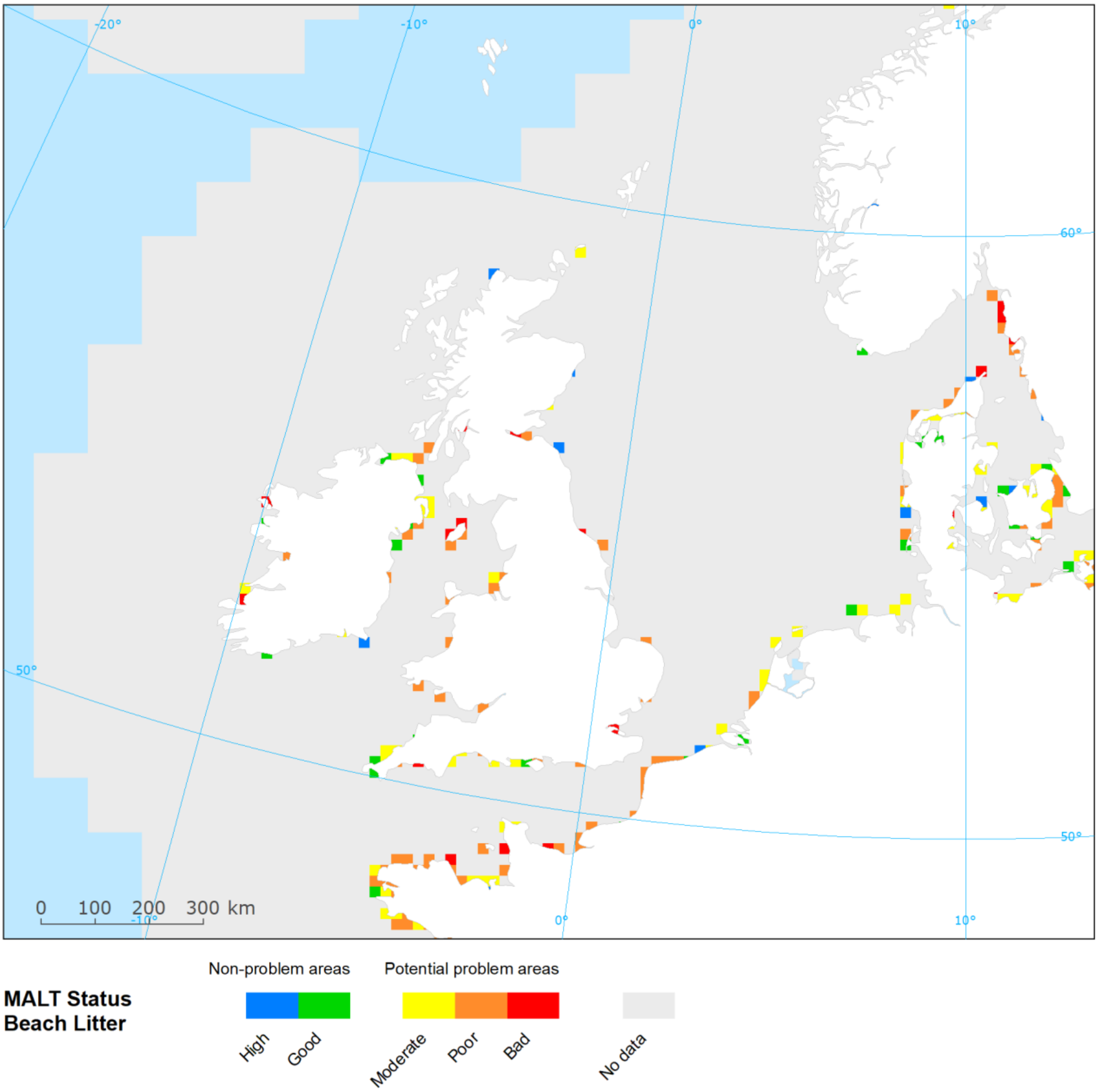


Figure A5.12: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

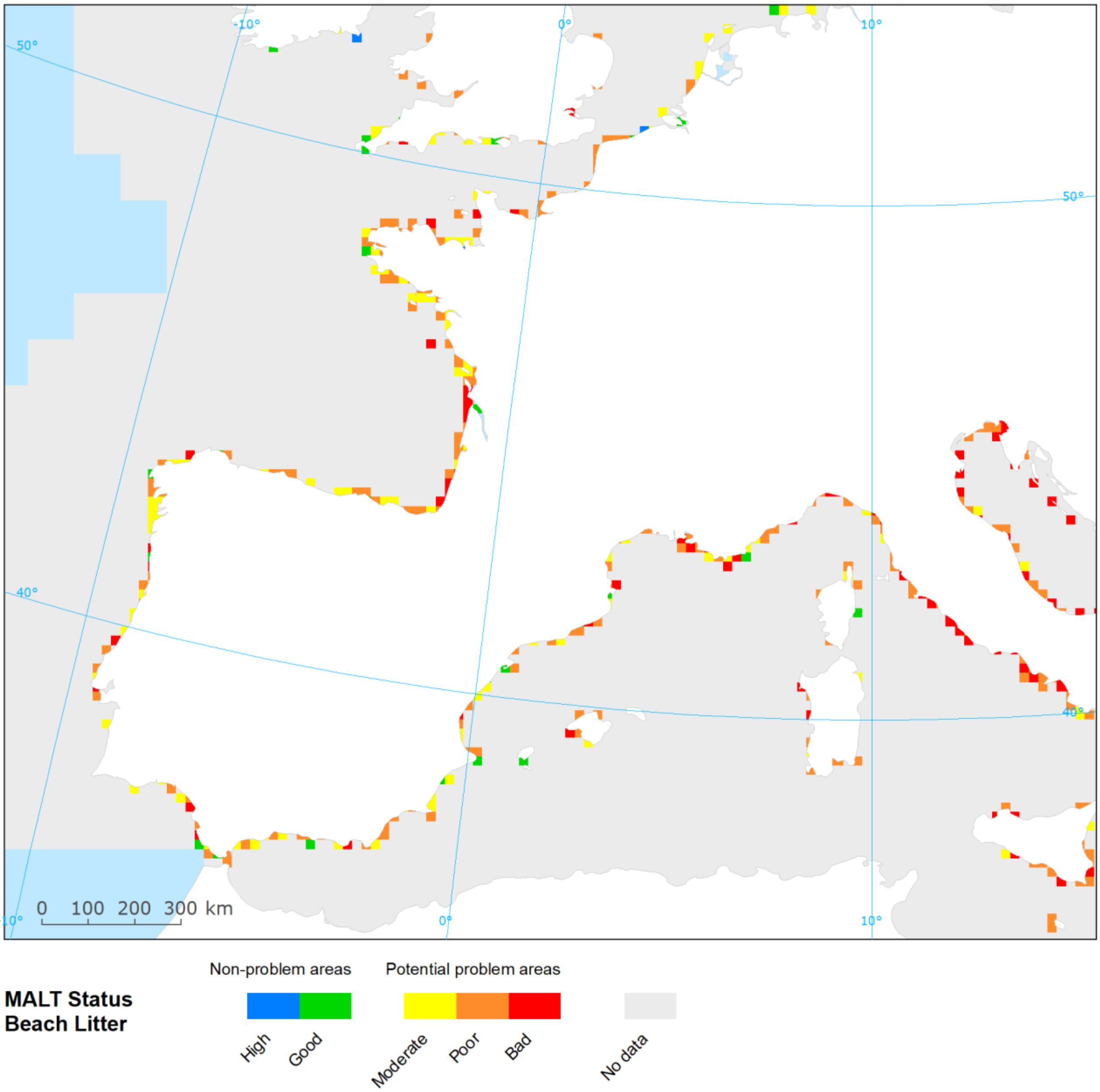


Figure A5.13: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter in the Eastern Mediterranean Sea

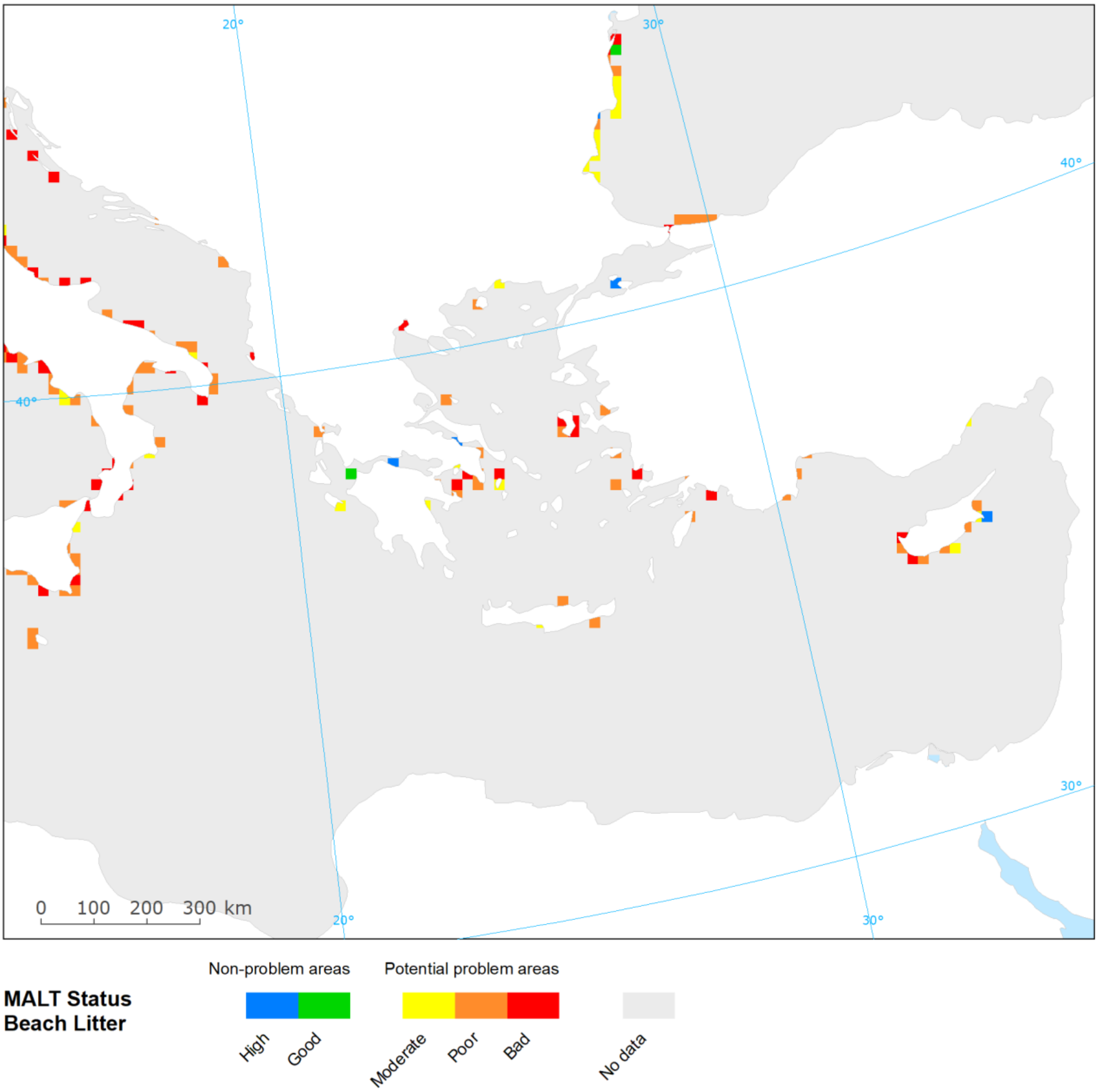


Figure A5.14: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to <u>beach litter</u> in the Black Sea

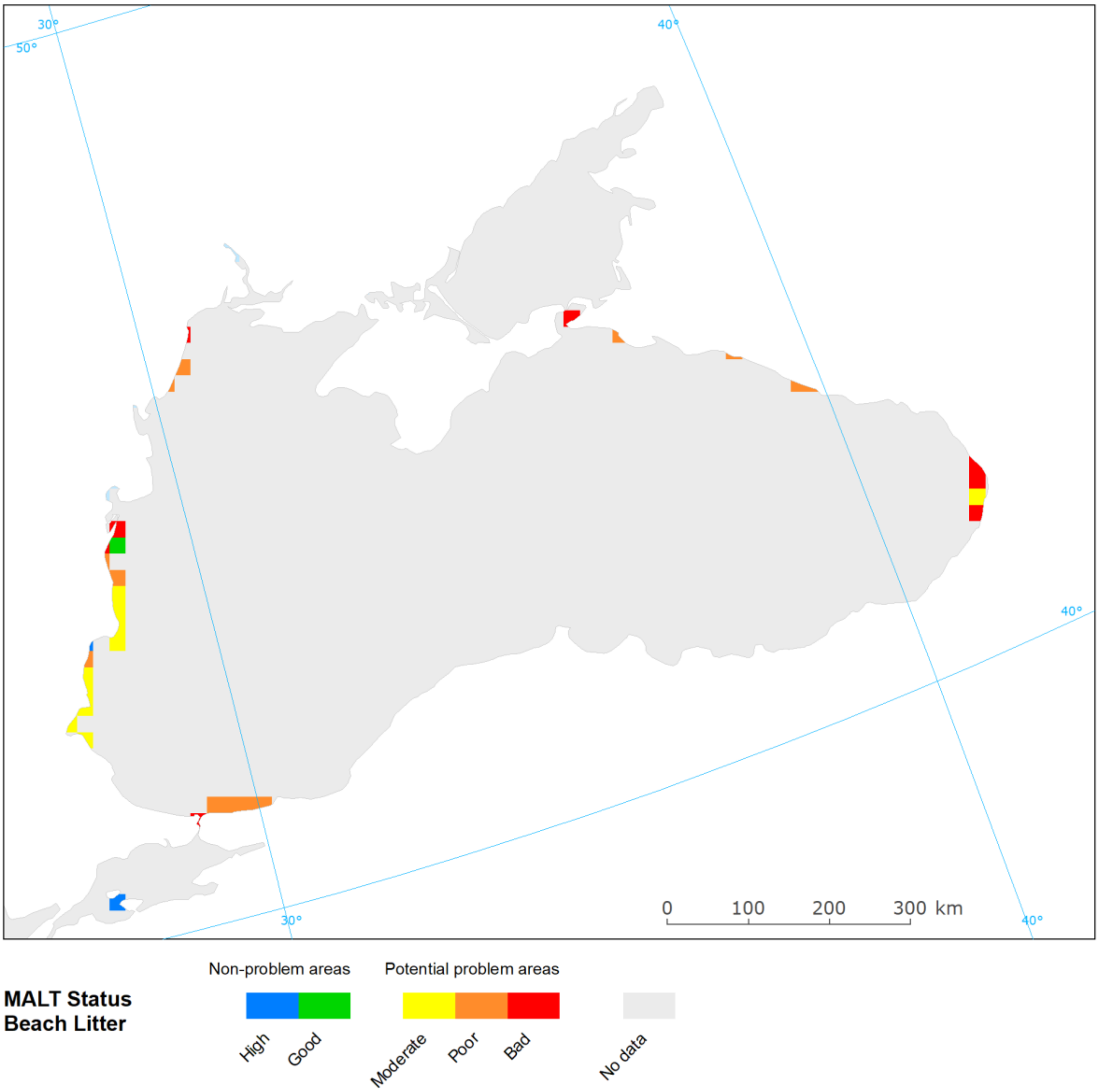


Figure A5.15: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Baltic Sea

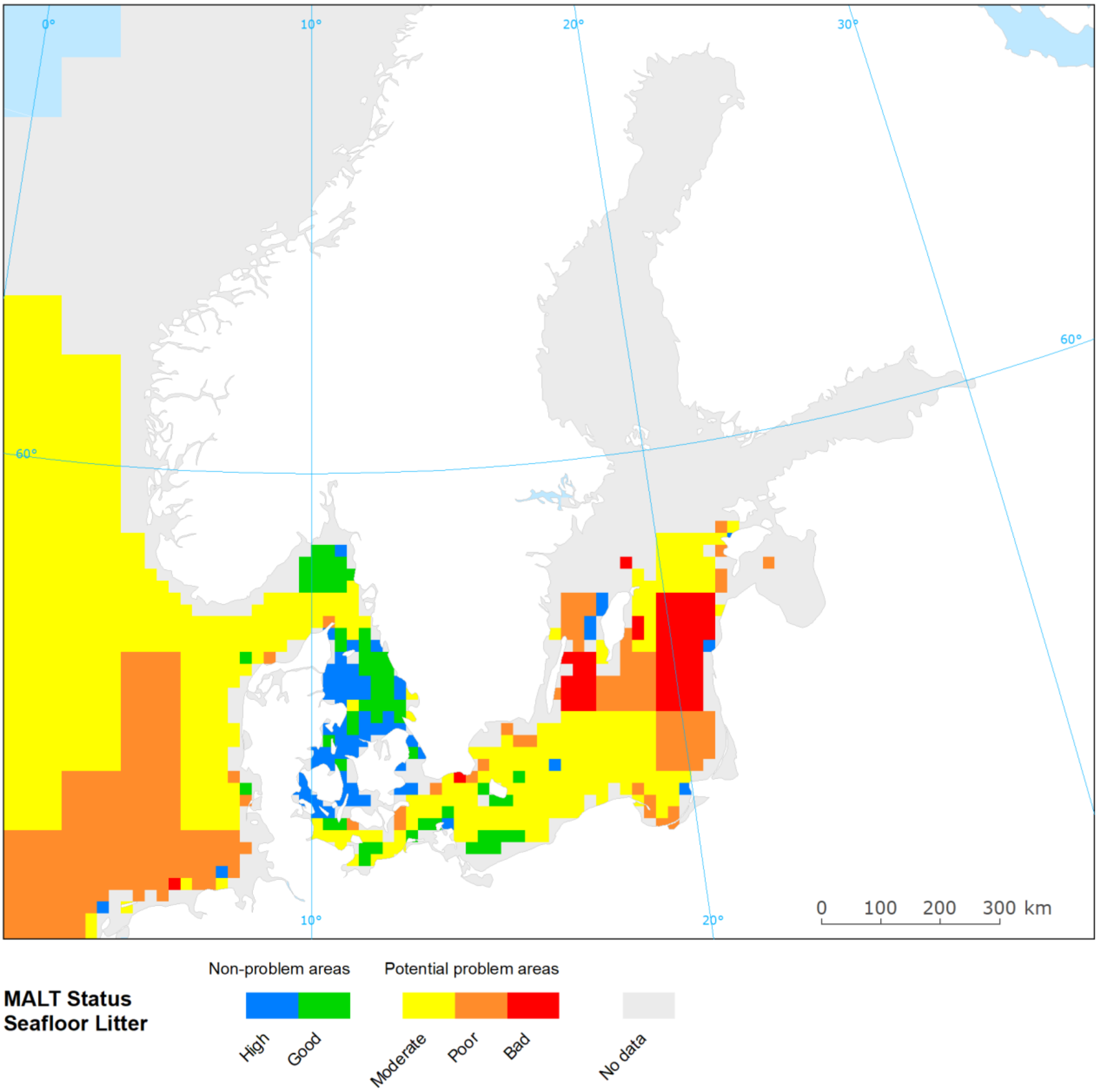


Figure A5.16: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the North Sea and Celtic Seas

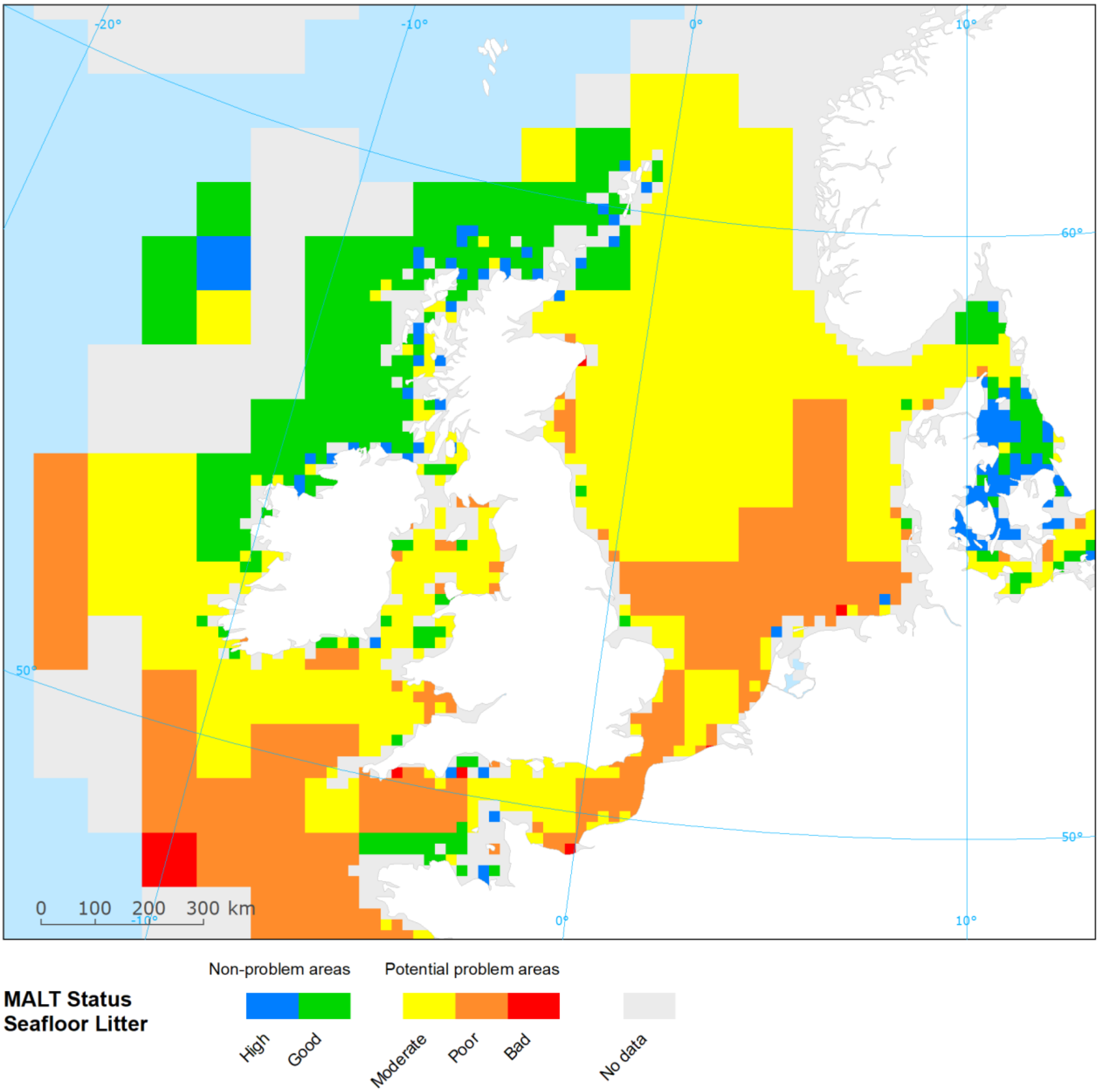


Figure A5.17: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

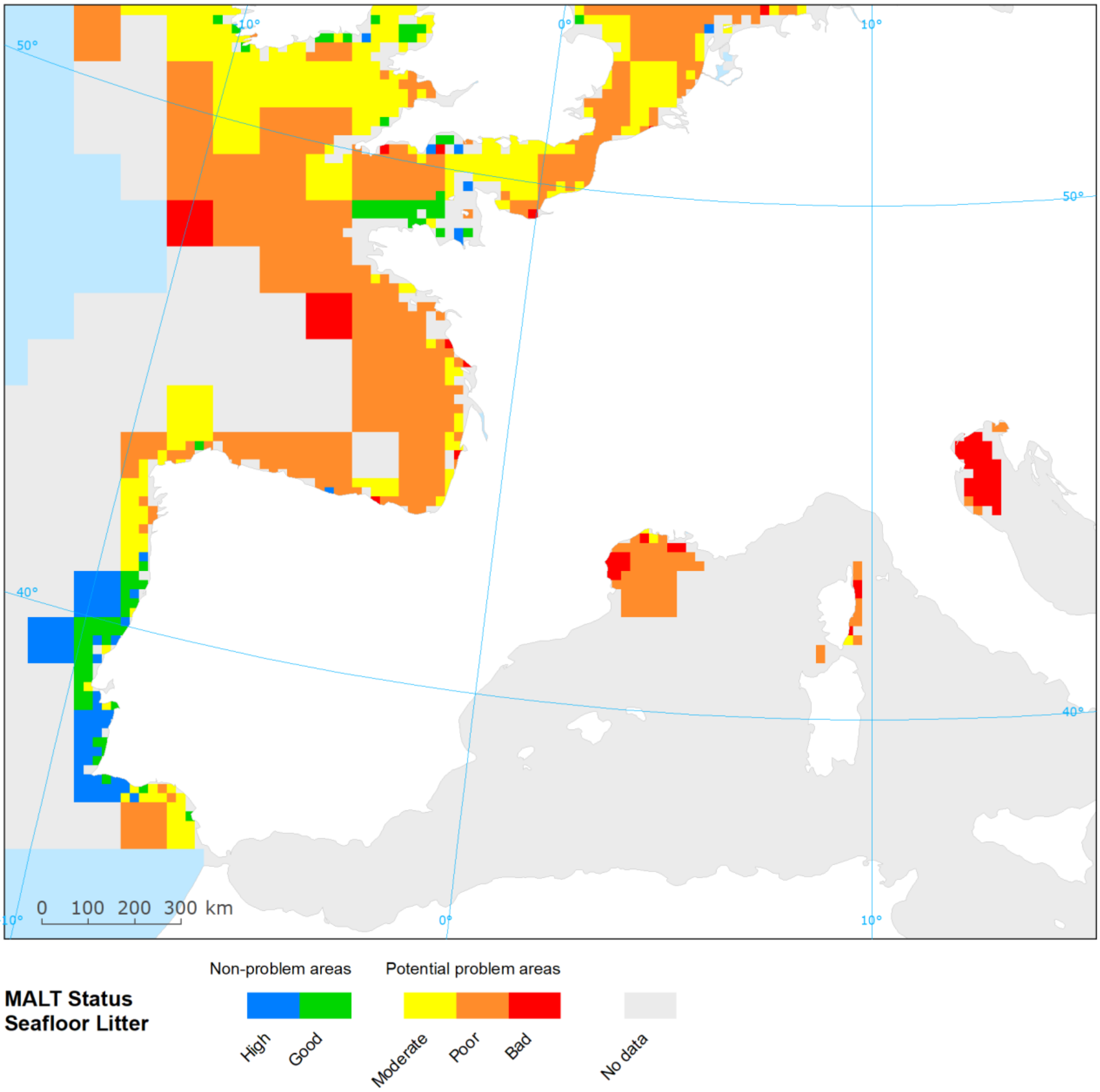


Figure A5.18: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Eastern Mediterranean Sea

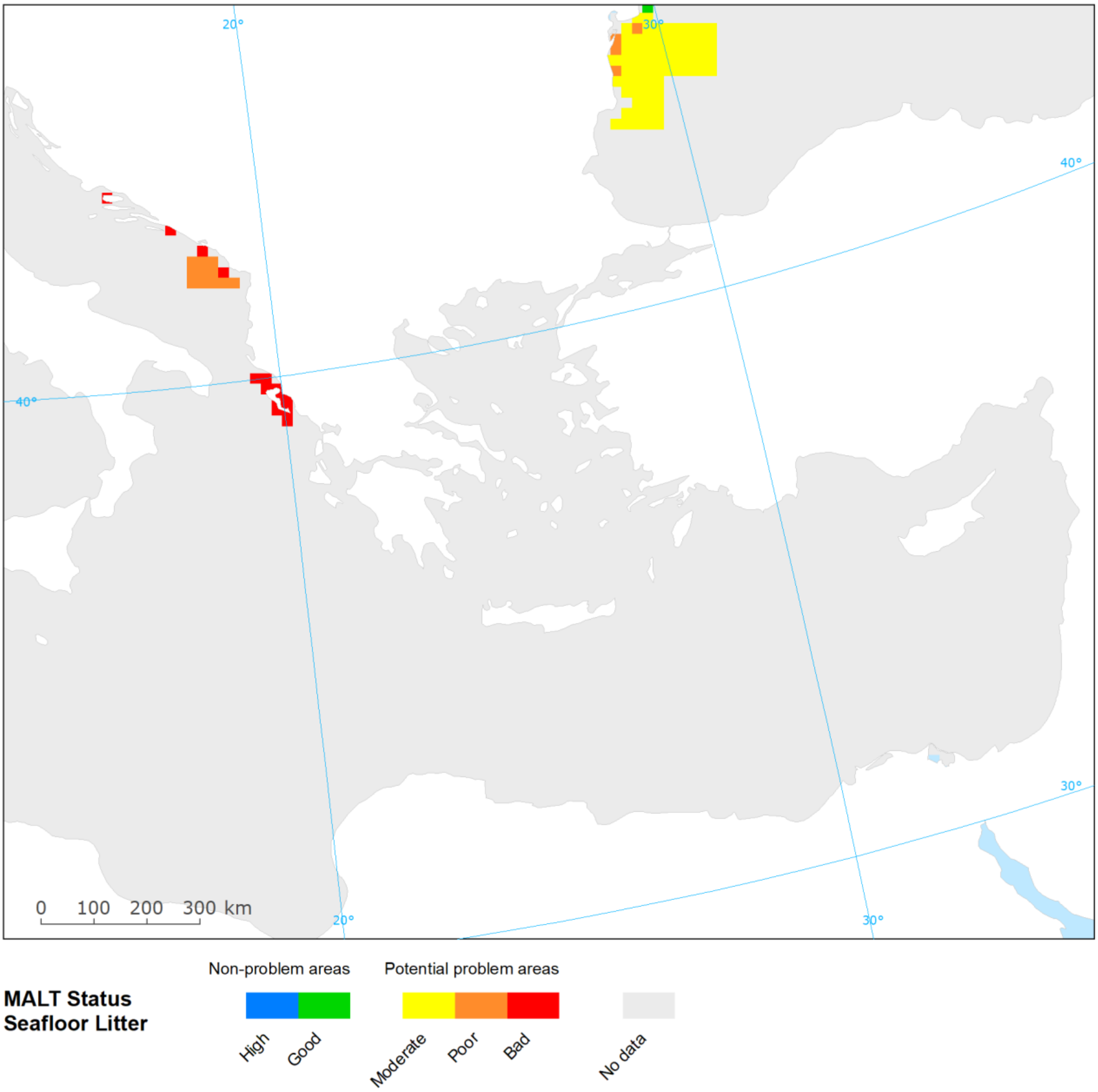


Figure A5.19: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Black Sea

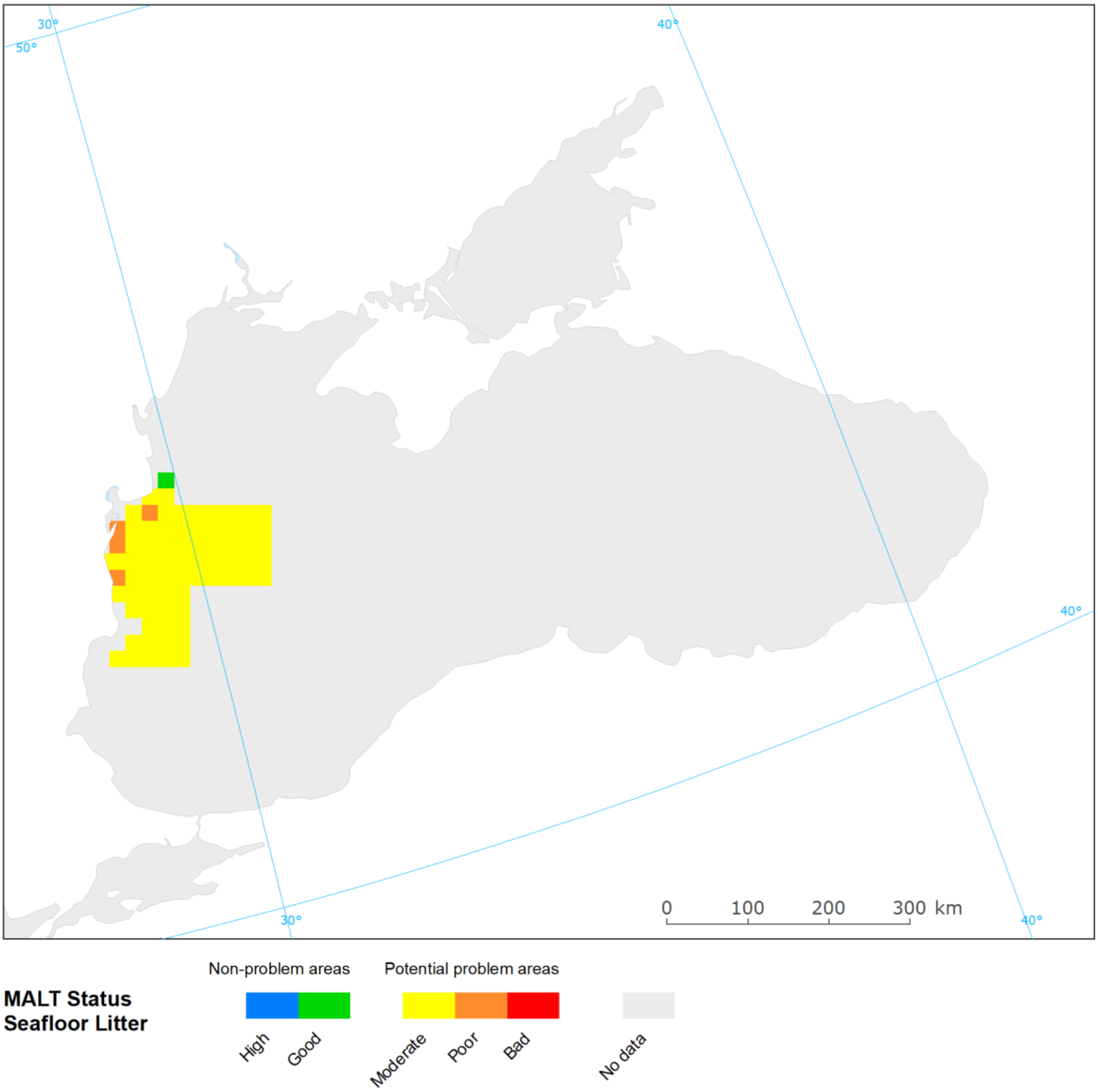


Figure A5.20: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter in the Baltic Sea

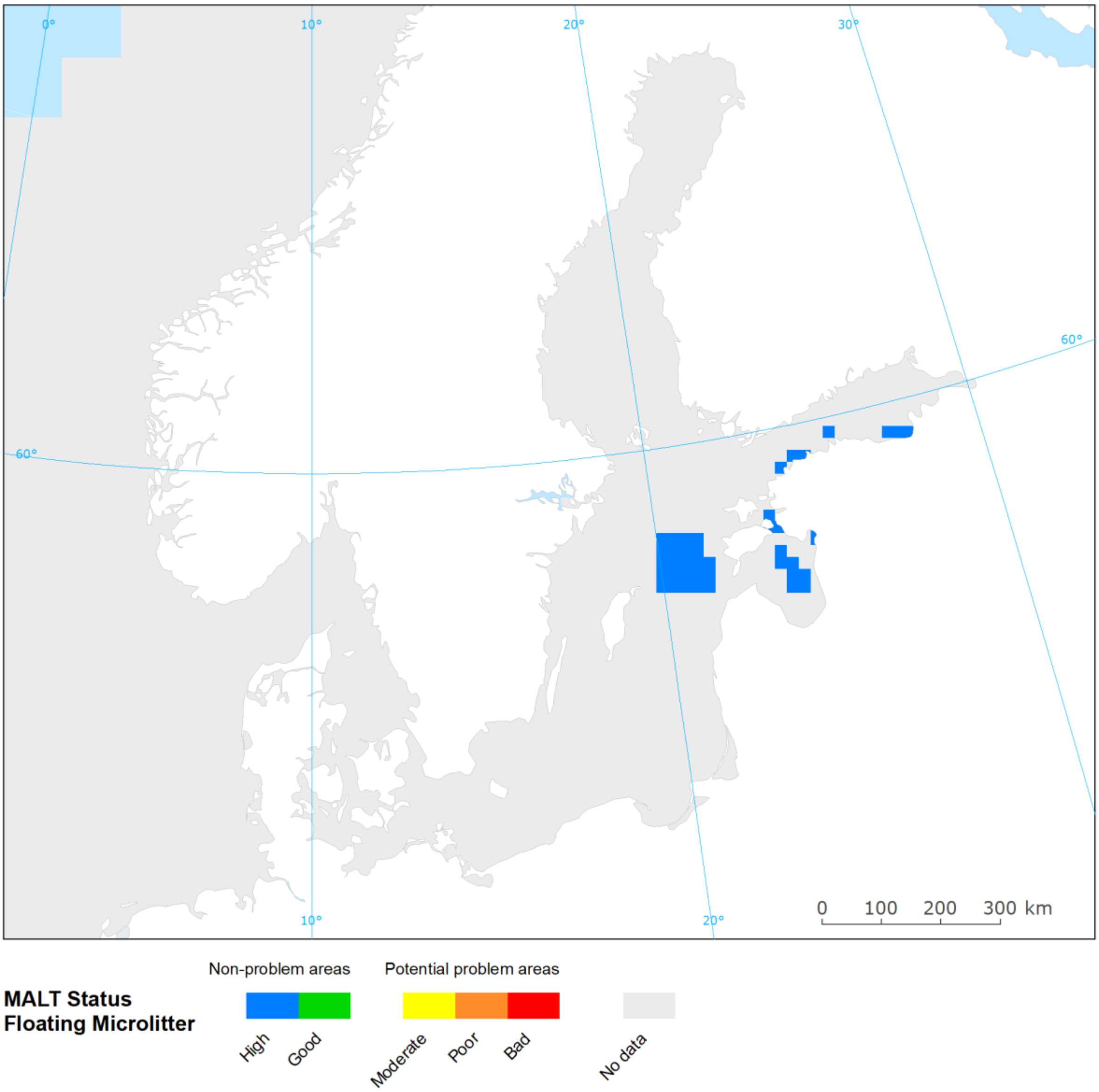


Figure A5.21: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter in the North Sea and Celtic Seas

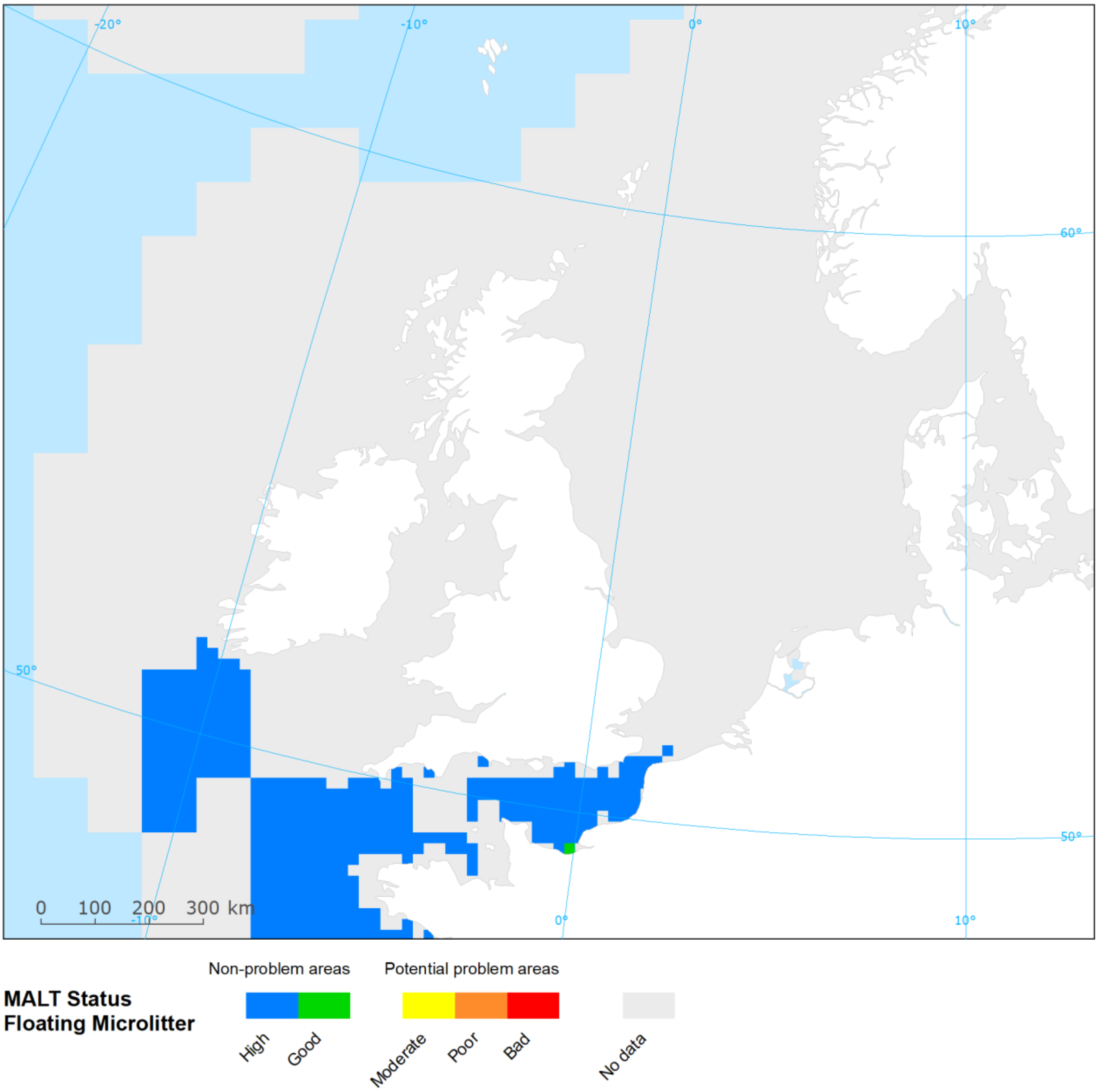


Figure A5.22: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to <u>floating microlitter</u> in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

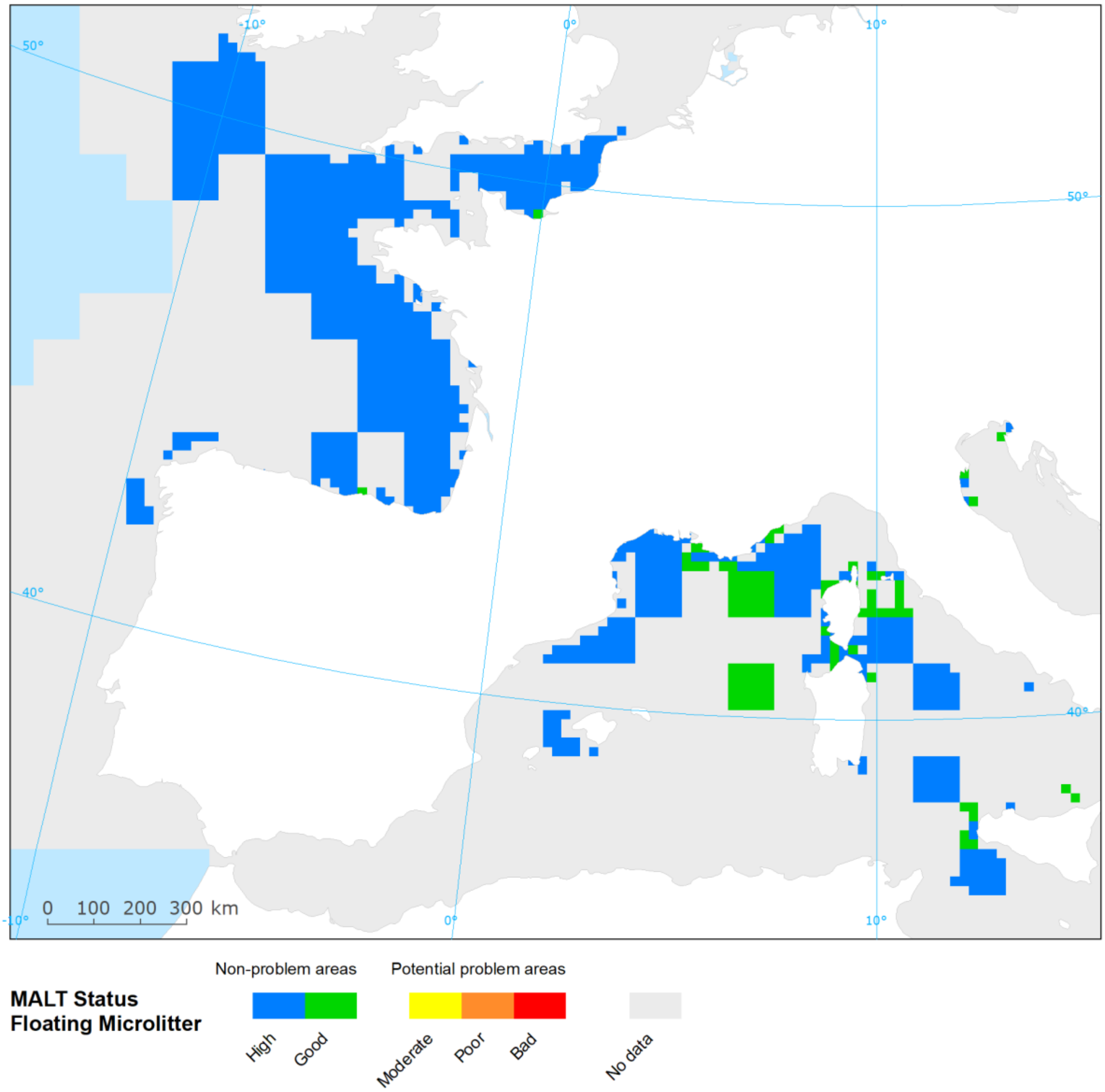


Figure A5.23: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter in the Eastern Mediterranean Sea

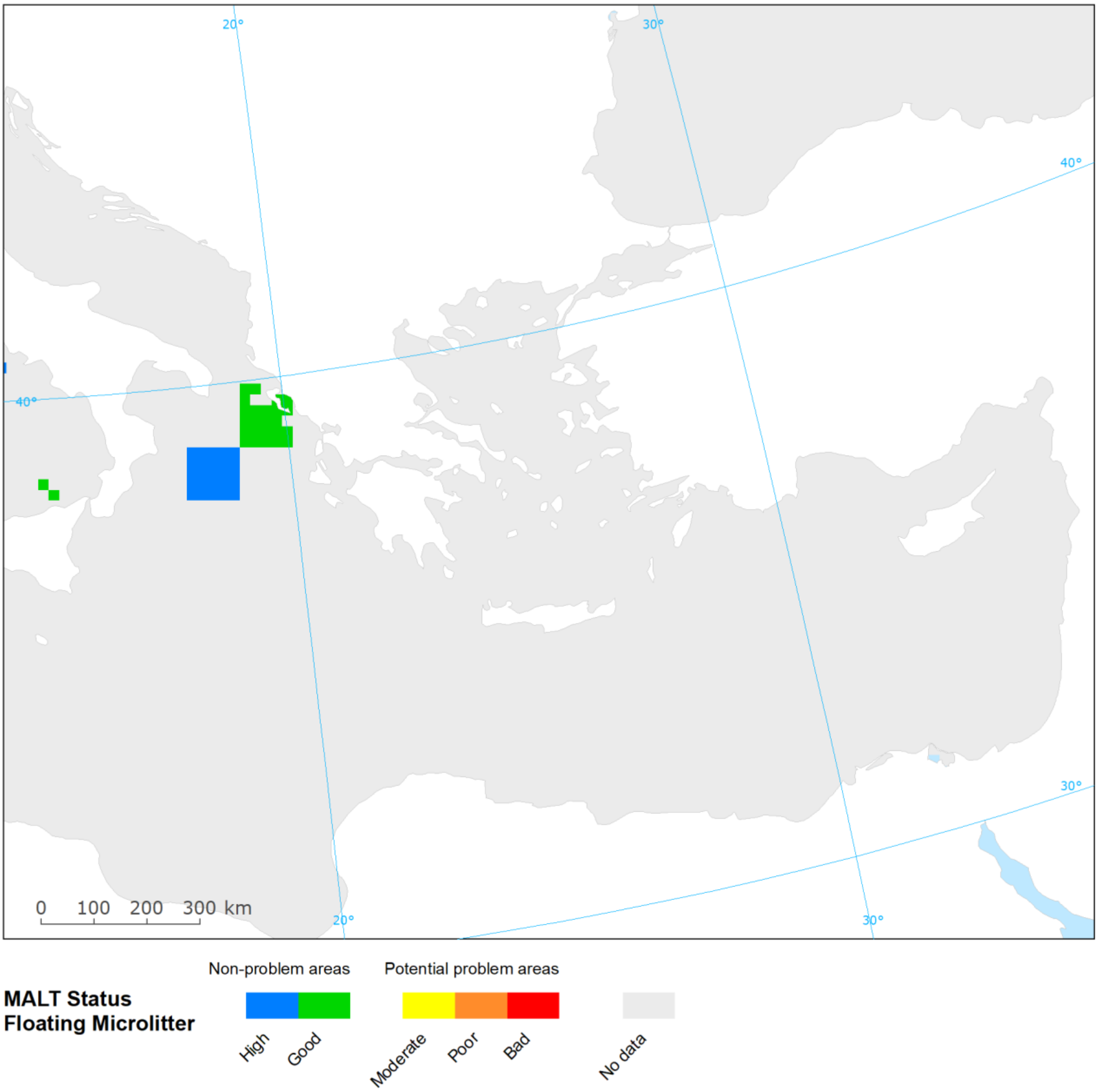
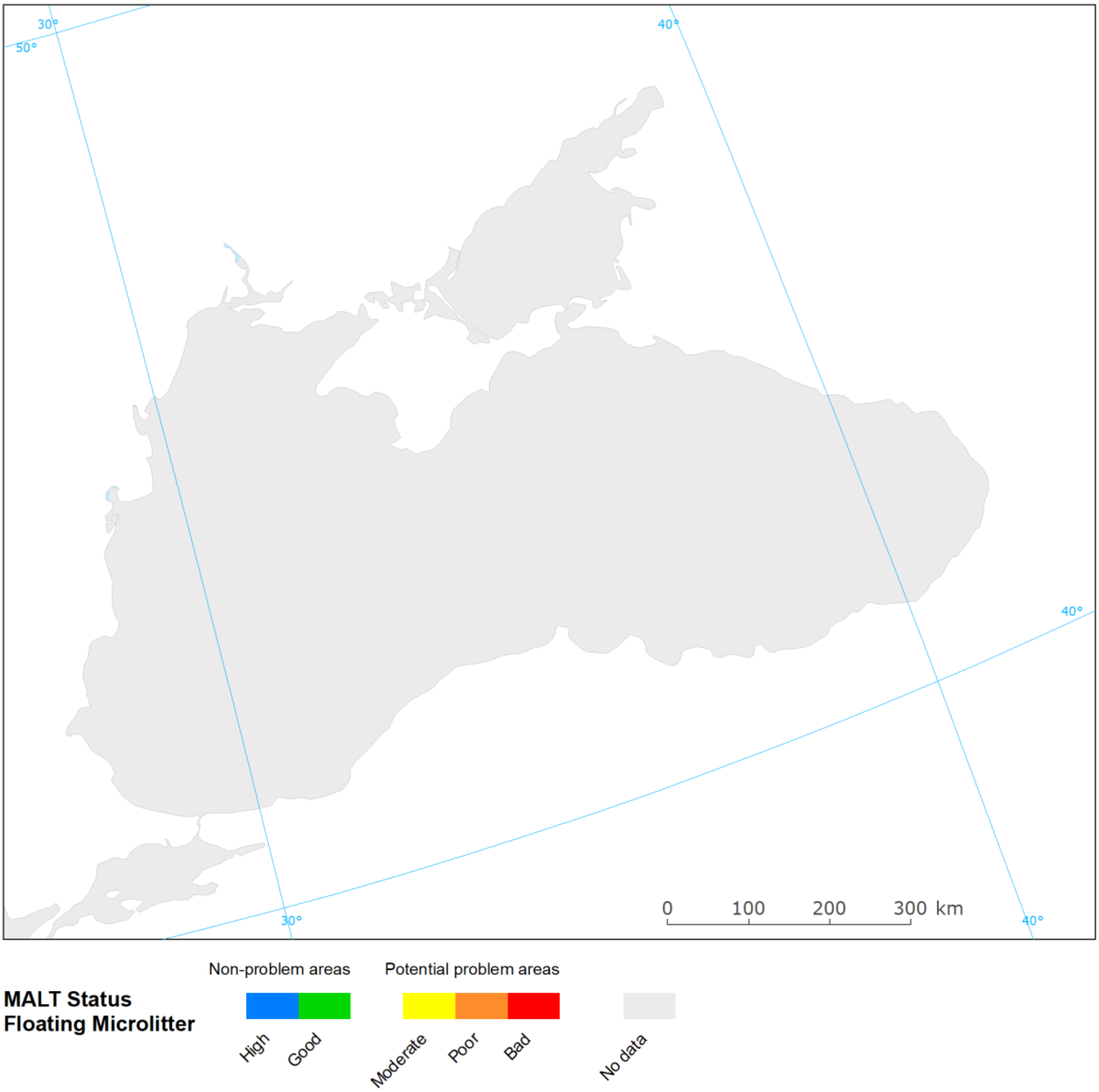


Figure A5.24: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter in the Black Sea



Annex 6 MALT Assessment results using alternative threshold value for seafloor litter

Table A6.1 Status class boundaries for the seafloor litter count indicators (EQR: Ecological Quality Ratio)

EQR	Boundary	Seafloor litter	
		n per km²	$log_{10}(n)$
1.0	Upper limit EQR	1.0	0.00
0.8	High/Good	15.2	1.18
0.6	Good/Moderate	230	2.36
0.4	Moderate/Poor	342	2.53
0.2	Poor/Bad	510	2.71
0.0	Lower limit EQR	759	2.88

MALT summaries for overall status and seafloor litter

Figure A6.1: Summary of preliminary classification and identification of 'non-problem areas' and 'potential problem areas' in Europe for all coastal areas (left) and for 4 regions

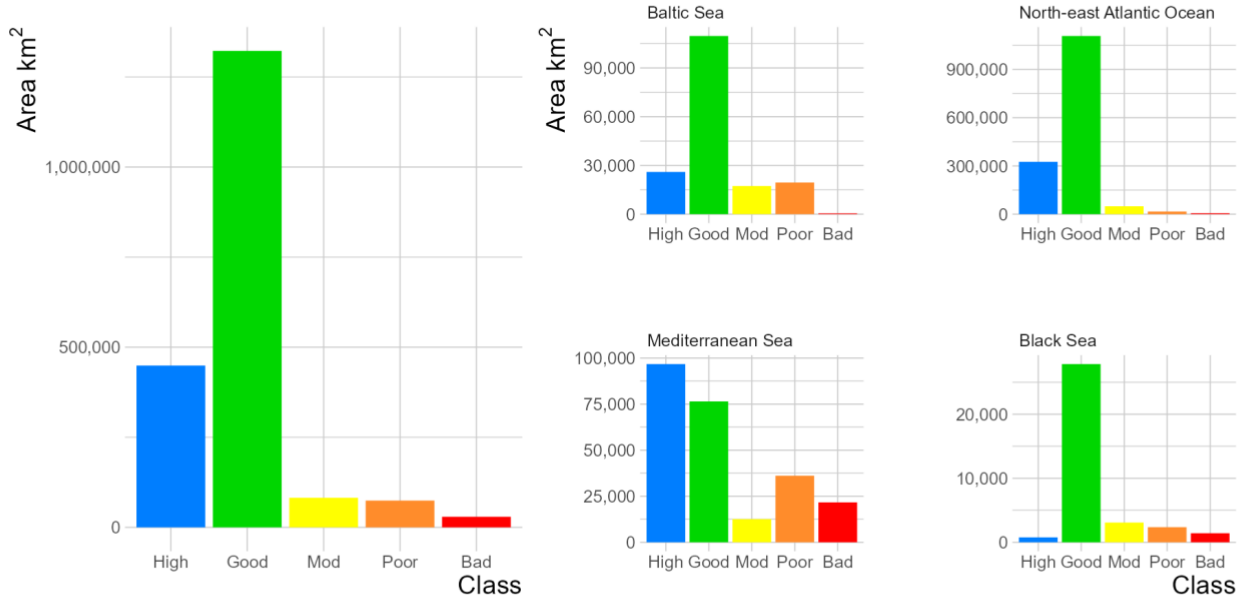


Figure A6.2: Summary of preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in Europe's Seas for all areas (left) and for 4 regions

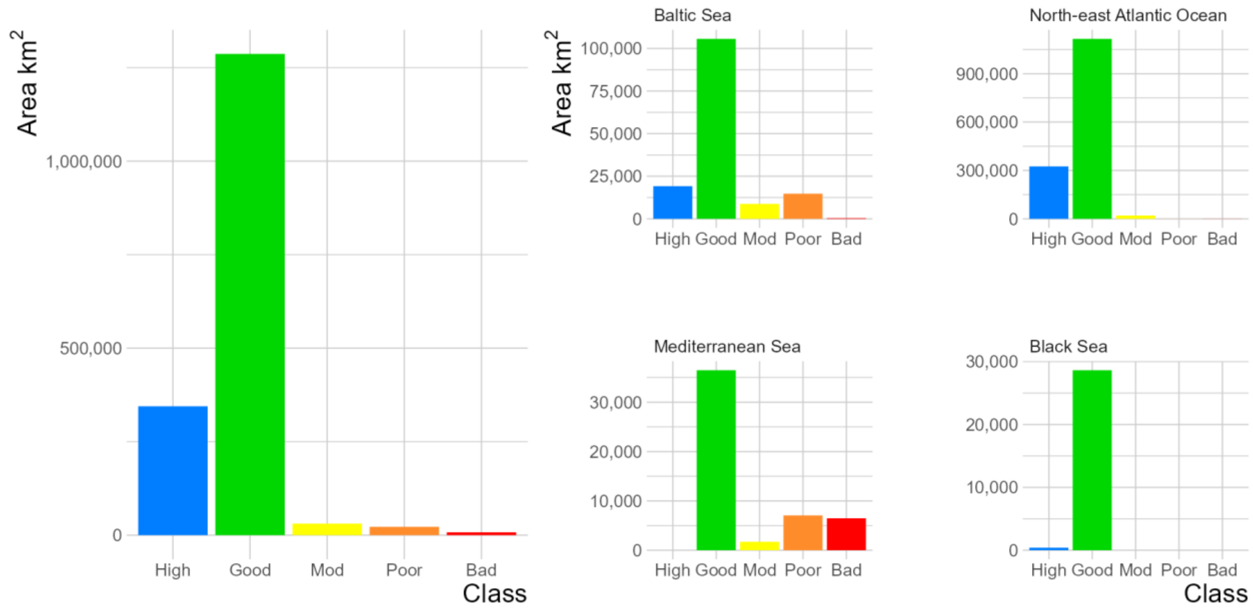


Table A6.2: Summary of assessment results by region for coastal and offshore assessment units

Region	Coastal/ Offshore	Total Area (km²)	Assessed area (km²)	Non-problem area (km²)	Potential problem area (km²)	Assessed Area %	Non-problem area (%)	Potential problem area (%)
Baltic Sea	Coastal	211,420	66,126	50,843	15,284	31.3	76.9	23.1
Baltic Sea	Offshore	186,800	106,800	84,800	22,000	57.2	79.4	20.6
Baltic Sea	**Total**	398,220	172,926	135,643	37,284	43.4	78.4	21.6
NE Atlantic	Coastal	640,467	230,814	179,881	50,933	36.0	77.9	22.1
NE Atlantic	Offshore	6,208,800	1,274,400	1,254,000	20,400	20.5	98.4	1.6
NE Atlantic	**Total**	6,849,267	1,505,214	1,433,881	71,333	22.0	95.3	4.7
Mediterranean	Coastal	601,334	91,481	25,966	65,515	15.2	28.4	71.6
Mediterranean	Offshore	1,919,600	152,000	147,200	4,800	7.9	96.8	3.2
Mediterranean	**Total**	2,520,934	243,481	173,166	70,315	9.7	71.1	28.9
Black Sea	Coastal	109,854	10,260	3,407	6,853	9.3	33.2	66.8
Black Sea	Offshore	365,200	25,200	25,200		6.9	100.0	
Black Sea	**Total**	475,054	35,460	28,607	6,853	7.5	80.7	19.3
Europe's Seas	Coastal	1,563,074	398,681	260,097	138,585	25.5	65.2	34.8
Europe's Seas	Offshore	8,680,400	1,558,400	1,511,200	47,200	18.0	97.0	3.0
Europe's Seas	**Total**	10,243,474	1,957,081	1,771,297	185,785	19.1	90.5	9.5

MALT integrated assessment status in European Regional Seas

Figure A6.3: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter

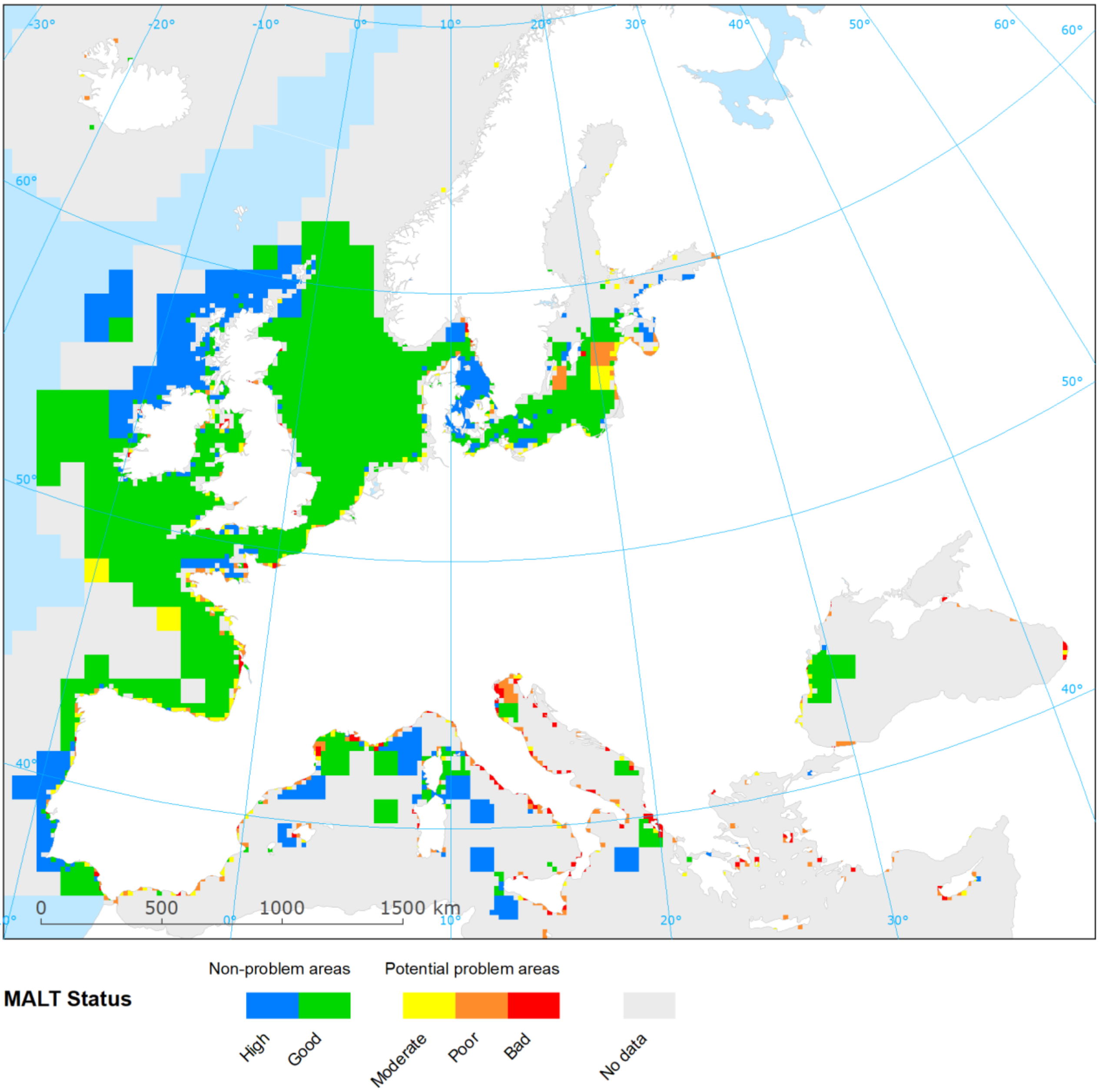


Figure A6.4: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Baltic Sea

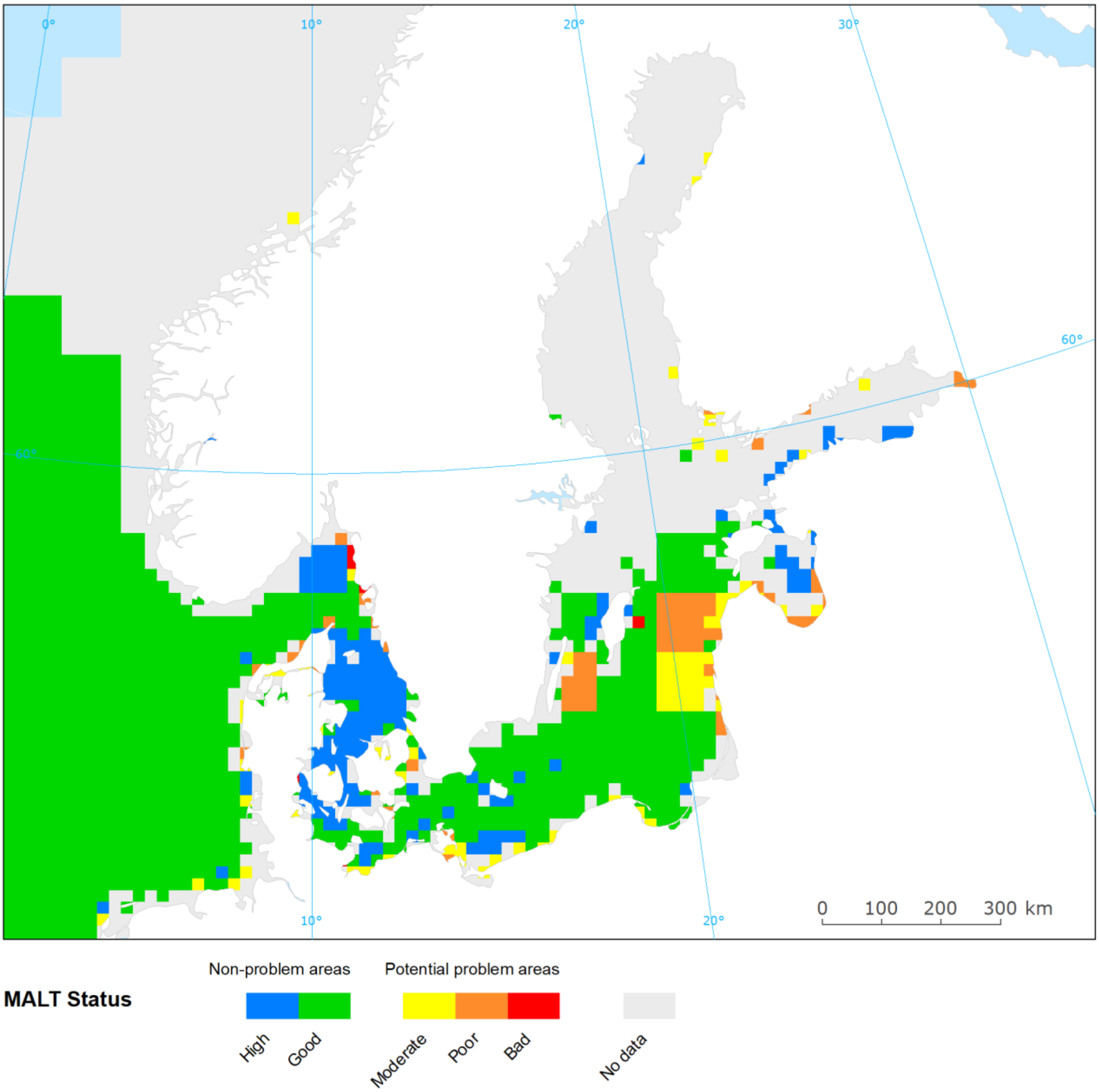


Figure A6.5: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the North Sea and Celtic Seas

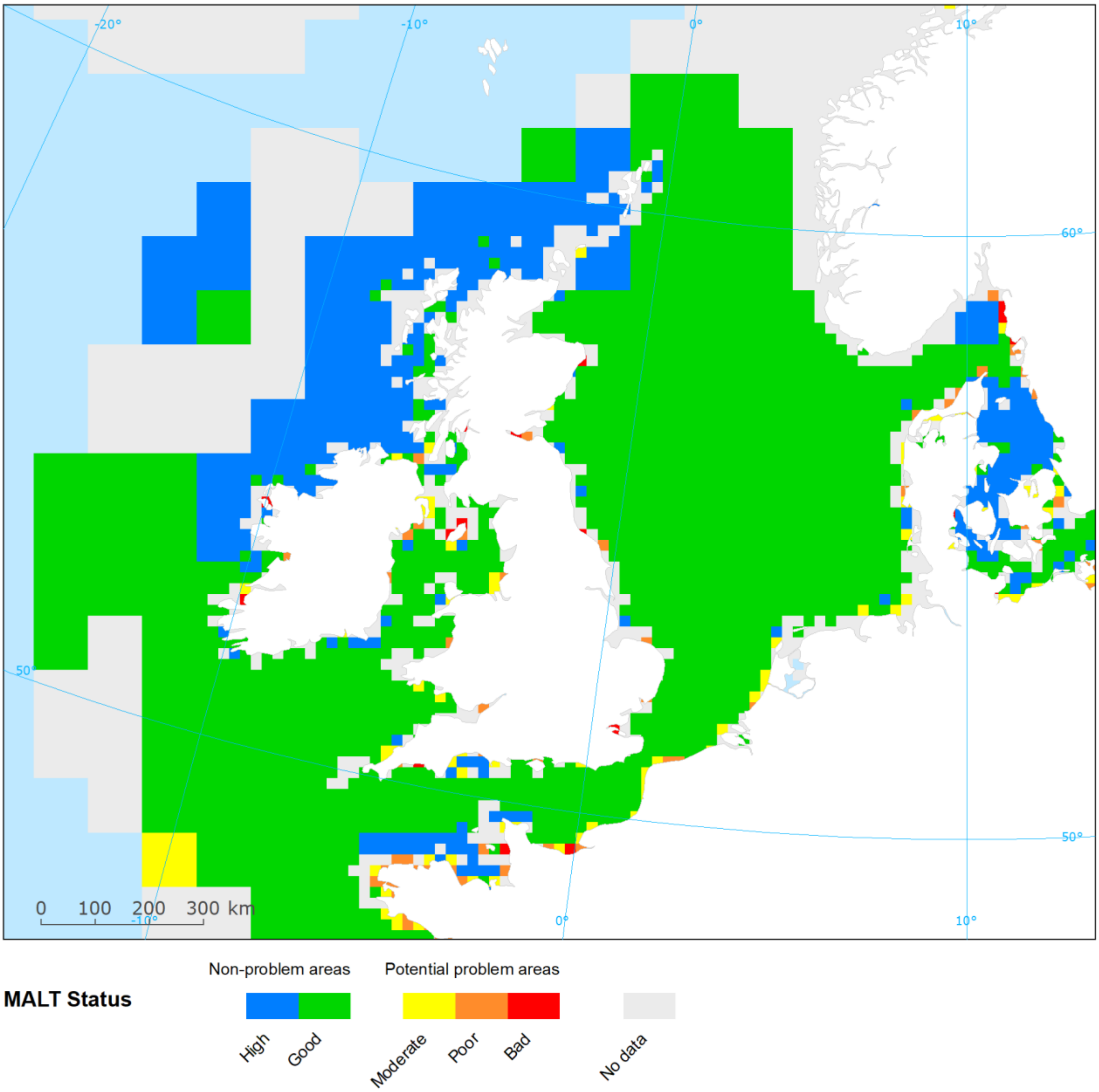


Figure A6.6: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

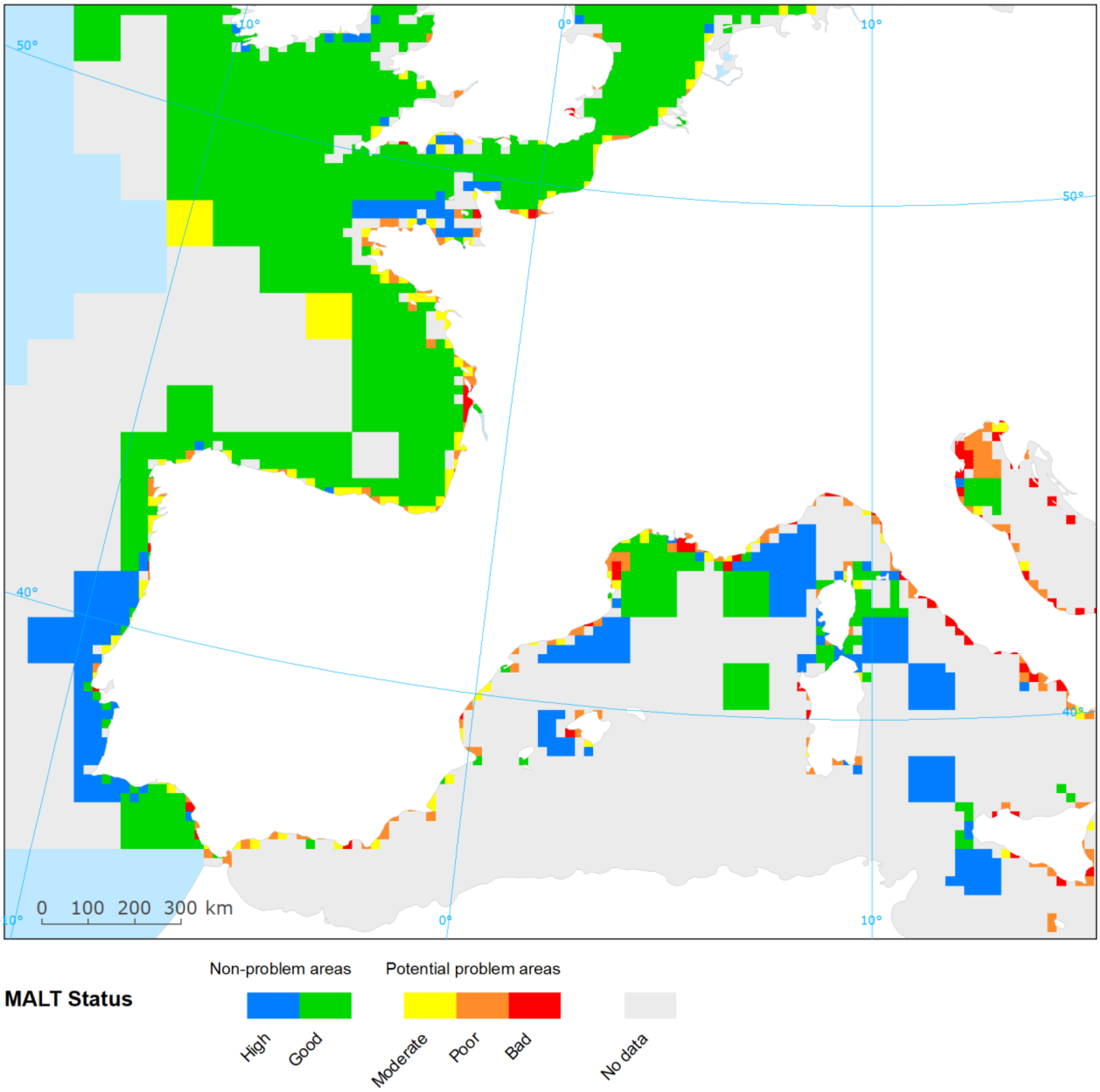


Figure A6.7: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Eastern Mediterranean Sea

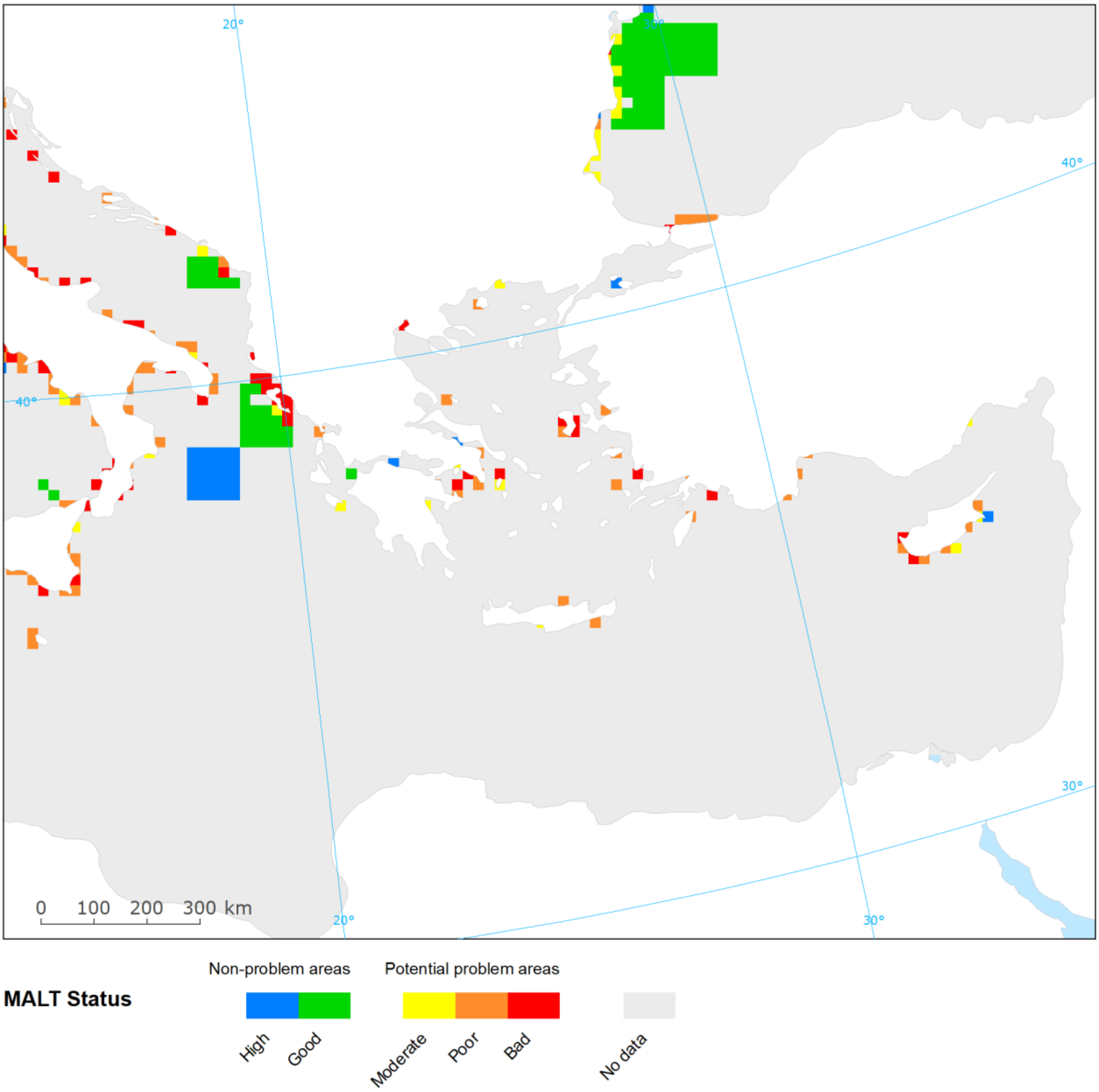


Figure A6.8: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter in the Black Sea

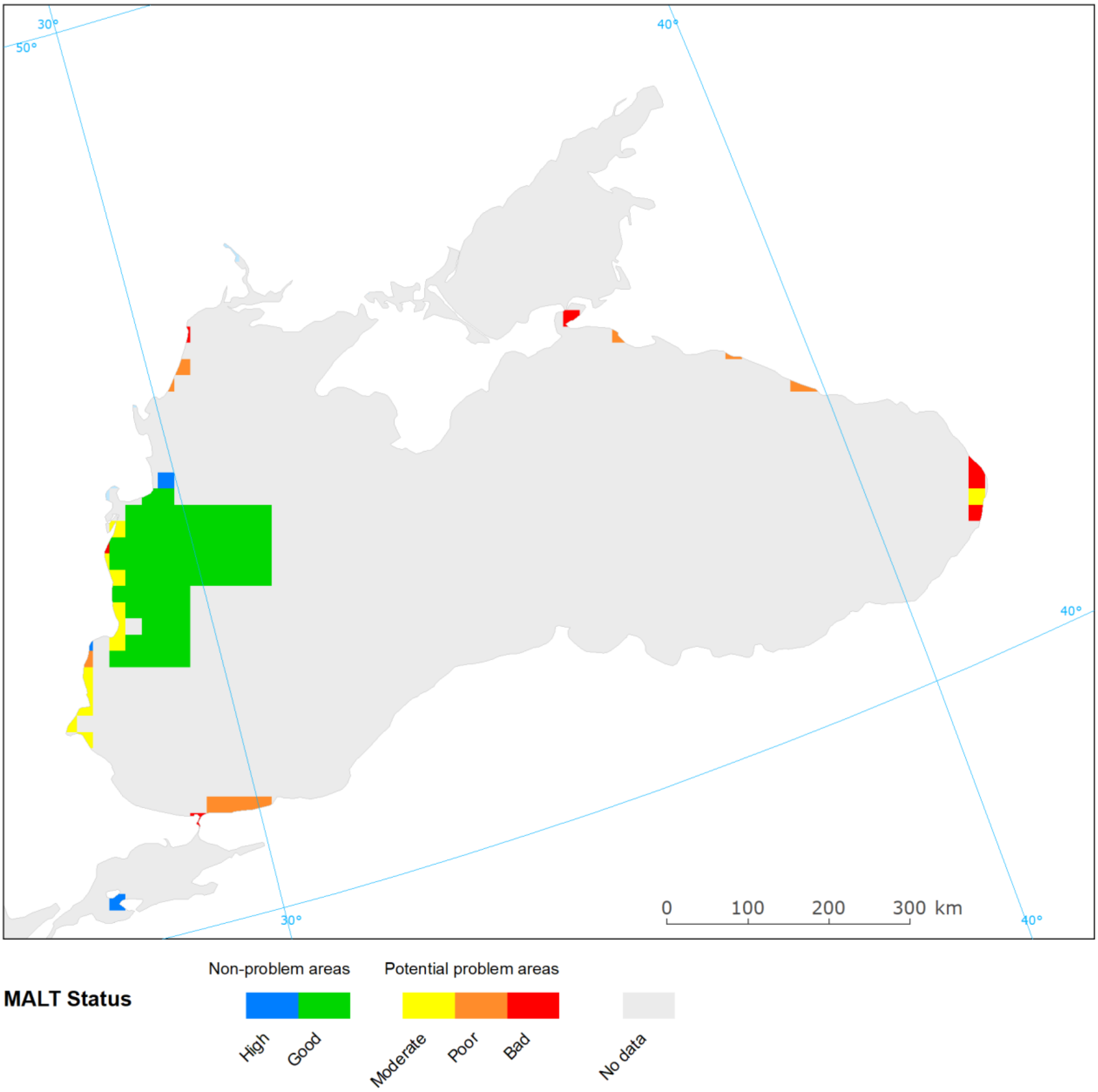


Figure A6.9: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to <u>seafloor litter</u>

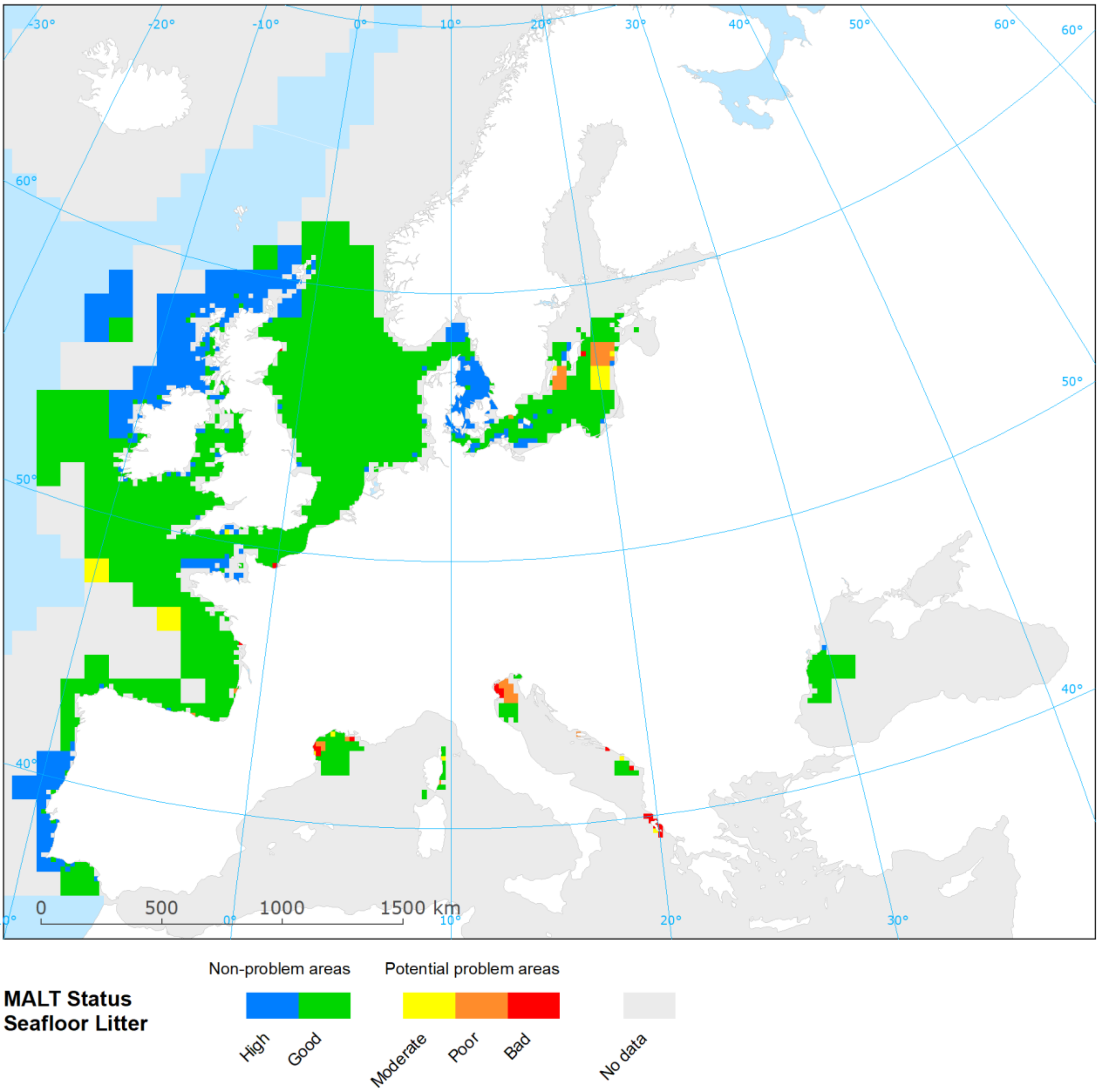


Figure A6.10: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Baltic Sea

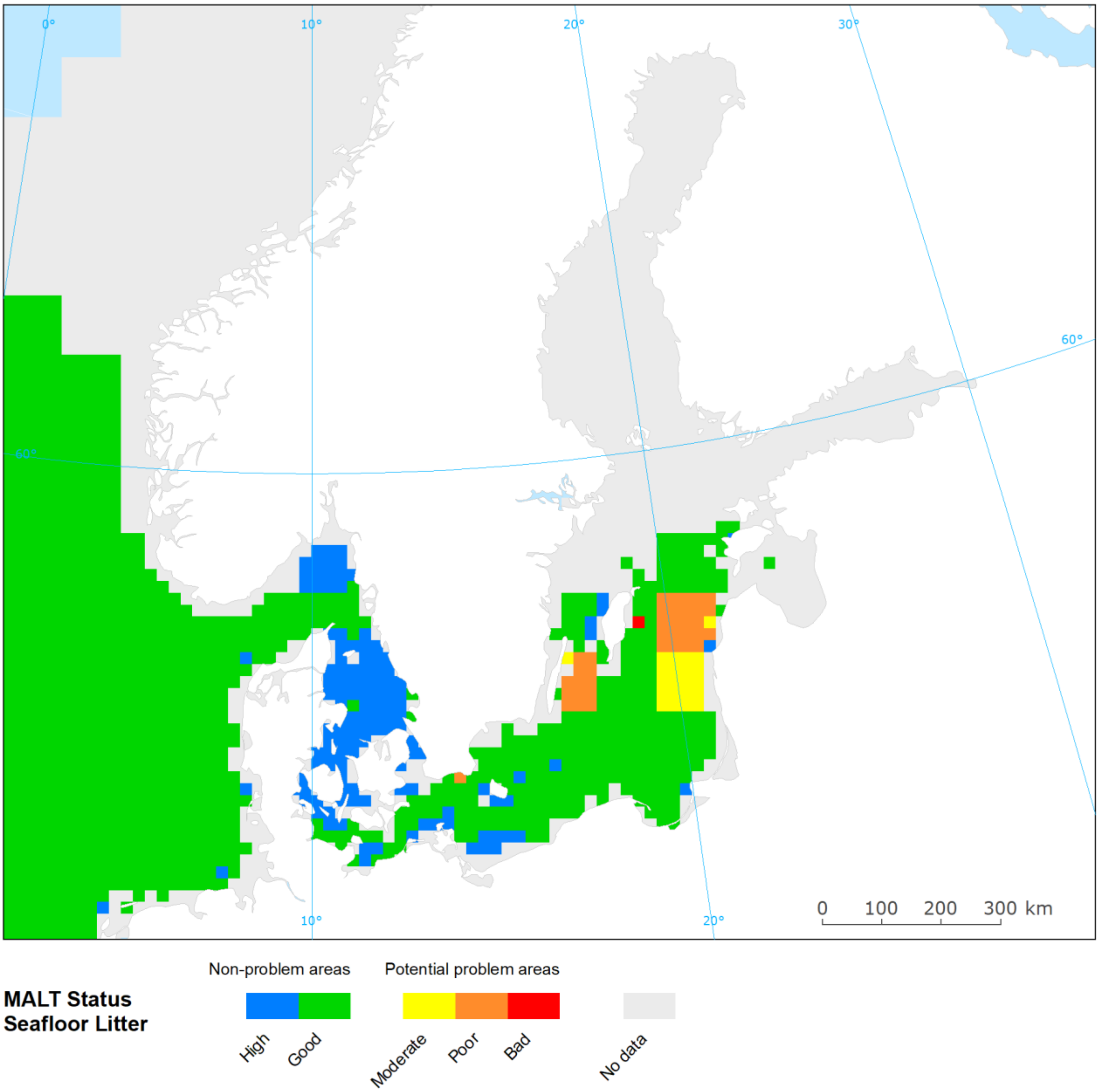


Figure A6.11: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to <u>seafloor litter</u> in the North Sea and Celtic Seas

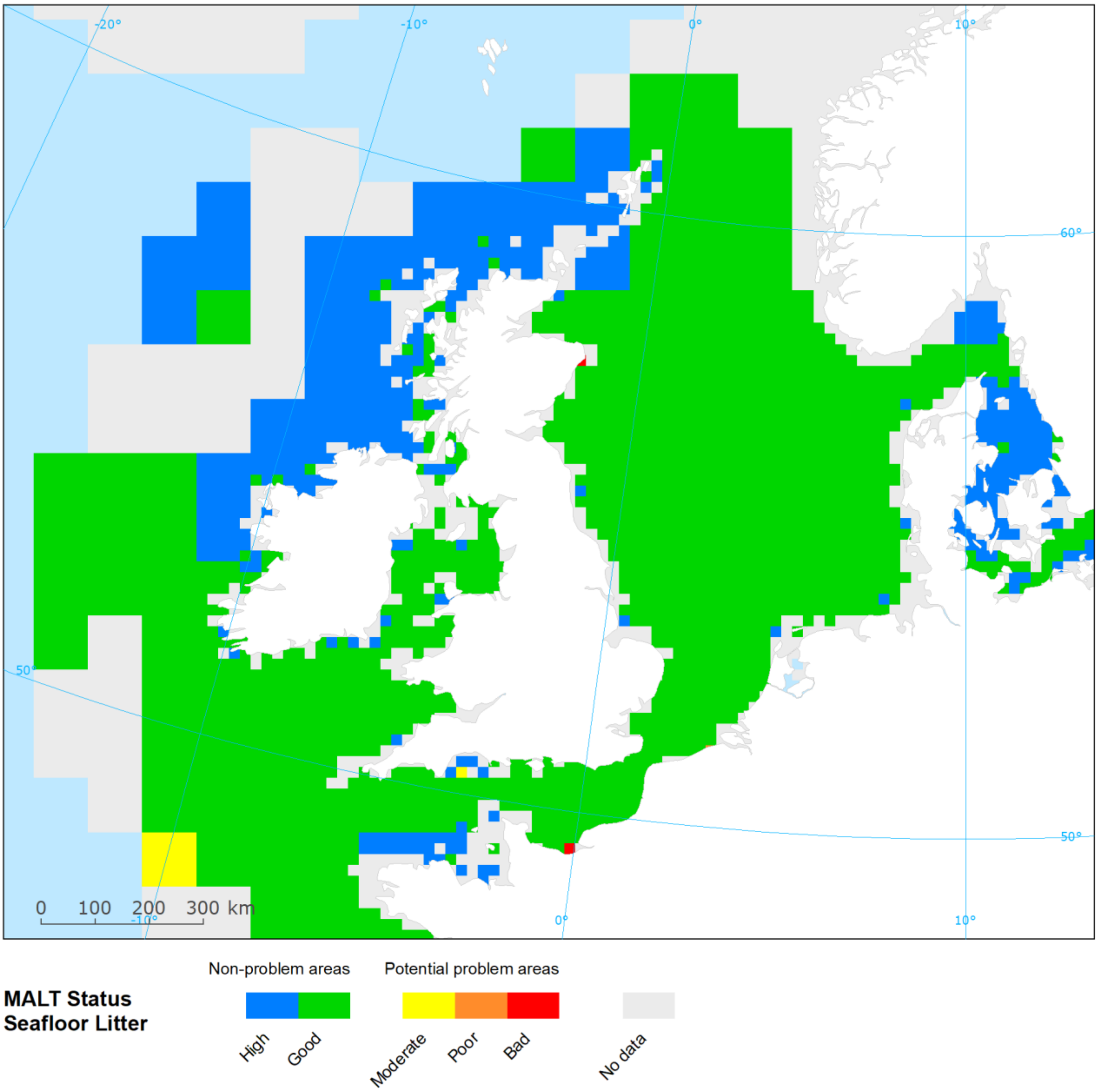


Figure A6.12: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Western Mediterranean Sea and Atlantic coasts of Spain, Portugal and France

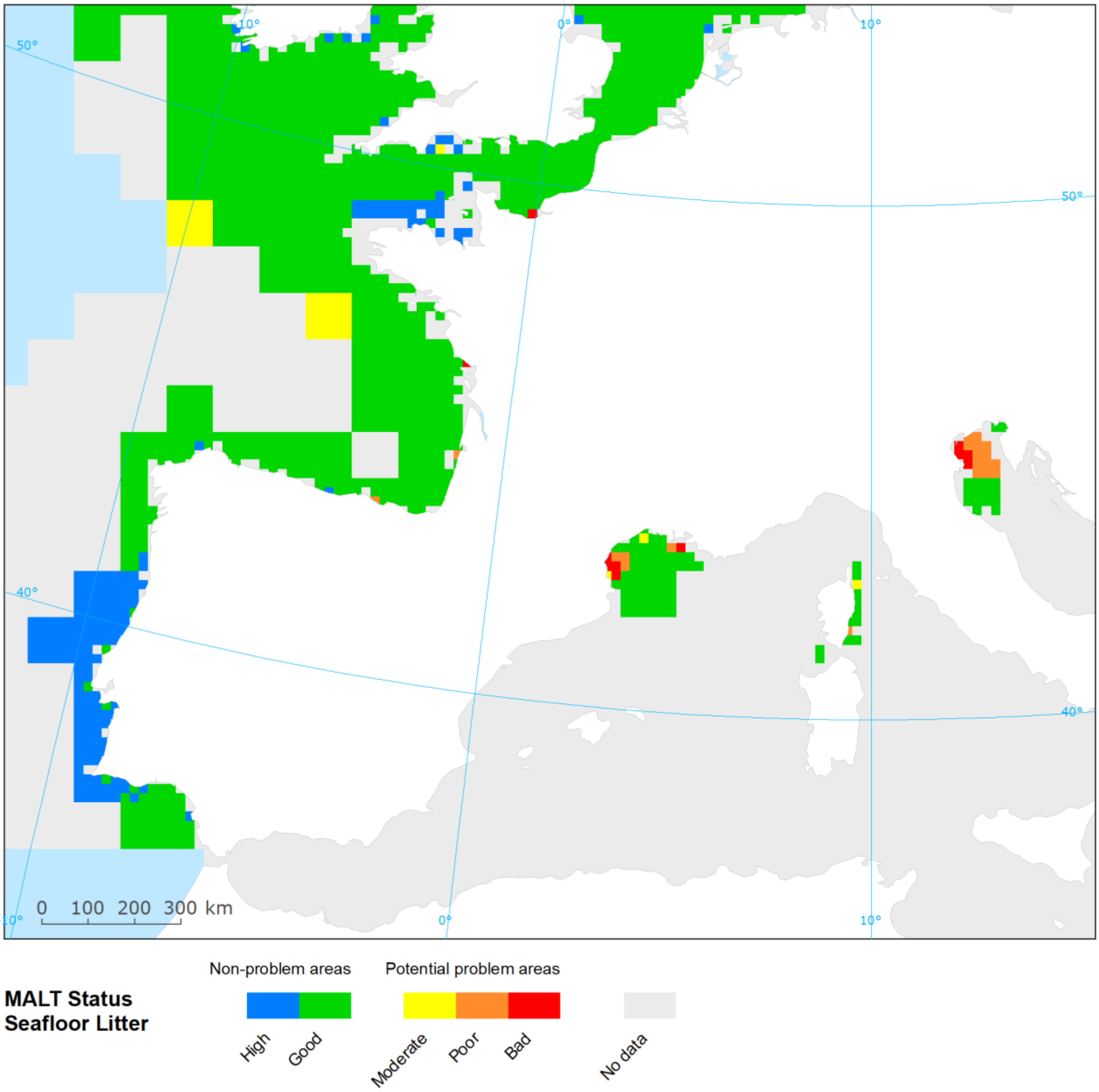


Figure A6.13: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Eastern Mediterranean Sea

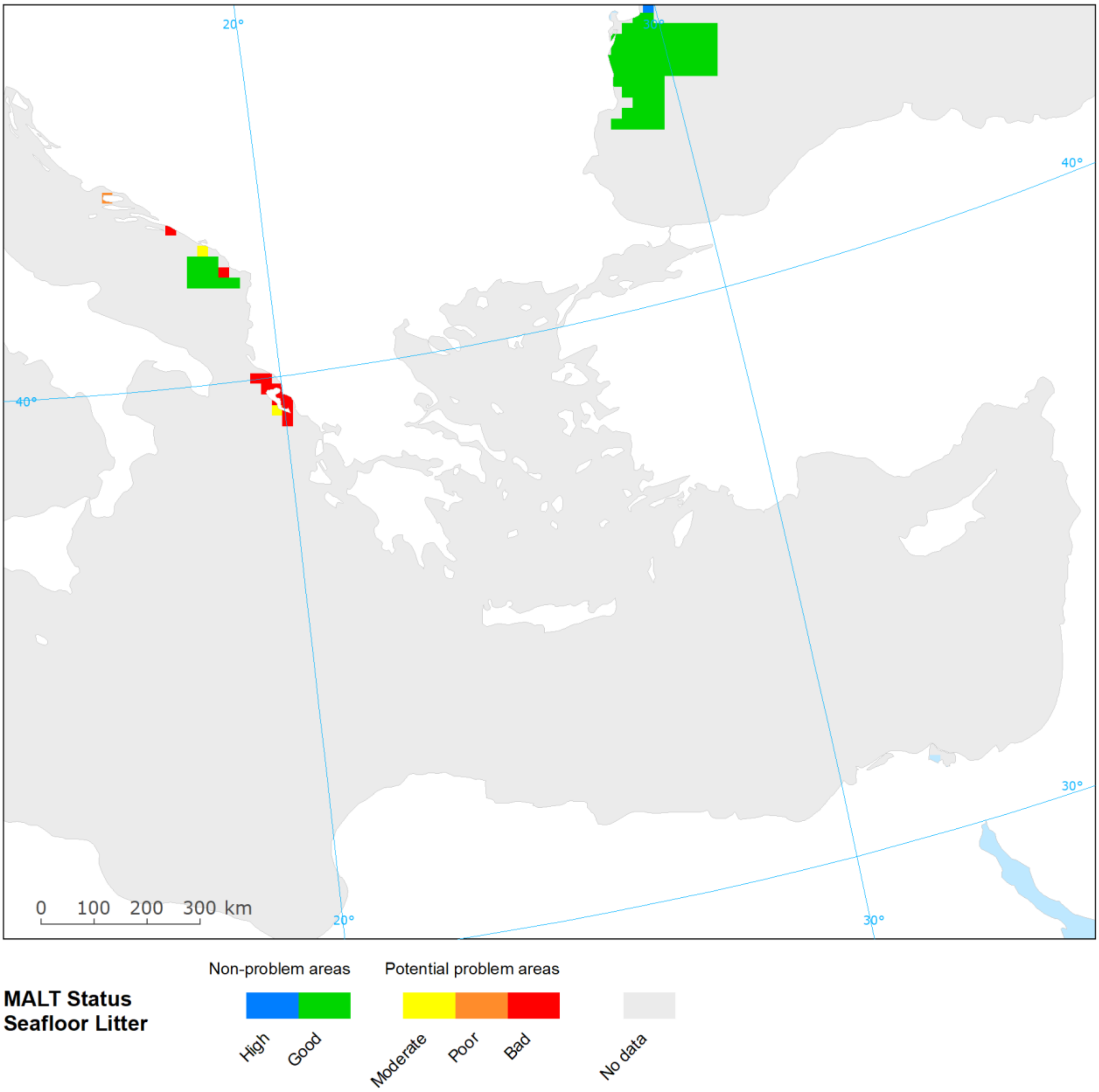
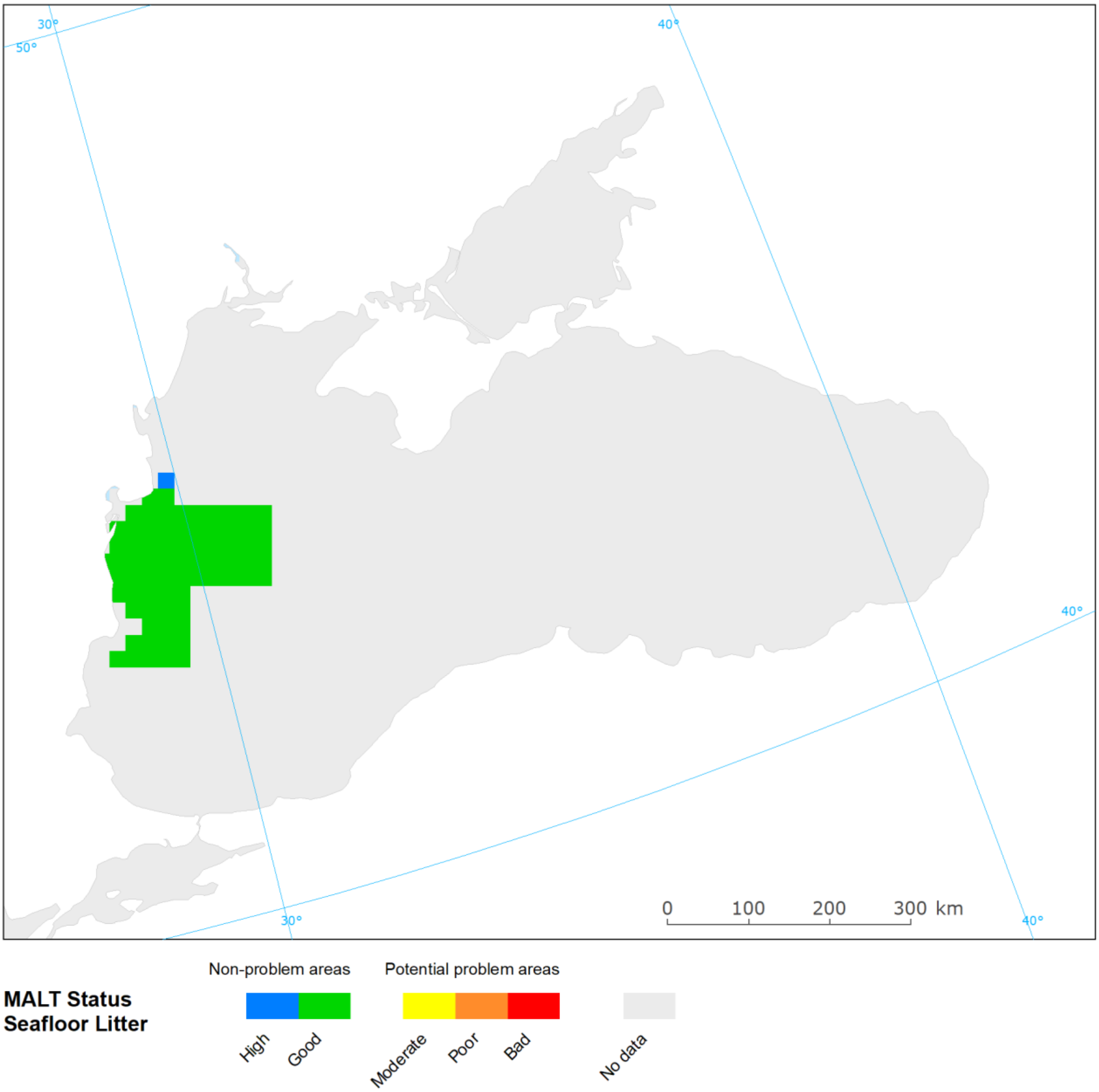


Figure A6.14: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter in the Black Sea



Annex 7 MALT Assessment results for two separate periods: 2011–2013 and 2017–2019

The same data used for the primary assessment presented in this report was filtered and collected into two separate datasets for the following three-year periods:

- 01-01-2011 to 31-12-2013
- 01-02-2017 to 31-12-2019

The assessment calculations were the rerun for each of the periods. The results are summarized below:

Table A7.1 Summary of assessment results by region

Region	Assessed Area %		Non-problem area (%)		Potential problem area (%)	
	2011–2013	2017–2019	2011–2013	2017–2019	2011–2013	2017–2019
Baltic Sea	26.4	41.1	49.9	19.6	50.1	80.4
North-east Atlantic Ocean	18.9	20.2	33.1	18.8	66.9	81.2
Mediterranean Sea	2.3	5.0	93.6	46.0	6.4	54.0
Black Sea	6.1	1.2	1.4	12.7	98.6	87.3
Europe's Seas	14.5	16.4	36.0	20.9	64.0	79.1

Figure A7.1: Summary of area (km²) of 'non-problem areas' and 'potential problem areas' with respect to marine litter in Europe's Seas for all areas (top-left) and for four regions (top-right) and percentage of total area assessed overall (bottom-left) and by region (bottom right) with results for the period 2011–2013 indicated by "hollow" bars and 2017–2019 indicated by filled bars

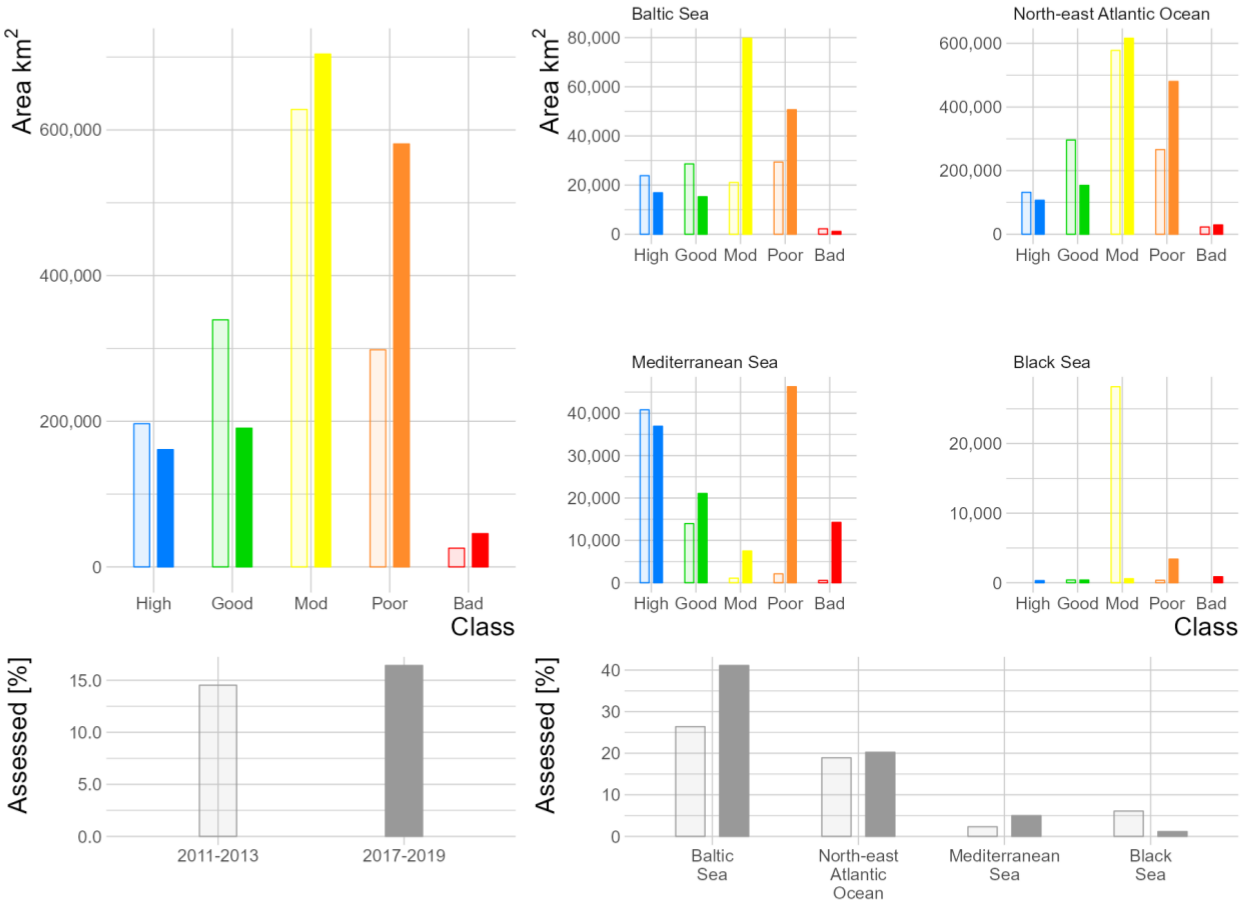


Figure A7.2: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter for the three-year period 2011–2013

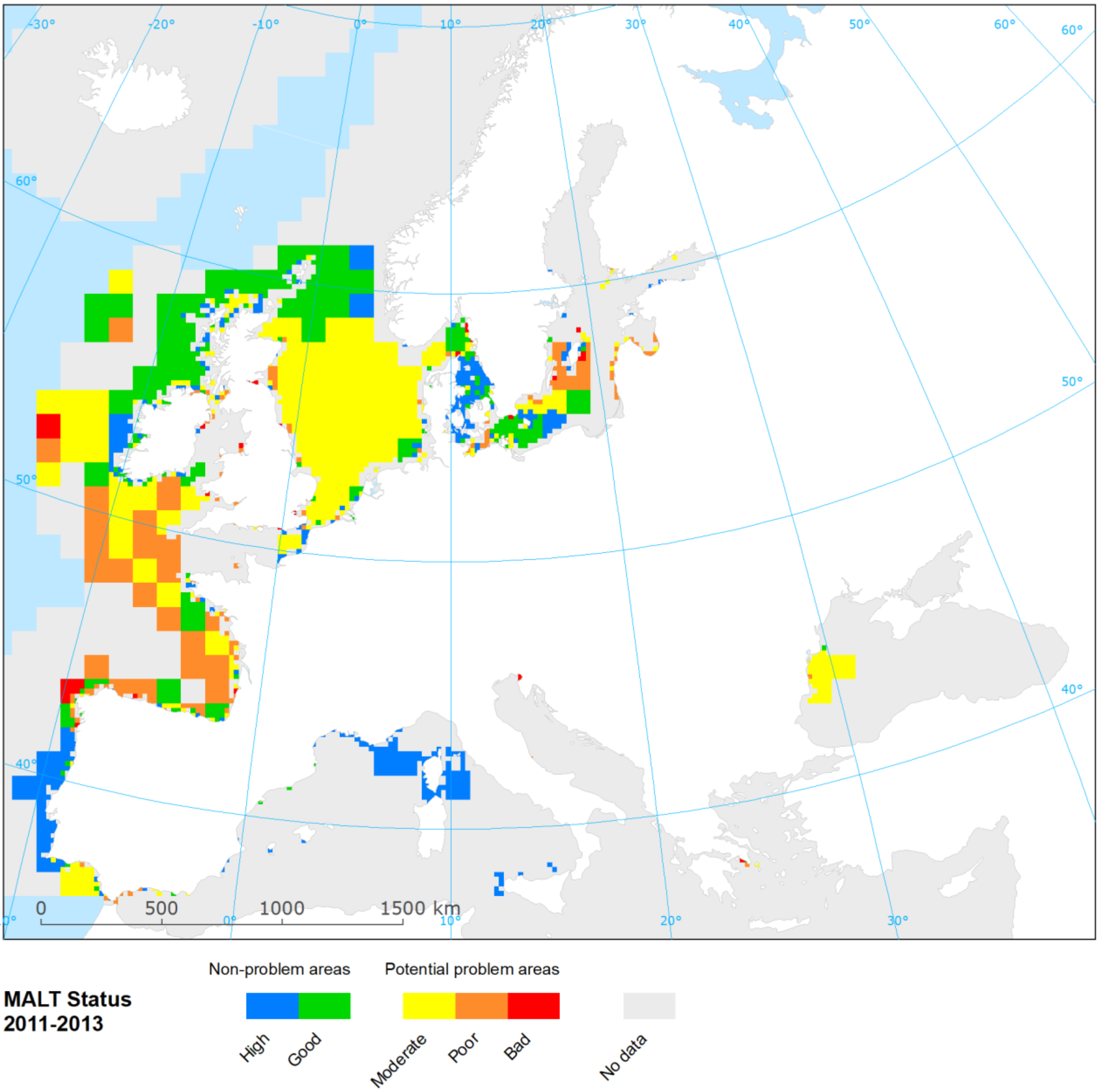


Figure A7.3: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to marine litter for the three-year period 2017–2019

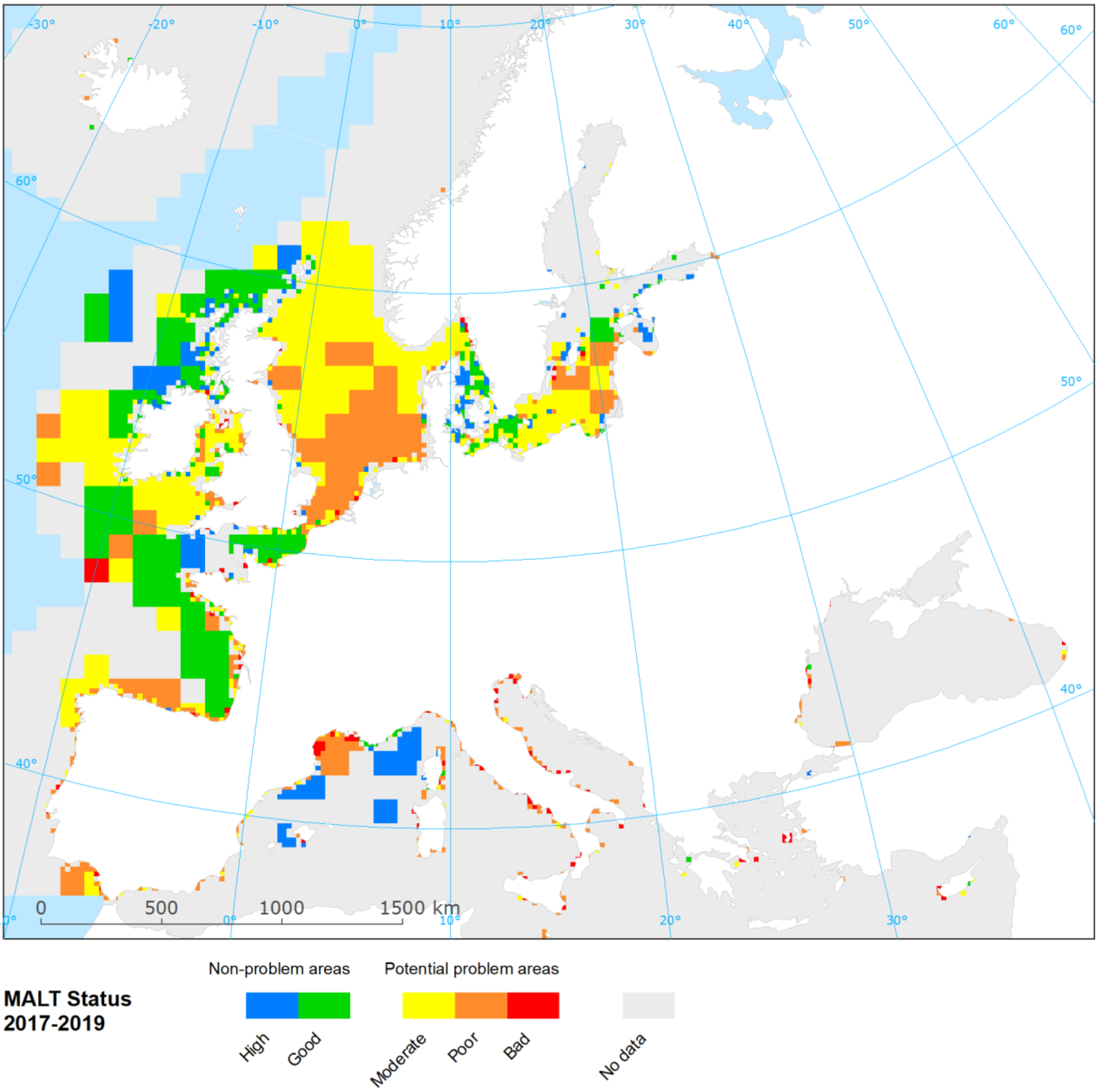


Figure A7.4: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter for the three-year period 2011–2013

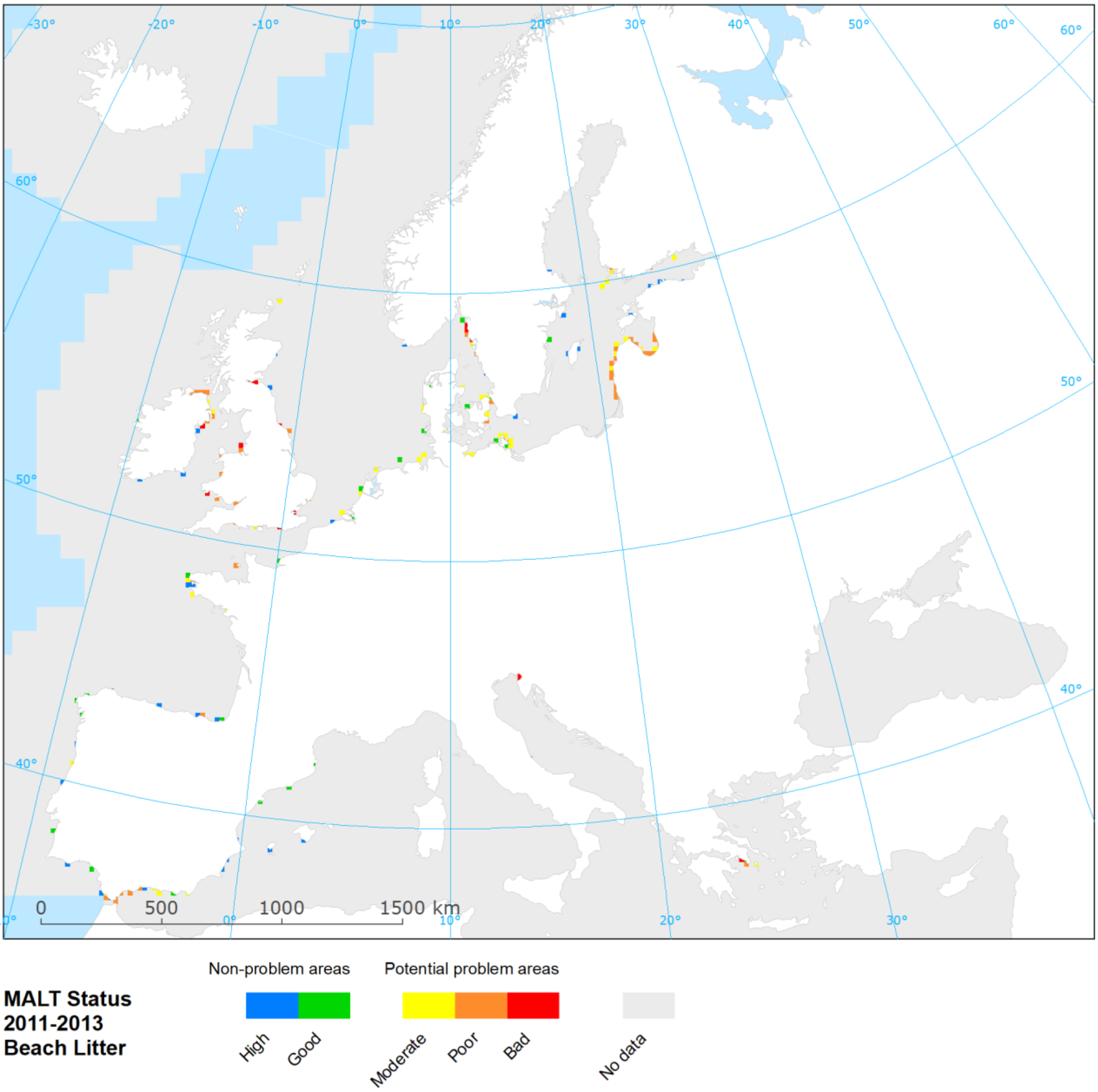


Figure A7.5: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to beach litter for the three-year period 2017–2019

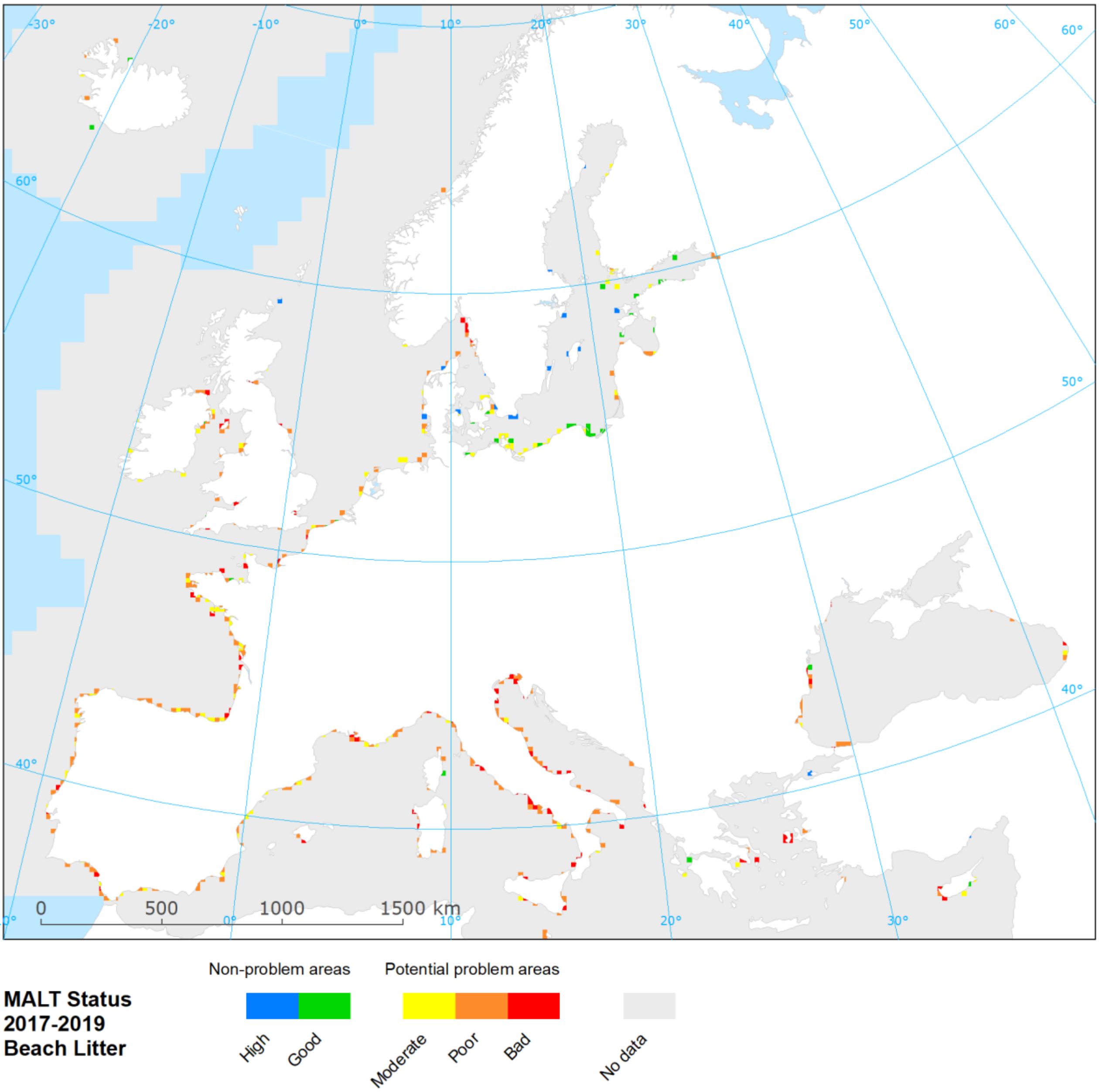


Figure A7.6: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter for the three-year period 2011–2013

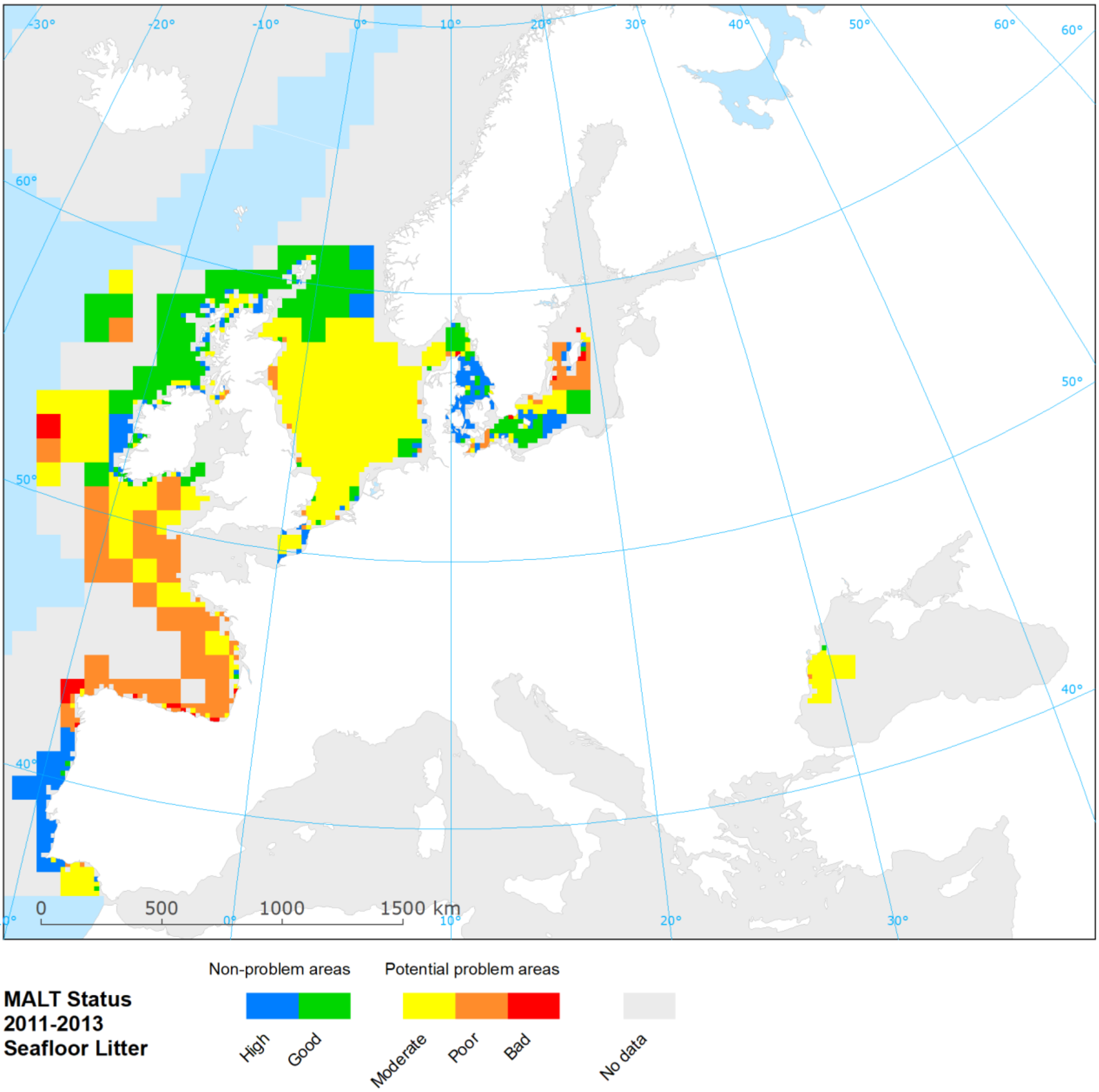


Figure A7.7: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to seafloor litter for the three-year period 2017–2019

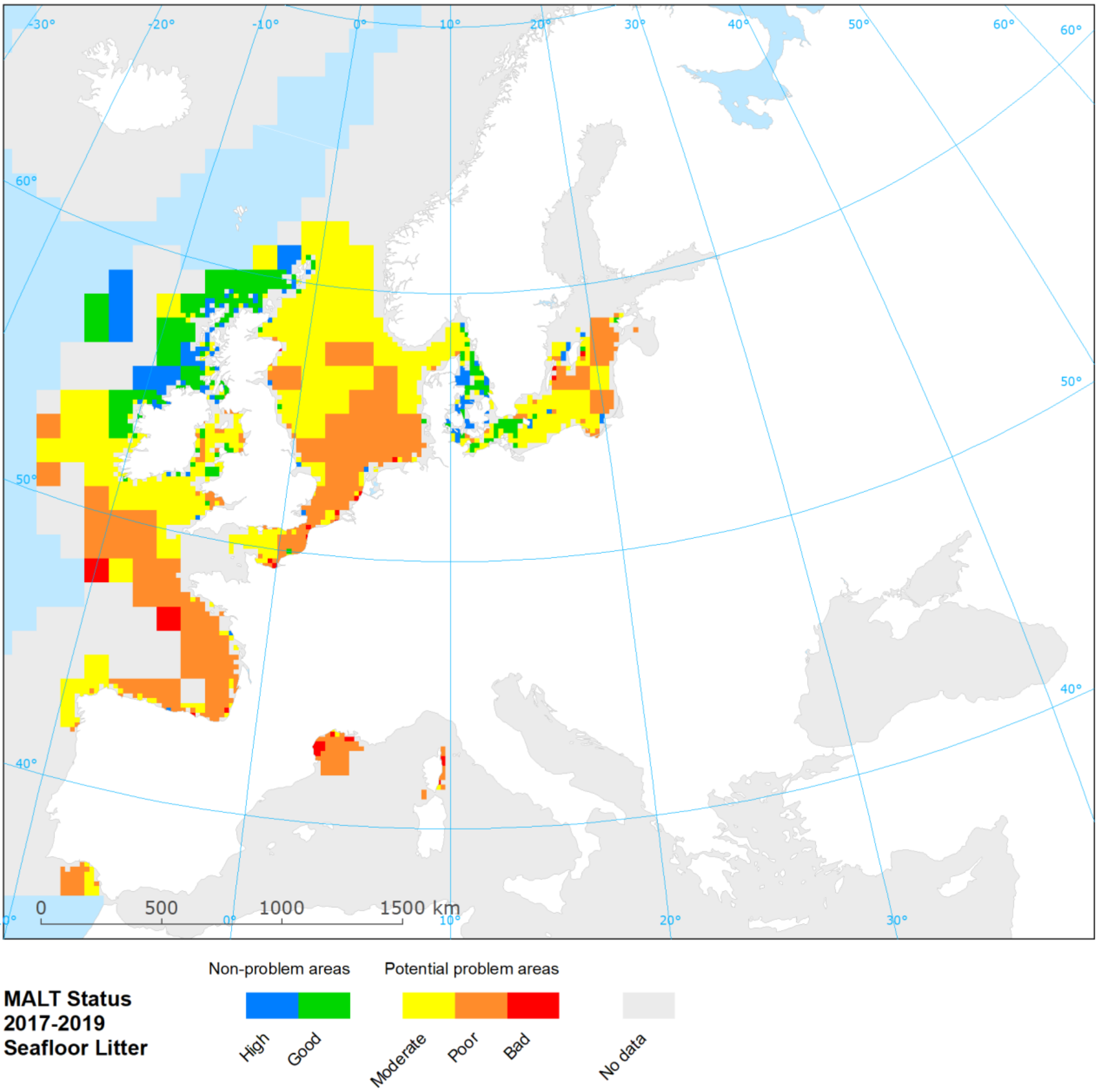


Figure A7.8: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter for the three-year period 2011–2013

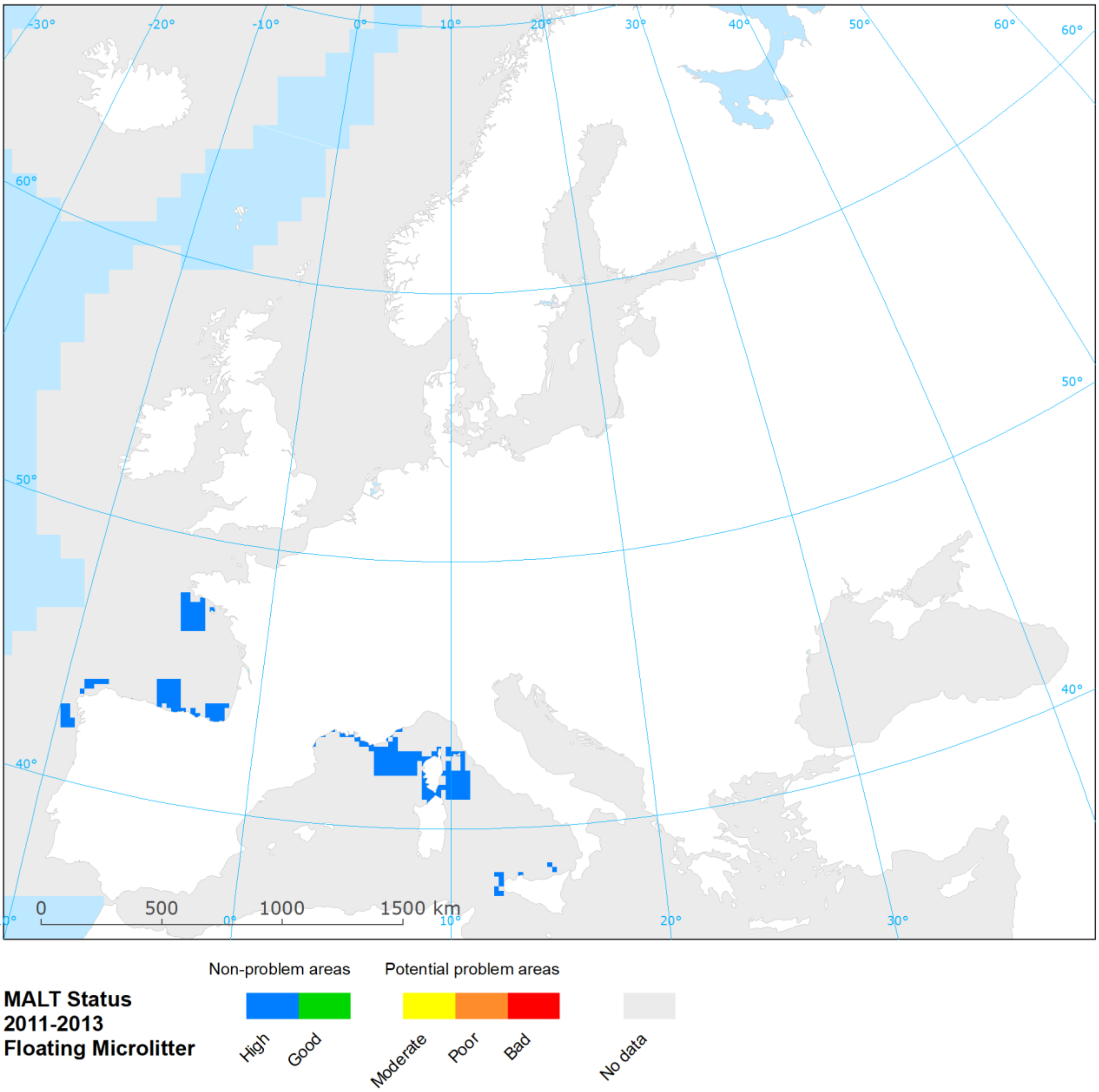
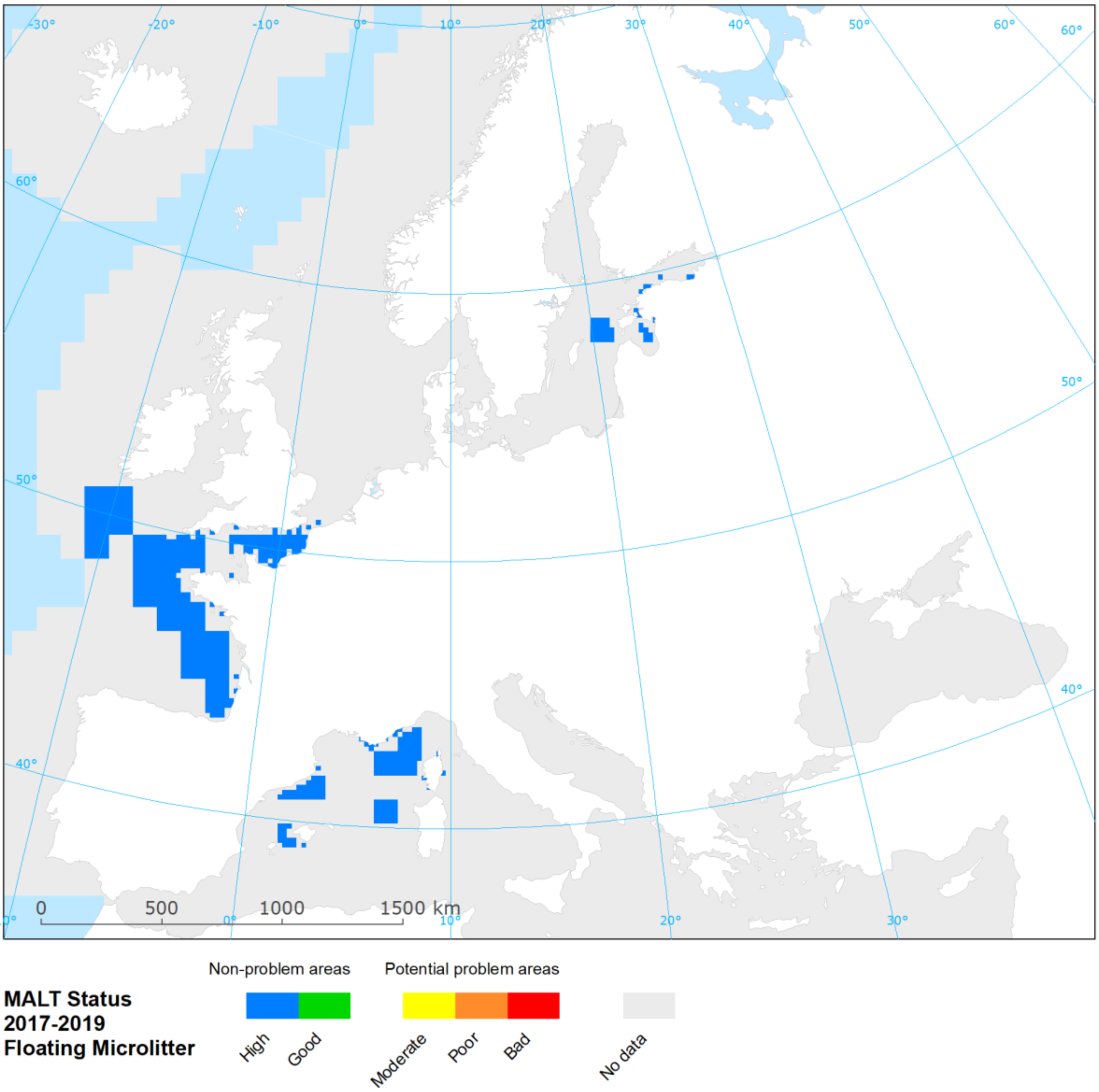


Figure A7.9: Preliminary classification and identification of 'non-problem areas' and 'potential problem areas' with respect to floating microlitter for the three-year period 2017–2019



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