Marine messages II

Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach

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European Environment Agency

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Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach

'Our environment, our natural jewels, our seas and oceans, must be conserved and protected.'

Ursula von der Leyen, Political guidelines for the next European Commission 2019-2024, 9 October 2019

European Environment Agency

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Contents

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The assessments included in the report synthesise the work of the EEA's ETC/ICM. They are based on the information reported by EU Member States as part of the implementation of the Water Framework Directive and Marine Strategy Framework Directive (although no information was available from the second reporting under Articles 8, 9 and 10 because of late reporting) as well as a suite of other information sources, e.g. the European Marine Observation and Data Network (EMODnet), and the European Environment Information and Observation Network (Eionet). In addition, the report includes information from the Regional Sea Conventions' and other international organisations' assessment activities.

The EEA and the authors are indebted to those people and institutions planning, implementing and reporting on the monitoring and assessment of Europe's seas. This second *Marine messages* report would not have been possible without their sustained and dedicated work. Likewise, we would like to thank those individuals who provided valuable feedback during the Eionet consultation on the final draft of the report.

Executive summary

Europe's seas are precious. Our quality of life, livelihoods and economies depend on the condition of our seas. Clean, healthy and productive seas can sustain the supply of ecosystem services to people. In this way, our seas have played a central role in the development of European communities and cultures throughout history. Even today, we still expect our seas to be a significant economic provider, and the EU's maritime economy is expected to double by 2030.

The historical and current use of Europe's seas is taking its toll on the overall condition of marine ecosystems, putting the expectations for their further use at odds with the long-term policy visions for clean, healthy and productive seas. Signs of stress are visible at all scales — from changes in the composition of marine species and habitats to changes in the seas' overall physical and chemical characteristics. The combined effects of these changes are on a path to cross complex planetary boundaries — boundaries that, if exceeded, will cause irreversible changes to the ecological conditions under which humanity has evolved and thrived.

There are, however, signs of marine ecosystems recovering as a result of significant, often decade-long, efforts to reduce certain impacts. Although these examples remain fragmented, they provide not only emerging lessons for recovery but also a ray of hope — the EU still has a chance of restoring key pieces of marine ecosystems' resilience if it acts urgently and decisively to better balance human use of Europe's seas with its impacts on marine ecosystems.

Marine messages II is, thus, set within the narrative of 'living well, within the [ecological] limits' of Europe's seas according to the EU's Seventh Environment Action Programme (7th EAP). It provides a set of key messages on the current use of Europe's seas and its combined effects on marine ecosystem condition. These messages underpin a set of lessons from marine ecosystem recovery from which solutions for a brighter future can be identified. These solutions are not only pragmatic and operational but also achievable within the next decade and within the existing EU framework of marine policy, strategies and legislation. Therefore, *Marine messages II* provides a timely, thematically relevant input to EU policy processes for developing the next EU biodiversity strategy and the 8th EAP as well as the evaluation and possible review of the Water Framework Directive and Marine Strategy Framework Directive (MSFD). In doing so, *Marine messages II* picks up from the first *Marine messages*, published in 2014.

The overarching aims of *Marine messages II* are to provide (1) a harmonised overview of use, pressures, exposures and their potential effects and of the overall condition of Europe's seas; (2) a set of data-driven indicator-based and spatial tools supporting a holistic, harmonised approach to the ecosystem-based management of human activities using and influencing Europe's seas; and (3) emerging lessons from marine ecosystem recovery in order to identify a set of solutions for marine governance.

Marine messages II is a synthesis based on available information collected under EU directives, the Common Fisheries Policy's data collection framework, the Regional Sea Conventions (RSCs) and other international organisations, EU-level initiatives i.e. the European Marine Observation and Data Network (EMODnet). It builds on EEA marine indicators and assessments, material from RSCs, peer-reviewed papers as well as novel assessment methodologies. The findings support those originating in the conventions, although they are presented from an EU perspective, i.e. integrated across EU marine regions to inform EU-level policy. It has not been possible to include any information from the MSFD's second reporting under Articles 8, 9 and 10 because of late reporting by EU Member States.

Chapter 1 sets the scene, defines the challenges faced by Europe's seas and focuses on the policy framework.

- The intertwined climate, biodiversity and resource use crises remain the challenge of this generation for the EU. Solutions are needed urgently if we are 'to stay within the ecological limits of the seas'.
- The EU has a policy framework in place, which enables the implementation of an ecosystem-based approach to managing human activities in Europe's seas, while delivering EU and United Nations (UN) commitments.

Chapter 2 takes a dive into the EU maritime economy.

- Overall, the EU maritime economy continues to increase: although while some sectors are declining or stagnating, new sectors are emerging.

- The EU maritime economy is anticipated to double by 2030 in the light of the EU's 'Blue economy' objectives. Competition for marine natural capital (i.e. marine biotic and abiotic assets such as resources and space) by maritime sectors is expected to increase. This increase needs to be decoupled from the degradation and depletion of marine ecosystem capital, and be contained within the limits of marine ecosystems.

Chapter 3 describes the current condition of marine species, habitats and ecosystems in Europe's seas.

- The loss of marine biodiversity in Europe's seas has not been halted.

- A high proportion of marine species and habitat assessments continue to find an 'unfavourable conservation status', failing to meet the nature legislation's objectives. Marine ecosystem condition is generally not 'good', which means that 'good environmental status' across all of Europe's seas is unlikely to be attained by 2020, as required by the marine legislation.

- Management measures targeting individual marine species and habitats have led to improvements in their condition in some EU marine regions, but this fragmented success does not offset the combined effects of multiple pressures from human activities across all of Europe's seas.

Chapter 4 describes the causes of the impaired condition of Europe' seas. Special focus is placed on sea-based activities, upstream land-based activities and the impacts of anthropogenic climate change.

- Where regional cooperation has been established and implemented consistently, negative trends in certain pressures are beginning to be reversed, for example, levels of nutrients and contaminants or the introduction of non-indigenous species.

- Europe's seas are unlikely to attain 'good' marine ecosystem condition in relation to reducing key pressures, such as seabed damage caused by fisheries, contaminants, eutrophication, non-indigenous species and marine litter, by 2020. There are regional differences in individual pressures and the interpretation of 'good' varies among assessment approaches.

- Changes in ocean temperature and oxygen content, and ocean acidification, indicate that systemic changes are taking place in EU marine regions, which further reduce marine ecosystems' resilience and hence resilience to the climate crisis.

Chapter 5 brings the findings of the report together. Decades of implementing EU and regional policy allows us to identify a set of lessons for restoring marine ecosystems. These should be used when taking action to overcome the challenges for Europe's seas and coming up with solutions to attain clean, healthy and productive seas.

- We have proven that marine ecosystem condition is directly linked to the combined effects of multiple pressures from human use of Europe's seas, and we have developed a way of identifying the limits for the sustainable use of our seas.

- Up until now, the EU has not managed to decouple the use of Europe's seas from marine ecosystem degradation. The way we use the natural capital held in our seas does not appear to be sustainable.

- However, the EU still has a chance to restore some marine ecosystem resilience piece by piece, which would increase resilience to the climate crisis and to other pressures; although there is an urgent need to act now.

- Solutions for halting the loss of marine biodiversity and starting to restore ecosystem resilience, while allowing for the sustainable use of Europe's seas, are obvious and available. They just need to be implemented. Moving towards achieving 'good condition' for our seas is feasible within the existing EU policy framework by 2030 with real political resolve, increasing coordination among stakeholders and policy integration. This needs to start by reducing pressures on marine ecosystems.

Ultimately, *Marine messages II* is about solutions that can help steer the EU towards achieving ecosystem-based management of Europe's seas. This report is not the full answer to that, but it represents a tangible, pragmatic contribution towards making ecosystem-based management operational within the 2020s. Therefore, this stand-alone report is both a contribution to the MSFD Article 20.3 reporting and to overarching EU policies, such as the new biodiversity strategy and 8th EAP. Elements of it can also be used in the context of the UN. The contribution of *Marine messages II* can embrace the EU's diversity while building on its strengths — evidence-based governance and the will to cooperate across boundaries. Based on these premises, clean, healthy and productive seas could — eventually — be attained.

1 Our seas, our responsibility

More than 65 % of Europe is covered by its oceans and seas (EEA calculation). This is more than in any other continent. Therefore, Europe's seas — spanning from the Baltic Sea and the North-East Atlantic Ocean in the north to the Mediterranean Sea and Black Sea in the south and east (Figure 1.1) — have, throughout history, played a decisive role in the development of our cultures, our economies, our global influence and our individual lives. We depend on Europe's seas for transport, energy, food, income and leisure activities as well as for often less well-recognised life support functions, such as the oxygen in the air we breathe and climate regulation (EEA, 2019f).

As we exploit the seas, multiple pressures arise that lead to unprecedented combined effects on marine species, habitats and ecosystems (Jackson et al., 2001; Halpern et al., 2008). This weakens their self-renewal and resilience, jeopardising the ecosystem services they can supply and upon which we depend (McLeod and Leslie, 2009; EEA, 2015b). In fact, and in what should be a major cause of concern, humanity is now documented to be the cause of the start of the sixth extinction event (IPBES, 2018, 2019). Overall, our ecological footprint has been accelerating since the 1960s, and the impacts, including those from anthropogenic climate change, are reaching levels that jeopardise the essential structures and functioning of all ecosystems (Lotze et al., 2019; IPCC, 2018; WWF, 2019; IPBES, 2019; IUCN, 2019). These are, thus, being pushed beyond the limits of a safe operating space for humankind, especially, with global demand for resources expected to double in just 40 years (Rockström et al., 2009; Steffen et al., 2015; IRP, 2019). This is also true for Europe's seas, as the human activities and pressures upon them are likely to continue to increase (EC, 2018e, 2014; Eikeset et al., 2018). So far, however, the EU has not been successful in achieving economic growth without environmental degradation (IPBES, 2018; EC, 2019d). Both in the EU and globally, the number of actors (e.g. individual sovereign states or multinational industries) simultaneously looking towards the seas and oceans as the 'final, untapped frontier' for territories, resources and influence is growing (EC, 2018e; IBRU, 2019; Hayton, 2014).

In 2020, the current EU policy cycle comes to an end (e.g. the Seventh Environment Action Programme (7th EAP) and the EU biodiversity strategy to 2020) and a new one begins, Europe finds itself at a crossroads regarding how we face these intertwined climatic, environmental, economic, social and geo-political challenges over the next decade. How can we take further responsibility and identify the solutions needed to safeguard Europe's seas, their biodiversity and resources and our well-being, while maintaining jobs and a thriving maritime economy?

Set in this context, *Marine messages II* seeks to explore how Europe can balance environmental, social and economic objectives in the governance of our seas. It does so by assessing whether Europe has, and can expect to have, seas that are clean, healthy and productive, as well as providing knowledge to help achieve that. In this way, *Marine messages II* is different from *Marine messages I* (EEA, 2014), which limited itself to communicating the main outcomes from the EEA's monograph *The state of Europe's seas* (EEA, 2015b). Following from the 7th EAP, the overarching context of *Marine messages II* is the notion of 'natural capital' and the 'limits' to its use, and it starts exploring the relationship between these concepts and ecosystem-based management.

Marine messages II provides a set of practical tools and reflections on how to better achieve EU policy visions for implementing an ecosystem-based management of Europe's seas. The tools are based on free access to data and information, transparency of assessment methodologies and results, and sharing knowledge. But, above all, it is based on open communication and collaboration between sovereign states, recognising the necessity of jointly confronting the 'generational' challenges of accelerating demands on natural resources, anthropogenic climate change, loss of biodiversity and, ultimately, the overall impacts on the biosphere.

Marine messages II is built around readily available and formally reported information; recent national, regional and global assessments; existing EEA indicators and assessments, supplemented by peer-reviewed papers; and novel assessment methodologies. Unfortunately, it has not been possible to include a summary of the second round of reporting under the Marine Strategy Framework Directive (MSFD) (EU, 2008b) (no Member States had reported correctly on Articles 8, 9 and 10 by 15 October 2018). The reporting under the Habitats Directive (EU, 1992) is ongoing and only draft results have been included, as final results will become available only after the publication of *Marine messages II*. The availability of Europe-wide time series on the trends in the state of marine species groups, habitats and ecosystems is limited; therefore, *Marine messages II* tends to use more static information, such as data on their status.

1.1 Living within limits — the challenge of our generation

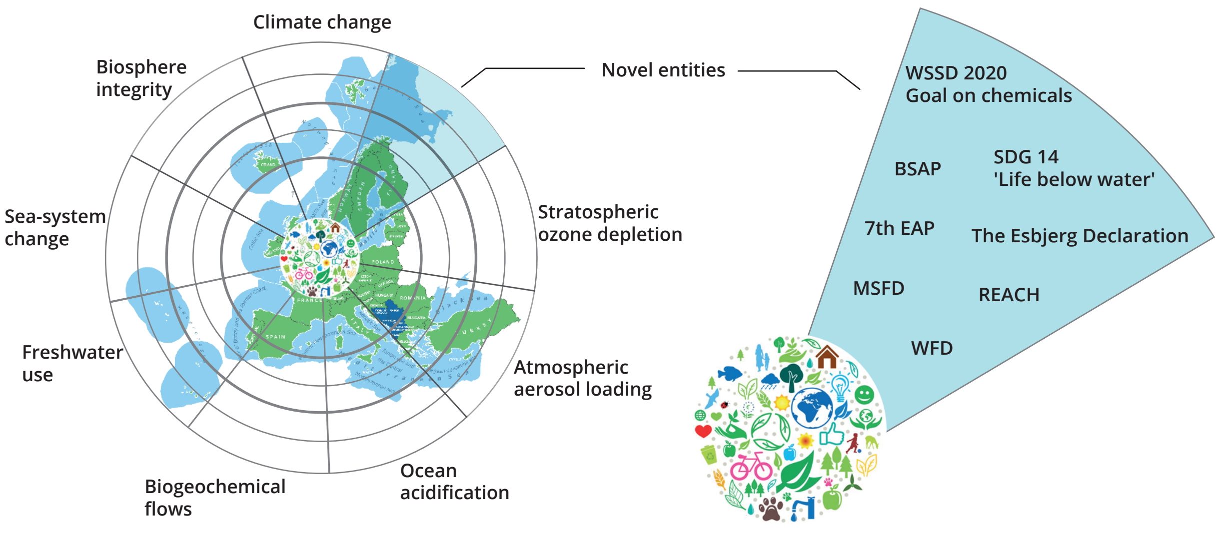
At the turn of the 20th century, a new understanding of how the planet functions emerged. The Earth acts as a single system within which the biosphere plays an essential role in maintaining the conditions under which human societies have developed and thrived. But also, more disturbingly, there is a new understanding that the combined effects of multiple pressures from human activities using this resource have reached such a scale that they no longer only affect individual habitats or local ecosystems but influence the entire Earth system through complex and interlinked pathways (Steffen et al., 2004).

Such realisation led to the development of a conceptual framework aimed at defining a 'safe operating space' for human societies to continue to develop and thrive in. It includes nine evolving planetary boundaries, or limits, that should not be transgressed (Figure 1.1) (Rockström et al., 2009; Steffen et al., 2015). The planetary boundaries are intimately linked to the oceans and seas and the ongoing changes observed (IPBES, 2018; IPCC, 2018) — staying within their limits may be the biggest challenge faced by our generation. It is beyond the scope of *Marine messages II* to provide an answer to the scientific challenges involved in defining the planetary boundaries. However, the planetary boundary framework allows us to disentangle the individual pieces of the overarching challenges and to narrow down their almost infinite complexity to produce a more restricted 'comprehension' space that is relevant for operational governance.

This is a space where existing information on past trends, present condition and potential trajectories of trends of Europe's seas can be placed in the context of individual planetary boundaries and used to identify a set of options to improve their current situation. These options will allow us to inform existing policies and strategies and choose practical solutions to achieve, for example, ecosystem-based management of human activities based on science, facts and evidence.

An example of how various policies relevant for Europe's seas could be linked to an individual planetary boundary, e.g. 'chemical pollution', is illustrated below (Figure 1.1; for a full explanation see EEA (2018a)). Similarly, a connection can also be made between several of these boundaries and

Figure 1.1 Living well within planetary limits — bridging the gap between science and policy



Notes: Planetary boundaries are adapted from Rockström et al. (2009). Many United Nations, regional and EU policies address the risks of transgressing these boundaries. Policies for addressing the 'novel entities' boundary, i.e. hazardous substances, pharmaceuticals, etc., in Europe, are illustrated to the right and set in the context of the 7th EAP, i.e. 'living well, within limits' (EEA, 2018a).

BSAP, Baltic Sea Action Plan; WFD, Water Framework Directive; SDG, Sustainable Development Goal; REACH, Registration, Evaluation, Authorisation and restrictions of Chemicals (Regulation); WSSD, World Summit on Sustainable Development; MSFD, Marine Strategy Frameworkd Directive.

policy objectives under, for example, the 7th EAP or the themes covered by the MSFD descriptors (Table 1.1) (EU, 2008b; EC, 2013). The linkages are only preliminary and indicative, given that no formal, clear linkages exist between either the planetary boundaries or the 7th EAP's description of 'within limits' and EU legislation.

1.2 Connecting science, policy and society

Evolving scientific understanding has caused a shift in the awareness of individuals, communities and society overall. Such visible changes, in not only science but also public sentiment, are moving policies towards more holistic visions and aspirations, e.g. the United Nations (UN) Sustainable Development Goals (SDGs) and the 7th EAP. This awareness continues to grow, as illustrated by the then 16-year-old Greta Thunberg's recent address to the European Parliament on the climate emergency (EP, 2019) and by the fact that 94 % of EU citizens believe that protecting the environment is 'very important' (EC, 2017b).

The 'planetary boundaries' and 'safe operating space' concepts are thus recognised by central policies of the UN. They are at the core of the UN SDGs for 2030 as a way to guide humankind towards a sustainable future. In particular, SDG 14, aims to raise awareness of the need to protect ocean health. It focuses on conservation, reduction of pressures and their impacts, and the sustainable and fair use of seas and oceans (UN, 2015). The EU has adopted and embraced these goals, which are to be delivered through a series of policies and legislation, some pre-dating the adoption of SDG 14 (Table 1.1). They are recognised by ongoing EU policy, e.g. the EU 7th EAP and its 2050 vision of living well within the planet's ecological limits (EC, 2013), the EU biodiversity strategy to 2020 (EC, 2011) and the EU action plan for the circular economy (EC, 2015c).

Looking specifically at Europe's seas, a comprehensive policy framework is now regulating individual human activities, sectors, pressures, species and habitats, and entire ecosystems, e.g. the Habitats Directive (EU, 1992), and the activities going on within them. Regarding the use of the sea and its natural capital, the EU integrated maritime policy (IMP) seeks to provide a more coherent approach to maritime activities and issues. This includes increased coordination of various policy areas in order to promote a 'sustainable blue economy' (EC, 2007). Within the IMP, the environmental pillar and main driver for clean, healthy and productive European seas is the 2008 MSFD (EU, 2008b), to which the Maritime Spatial Planning Directive (EU, 2014) makes a key contribution.

The MSFD is aimed at protecting and restoring the marine environment and phasing out pollution, so that there are no significant impacts on or risks to marine biodiversity, human health and the legitimate use of marine resources. It enshrines an ecosystem-based management (EBM) approach in EU marine policy (Box 1.1) to ensure the sustainable use of the marine environment for current and future generations. Thus, it requires the attainment of 'good environmental status' (GES) for EU marine waters by 2020. The MSFD is implemented by EU Member States and these efforts are supported by the efforts of the four regional sea conventions (the Helsinki Convention — HELCOM; the OSPAR Convention (Convention for the Protection of the marine environment of the North-East Atlantic); the Barcelona Convention; the Bucharest Convention).

Despite these significant efforts, GES under the MSFD is not likely to be attained by 2020 (EC, 2018c) and overall policy integration still needs improvement (EC, 2019c). The following chapters will show how key elements of the EBM process can be made more operational at the scale of the EU's seas. This involves demonstrating a spatial approach connecting the multiple components recognised within the MSFD. This includes maritime

Box 1.1 Ecosystem-based management in Europe's seas

Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans as part of it. The goal is to maintain ecosystems in a healthy, clean, non-toxic, productive and resilient condition, so that they can continue to provide humans with the services and benefits upon which we depend and to ensure the protection of these ecosystems.

It is a spatial approach that builds around (1) acknowledging connections, (2) combined effects (formerly 'combined impacts'), and (3) multiple objectives, rather than a traditional approach that addresses single concerns, e.g. species, habitats, sectors, activities and individual national interests.

Source: Adapted from McLeod and Leslie (2009) and EEA (2015b).

activities, sea-based and upstream land-based pressures, the combined effects of these pressures, and the state of the marine environment. The findings are supplemented with information on past trends and, where available, outlooks for key drivers and ecosystem features.

In this way *Marine messages II* will not only show the urgency for action (despite emerging positive environmental trends) but also demonstrate what the next step towards a systems approach for the marine and maritime domains may look like. It will show that, by reaching specific IMP/MSFD policy objectives, synergies with other environmental policy ambitions can be achieved. It will also question whether policy visions for growth and environmental condition are aligned in practice.

Table 1.1 Linking selected global and EU marine policies to planetary boundaries

Policy objectives and targets	Sources	MSFD descriptor	Planetary boundary
State of marine ecosystems, including their biodiversity			
Better protection and restoration of ecosystems and the services they provide	EU biodiversity strategy to 2020	D1	Biodiversity loss
Ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora	Council Directive 92/43/EEC; Directive 2009/147/EC (Habitats Directive)	D1	Biodiversity loss
The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographical, geographical and climatic conditions	Directive 2008/56/EC as amended by Directive 2017/845 and Commission Decision 2017/848 (Marine Strategy Framework Directive)	D1	Biodiversity loss; Climate change
Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock	Directive 2008/56/EC; Commission Decision 2017/848 (Marine Strategy Framework Directive); EU common fisheries policy	D3	Biodiversity loss; Sea system change
All elements of the marine food webs occur at normal abundance/diversity levels capable of ensuring the long-term abundance of the species and the retention of their reproductive capacity	Directive 2008/56/EC; Commission Decision 2017/848 (Marine Strategy Framework Directive)	D4	Biodiversity loss
Sea floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems are not adversely affected	Directive 2008/56/EC as amended by Directive 2017/845 and Commission Decision 2017/848 (Marine Strategy Framework Directive)	D6	Biodiversity loss; Sea system change
Pressures and their effects			
Non-indigenous species introduced are at levels that do not adversely affect the ecosystems	Directive 2008/56/EC; Commission Decision 2017/848; EU biodiversity strategy to 2020	D2	Biodiversity loss
Human-induced eutrophication is minimised, especially the adverse effects thereof	Directive 2008/56/EC as amended by Directive 2017/845 and Commission Decision 2017/848; Directive 2000/60/EC; EU common agricultural policy	D5	Bio-geochemical flows
The impacts of ocean acidification are addressed and minimised	Directive 2008/56/EC; SDG 14.3	D7 (MSFD Annex III)	Ocean acidification
The concentrations of contaminants are kept at levels that do not give rise to pollution effects	Directive 2000/60/EC (Water Framework Directive); Directive 2008/56/EC; SDG 14.1;	D8	Chemical pollution
Marine litter is reduced to a level that does not cause harm to marine environment	Directive 2008/56/EC; Commission Decision 2017/848; 7th EAP; SDG 14.1	D10	Chemical pollution

Notes: There is not necessarily a one-to-one relationship between an MSFD descriptor and a planetary boundary. However, if the targets related to the achievement of the MSFD descriptors are based on science and are met, the EU may be on the right track with regard to staying within limits for its seas. This assumption does not include considerations of the EU's global ecological footprint.

2 We depend on Europe's seas

Key messages		
Past trends (10-15 years)		Overall, the EU maritime economy continues to increase — with some sectors declining or stagnating (e.g. North Sea oil extraction), while new sectors (e.g. offshore wind) emerge and grow.
Outlook to 2030		The EU maritime economy is expected to double by 2030 in the light of the EU's 'blue economy' objectives, leading to increased competition for marine natural capital (i.e. marine biotic and abiotic assets) by maritime sectors. To be sustainable, this increase needs to be decoupled from the degradation and depletion of marine ecosystem capital, i.e. the biotic constituent of marine natural capital, and occur within the current limits of marine ecosystems.
Prospects of meeting policy objectives/targets for 2020	2020	The EU maritime policy's contribution to achieving sustainable growth, as required by the Europe 2020 strategy, is unlikely to be realised, in view of the current, generally poor, condition of marine ecosystems — part of the resource on which it relies and/or impacts. Progress has been made in achieving a fishing mortality rate and/or reproductive capacity compatible with having population biomass levels above those capable of producing maximum sustainable yield for a significant number of commercially exploited fish and shellfish stocks in the North-East Atlantic Ocean and the Baltic Sea. But the 2020 objective of the common fisheries policy that requires that all stocks across all EU marine regions are exploited at such a rate is unlikely to be met.
Robustness	There is large variation in the availability of data and information across maritime sectors and EU marine regions, and data gaps remain. The available outlook information is limited, so the assessment of outlooks relies primarily on expert judgement, supported by certain findings from the literature.	

The EU's maritime economy, often referred to as the 'blue economy', is a powerful driver of socio-economic growth and has some untapped potential. It is projected that many ocean-based industries will outperform the global economy by 2030, in terms of both added value and employment (EC, 2017a). Coastal and maritime activities include traditional/established sectors, such as fishing, shipping, tourism, aquaculture and the extraction of non-living resources (e.g. oil and gas, marine aggregates), as well as emerging sectors, such as offshore renewable energies, desalination, blue biotechnology and the extraction of mineral resources specifically in the deep sea (EC, 2015b, 2014, 2017a). All these sectors use the natural capital held in Europe's seas one way or another.

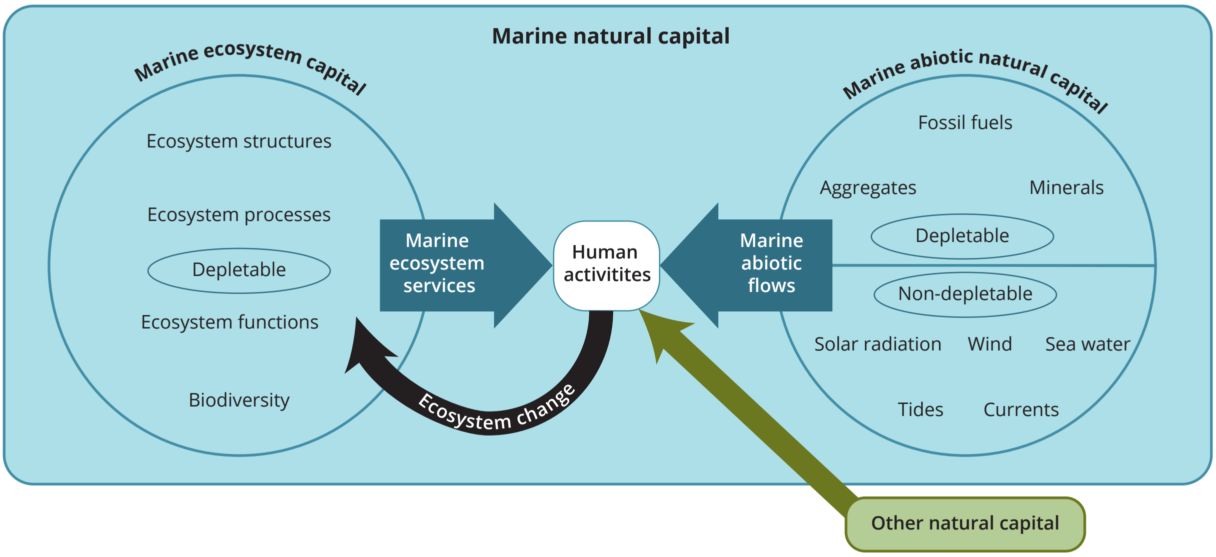
2.1 The natural capital held in Europe's seas

The biotic and abiotic assets of the marine environment constitute the natural capital held in Europe's seas, i.e. 'marine natural capital'. Part of this capital is depletable, such as marine ecosystems and the services they can supply to people. These latter assets make up marine ecosystem capital, which is the **biotic** constituent of the natural capital held in the sea. The **abiotic** constituent of this capital is made up of non-living marine assets, such as fossil fuels; geophysical assets, such as solar radiation, wind and currents; and tides (Figure 2.1; Figure 2.4) (Maes et al., 2013).

Marine ecosystem services are the final outputs of marine ecosystems that are directly consumed, used or enjoyed by people (EEA, 2015b; Fisher et al., 2008; Haines-Young and Potschin, 2013, 2016, 2018; Maes et al., 2013). They include food, building materials, medicines, energy and opportunities for leisure, as well as less tangible outputs, such as limited coastal erosion and seawater pollution.

These final outputs are generated through the normal functioning of marine ecosystems, which is underpinned by their strucutre and functioning. The structural and biological components of the ecosystem, i.e. marine biota in their habitats, generate these outputs by just being there (Figure 2.2; Table A1.1). Marine biota can also generate these outputs by interacting with their surrounding environment, for

Figure 2.1 The constituents of marine natural capital



Notes: There is no clear-cut boundary between the 'biotic' and 'abiotic' constituents of marine natural capital because, for example, sand is the substrate of many marine habitats (ecosystem structures). However, this distinction helps to identify and classify such categories, which is important in the context of assessing the condition of marine ecosystems and managing human activities using the concept of marine natural capital.

Marine ecosystems (CBD, 2004) and their services, such as fossil fuels, aggregates, minerals and any other geological deposits, are depletable. Seawater, salt, tides and geophysical assets, such as wind, currents and global solar radiation (which is constant above the atmosphere and hence considered to be a stable asset), are non-depletable.

'Ecosystem change' refers to the physical, chemical and biological impacts on marine ecosystems resulting from human activities drawing on marine and other natural capital.

'Other natural capital' refers to that held in terrestrial and freshwater environments.

Source: Modified from EEA (2015b).

example using physico-chemical elements (such as nutrients, light, and carbon) or feeding on other biota, i.e. through the ecological processes (e.g. photosynthesis) and functions (e.g. primary and secondary production) in which they are involved (Figure 2.2, Table A1.1). When used by people, these final outputs become marine ecosystem services and provide us with a series of important benefits, including nutrition and enhanced physical, mental and emotional health, as well as supporting livelihoods and the economy (Figure 2.2; Box A1.1) (Culhane et al., 2019).

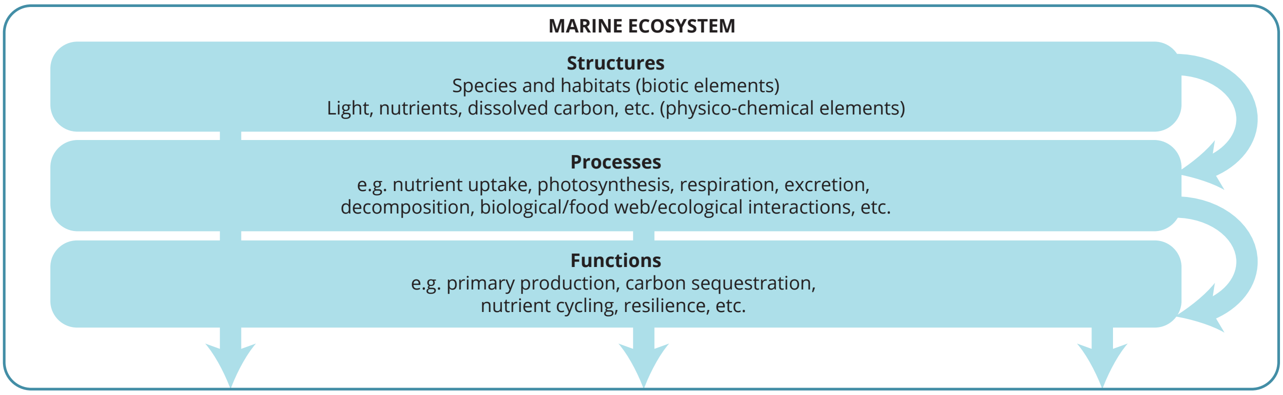
2.2 The blue economy — a major user of Europe's seas

There is no agreed classification of the blue economy sectors and related coastal and maritime activities across different pieces of EU policy, although efforts have been made on behalf of the European Commission to collect relevant EU data and information (e.g. the European Marine Observation and Data Network, EMODnet). *Marine messages II* builds upon those efforts, while retaining policy relevance and environmental linkages. The classification adopted here uses the annual economic reports on the EU blue economy (EC, 2019e) as a basis and builds on them by grouping and aligning coastal and maritime activities with those activities deemed relevant in EU environmental policy, namely the Marine Strategy Framework Directive (MSFD) (Annex III), as well as the Maritime Spatial Planning Directive (MSPD). The resulting groups (themes or sectors) are as follows: extraction of non-living resources, living resources, production of renewable energy, maritime transport, coastal tourism and leisure, and the public sector (Figure 2.3).

With the available data and information at hand, it can be estimated that in 2017 the EU's maritime economy generated EUR 216 247 million in gross value added (GVA), representing 1.6 % of the total EU economy, and employed roughly 4.9 million people (based on the GVA of all economic activities based on prices for the year 2017) (Eurostat, 2019e).

The subsections below provide a short description of each of the sectors above, including key economic information (Table 2.1) and a general overview of their pressures and impacts on Europe's seas. More

Figure 2.2 Marine ecosystem services and examples of their benefits for people



MARINE ECOSYSTEM SERVICES

Provisioning	Regulation and maintenance	Cultural
· Seafood and other nutritional outputs from in-situ aquaculture of plants and algae · Raw materials from in-situ aquaculture of plants and algae · Biofuels from in-situ aquaculture of plants and algae · Seafood and other nutritional outputs from in-situ aquaculture of animals · Raw materials from in-situ aquaculture of animals · Biofuels from in-situ aquaculture of animals · Seafood and other nutritional outputs from in-situ aquaculture of wild plants and algae · Raw materials from in-situ aquaculture of wild plants and algae · Biofuels from in-situ aquaculture of wild plants and algae · Seafood and other nutritional outputs of wild animals · Raw materials from wild animals · Biofuels from wild animals · Genetic materials from plants and algae: seeds and spores · Genetic materials from plants and algae: whole organisms · Genetic materials from plants and algae: genes · Genetic materials from animals: spat and gametes · Genetic materials from animals and micro-organisms: whole organisms · Genetic materials from animals and micro-organisms: genes	· Anthropogenic waste and toxicant treatment via biota · Anthropogenic waste and toxicant removal and storage · Smell reduction · Reduction of visual impacts · Erosion prevention and sediment retention · Flood protection · Seed and gamete dispersal · Maintaining nursery populations and habitats · Gene pool protection · Pest control · Disease control · Sediment nutrient cycling · Chemical condition of sea water · Global climate regulation · Oxygen production	· Recreation and leisure · Scientific · Educational · Heritage, cultural · Aesthetic · Symbolic · Sacred and/or religious · Entertainment · Existence · Bequest

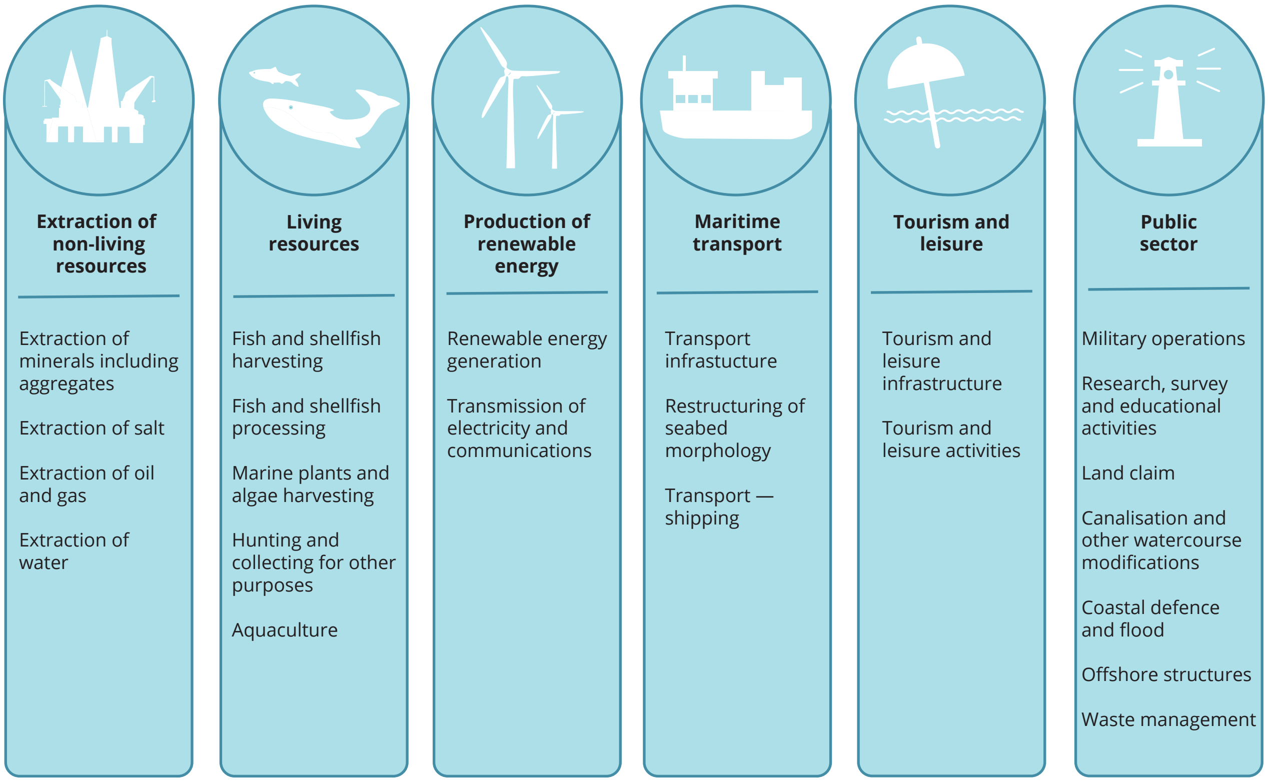
EXAMPLES OF BENEFITS

· Nutrition (from seafood and seafood supplements) · Maintaining food production (via e.g. fish, feed, aquaculture seed and fertiliser) · Maintaining and enhancing health (from e.g. pharmaceutical products and food supplements) · Beauty gains (from e.g. ornaments and cosmetic products)	· Natural cleaning of sea water and sediments · Removal of unpleasant smells and visual nuisances · Erosion prevention · Sea defence (against floods) · Breathable air (via oxygen production) · Maintaining physical health (via e.g. pest and disease control) · Habitable ambient climate	· Enhanced physical, emotional or mental health · Visual and other sensorial enjoyment · Relaxation · Touristic gains · Knowledge gains · Maintaining heritage · Cultural/spiritual/religious fulfilment · Art and design inspiration · Solace/comfort

Note: Marine ecosystem services are based on the ecosystem (biotic) service 'classes' in the hierarchy of the Common International Classification of Ecosystem Services (CICES) version 5.1; original service names have been simplified and adapted to a marine context where needed.

Source: Modified from Culhane et al. (2019).

Figure 2.3 Marine messages II classification of EU coastal and maritime activities



detail on the latter is found in Chapters 3 and 4 of this report. Chapter 3 considers impacts from the point of view of the state of key species groups (e.g. fish, marine mammals) and seabed habitats and provides a spatial assessment of the overall condition of marine ecosystems. Chapter 4 includes a summary of a spatial assessment of the combined effects of several pressures (e.g. nutrient loads, contaminant inputs and introduction of non-indigenous species) from human activities.

2.2.1 Non-living resources

The extraction of non-living resources sector includes activities related to the mining of marine minerals and aggregates, as well as the extraction of salt, oil, gas and seawater for desalination. Overall, these activities generated EUR 22 881 million in GVA and employed an estimated 166 000 people in 2017 (COGEA et al., 2017; EC, 2019e) (Table 2.1).

Trends for this sector in the EU vary between activities. For example, the extraction of marine minerals is expected to expand in the future because, in the coming decades, the world's precious metals, including cobalt, copper, zinc and rare Earth metals, are expected to increasingly come from the sea floor (Table 2.1). Extraction of aggregates such as gravel is expected to decrease in the future (EC, 2019e). No EU-wide information is available for sand extraction. Meanwhile, salt production in the coming decade is expected to continue to move away from the EU to the Middle East, Asia-Pacific and South America, due to available land, transfer of technologies and less stringent political conditions (Table 2.1) (Sedivy, 2017). A key aim of seawater extraction is desalination, which produces freshwater for drinking or irrigation purposes (Veerapaneni et al., 2007; Parise, 2012). As desalination occurs predominantly in EU Member States with limited access to freshwater, such as Cyprus, Greece, Italy, Malta, Portugal and Spain, it is likely that desalinated water will become a competing alternative to potable water production (Table 2.1) (IWA, 2016). Seawater is also used for cooling coastal power plants.

The main activity of oil and gas extraction is expected to continue its declining trend in Europe's seas (Table 2.1). This relates to the fact that offshore oil and gas reserves in EU waters are declining, rather than the demand for them. Thus, though considered important as a transitional fuel, offshore oil and gas production in the EU is expected to decrease significantly to 21.7 million tonnes of oil (-88 %) and

Table 2.1 **EU coastal and maritime activities, their estimated economic value (GVA), number of people employed, expected future trends, current (main) dependence on marine natural capital constituents and current (main) pressure on marine natural capital constituents (years vary)**

Theme ('sector')	Activity	GVA (EUR million)	Employment (thousands); % (of total employees)	Expected trends (a)	Main dependence on		Main pressure on	
					Marine abiotic natural capital	Marine biotic natural capital	Marine abiotic natural capital	Marine biotic natural capital
Extraction of non-living resources	Extraction of minerals, including aggregates (b) (c)	5 660 (2.5 %)	100.6 (2.1 %)	GVA: → Empl: →	✓		✓	✓
	Extraction of salt (c)	40 (< 1 %)	0.7 (< 1 %)	GVA: → Empl: →				
	Extraction of oil and gas (b)	17 181 (7.6 %)	62.8 (1.3 %)	GVA: ↘ Empl: ↘				
	Extraction of water (d)	–	3.8 (< 1 %)	GVA: ↗ Empl: ↗				
Living resources	Fish and shellfish harvesting (b)	4 622 (2 %)	151.2 (3.1 %)	GVA: ↗ Empl: ↘	✓	✓		✓
	Fish and shellfish processing (b)	14 062 (6.2 %)	347.5 (7.1 %)	GVA: ↗ Empl: →				
	Marine plant and algae harvesting	–	–	–				
	Hunting and collecting for other purposes (d) (e)	9 (< 1 %)	17 (<1 %)	GVA: ↗ Empl: ↗				
	Aquaculture (b)	2860 (1.3 %)	74.9 (1.5 %)	GVA: ↗ Empl: ↘	✓	✓		✓
Production of renewable energy	Renewable energy generation (c) (d)	684 (< 1 %)	185.3 (3.8 %)	GVA: ↗ Empl: ↗	✓		✓	✓
	Transmission of electricity and communications (f)	185 (< 1 %)	–	GVA: ↗ Empl: ↗				
Maritime transport	Transport infrastructure (b)	31 215 (13.8 %)	508.9 (10.4 %)	GVA: ↗ Empl: ↗	✓		✓	✓
	Restructuring of seabed morphology (b)	3 225 (1.4 %)	65.2 (1.3 %)	GVA: ↘ Empl: ↘				
	Transport — shipping (b)	45 837 (20.3 %)	719.9 (14.8 %)	GVA: ↗ Empl: →				
Coastal tourism and leisure	Tourism and leisure infrastructure	–	–	–	✓	✓		✓
	Tourism and leisure activities (b)	69 423 (30.7 %)	2 267.0 (46.5 %)	GVA: ↗ Empl: ↗				

Table 2.1 EU coastal and maritime activities, their estimated economic value (GVA), number of people employed, expected future trends, current (main) dependence on marine natural capital constituents and current (main) pressure on marine natural capital constituents (years vary) (cont.)

Theme ('sector')	Activity	GVA (EUR million)	Employment (thousands); % (of total employees)	Expected trends ([a])	Main dependence on		Main pressure on	
					Marine abiotic natural capital	Marine biotic natural capital	Marine abiotic natural capital	Marine biotic natural capital
Public sector	Military operations (c)	28 769 ([g]) (12.7 %)	360.7 (7.4 %)	GVA: ↗ Empl: ↘				
	Research, survey and educational activities	–	–	–				
	Land claim (c)	1 390 ([g]) (< 1 %)	5.7 (<1 %)	GVA: ↗ Empl: →				
	Canalisation and other watercourse modifications	–	–	–	✓	✓	✓	✓
	Coastal defence and flood protection (c)	1 145 ([g]) (< 1 %)	5.4 (< 1 %)	GVA: ↗ Empl: →				
	Offshore structures	–	–	–				
	Waste treatment and disposal	–	–	–				
TOTAL		**226 307**	**4 876.5**					

Notes: ([a]) Trends are a best estimate based on available sources and expert opinion.

([b]) Data extracted from the EU's Blue Indicators Tool (EC, 2019a) on 29 May 2019, but for the 'extraction of oil and gas', the International Association of Oil and Gas Producers (IOGP) estimates 'well above 500 000 jobs' (personal communication, 2019, unpublished data).

([c]) Data extracted from COGEA et al. (2017).

([d]) Estimate taken from the European Commission (EC, 2019e).

([e]) Estimate taken from the European Commission (EC, 2016a).

([f]) Data extracted from Douglas-Westwood Limited (2005).

([g]) Data represents public expenditure (EUR million) in 2014, extracted from COGEA et al. (2017).

135 million tonnes of oil equivalent in 2050 (-21 %), respectively (DNV GL, 2017). In addition, as the EU committed to the Paris Agreement of 2015 to limit the extent of the climate emergency, a dramatic reduction in the use of hydrocarbons and a boost in the use of alternative energy sources, such as solar and wind power should take place. This is even if Europe remains an attractive region for oil and gas producers (IOGP, personal communication, 2019). In contrast, the focus in China and Russia is on increasing the marine fleet of nuclear reactors for the generation of electricity and geo-political positioning (McDonald, 2016; The Barents Observer, 2019).

Pressures caused by the extraction of non-living resources can deplete marine abiotic resources and impact marine ecosystems. Examples of the latter include the direct removal and/or smothering of marine habitats and species caused by the underwater plumes resulting from the extraction of minerals and aggregates. Salt extraction impacts coastal areas where salt ponds are built and can cause increased local soil salinity and hypersaline run-off, which affect terrestrial and marine species and habitats (Wolchok, 2006). Oil and gas extraction may generate numerous pressures, including contamination (Tornero and Hanke, 2016), physical loss and disturbance to seabed habitats, and underwater noise (Ellis et al., 2012; Cordes et al., 2016; Vad et al., 2018). The extraction of water for desalination involves pressures such as changes to the hydrographical conditions, contamination and deoxygenation. These pressures relate to the brine from desalination plants, which consists of warm, highly salinised water.

2.2.2 Living resources

The extraction of living resources sector includes activities related to fish and shellfish harvesting and processing, aquaculture, marine plant and algae harvesting (or their outputs), hunting, and collecting marine biota for other purposes (e.g. biotechnology). Overall, these activities generated EUR 21 553 million in GVA and employed an estimated 591 000 people in 2017 (Table 2.1).

Trends in the production (wild capture) and cultivation (aquaculture) of marine living resources show a general increase in terms of generated GVA, although employment numbers are more uncertain. Marine aquaculture in EEA countries increased by 198 % from 0.855 million tonnes in 1993 to 2.548 million tonnes in 2015 (EEA, 2019a). Conversely, wild capture of fish decreased from 6.483 million tonnes in 2000 to 5.145 million tonnes in 2015, a fall of 21 % over this period (Eurostat, 2019a). The combined growth rate of wild capture fish and shellfish and marine aquaculture in the EU between 2013-2015 and 2025 is expected to be modest, with a 2.3 % increase (Table 2.1). However, aquaculture on its own is expected to have a growth of 8.9 % during this period (Table 2.1) (FAO, 2018). Movement towards offshore aquaculture as opposed to coastal production may take place, driven by the scarcity of coastal space, new technological developments (e.g. submersible cages) and the potential to utilise offshore wind farms as production areas (EC, 2016a).

The extraction of living resources causes biological pressure and impacts marine ecosystems. Commercial fishing, which aims to maximise the amount of fish and shellfish caught, impacts the populations of the target species (by their removal, changing age structures, etc.) and can also result in by-catch, which impacts non-target fish and shellfish and populations of other species, e.g. turtles and dolphins (EEA, 2015b). It, therefore, also influences the structure of marine food webs.

The fishing mortality rate (i.e. fishing pressure) and reproductive capacity (i.e. spawning stock biomass) of the populations of all commercially exploited fish and shellfish species across all EU marine regions need to be compatible with having biomass levels above those capable of producing maximum sustainable yield ([1]) (MSY) by 2020 as required by the MSFD (EU, 2017b). This objective, which is partly shared by the common fisheries policy (CFP) (EU, 2013), is unlikely to be met (Table 4.1) (EEA, 2019e). Despite being the most heavily fished regions, the North-East Atlantic Ocean and the Baltic Sea have been showing progress towards achieving this 2020 goal due to reductions in fishing pressure, but the Mediterranean Sea and the Black Sea remain highly overfished. Thus, 62.5 % and 82.3 %, respectively, of the assessed stocks in the Baltic Sea and the North-East Atlantic Ocean populations met at least one of those two criteria in 2017, compared with only 6.1 % in the Mediterranean Sea and 14.3 % in the Black Sea in 2016 (EEA, 2019e).

Bottom-trawling activities can cause physical loss or disturbance of seabed habitats, including through abrasion and smothering (EEA, 2015b; Piet and Royo-Gelabert, 2019). Impacts from commercial fisheries can be exacerbated by fishing quotas not always being set according to scientific advice (Carpenter, 2018) and by certain fishing subsidies, e.g. those contributing to fleet overcapacity (Birdlife Europe et al., 2019). There are also impacts from illegal, unreported and unregulated fishing, which, despite legislation to prevent it (EU, 2008a), still takes place in EU marine waters (Europol, 2018; Folketinget Rigsrevisionen, 2018; Guardia Civil, 2019).

For aquaculture, the cultivation of carnivorous finfish in open sea-cage systems places pressure on marine ecosystems. The reared fish require external inputs, such as feed and medicines, which pollute the local ecosystem. The degree of pollution depends on the species being cultivated, the quality of the feed and the medicines used. The cultivation of shellfish tends to involve fewer pressures because they require less or no external inputs (Rurangwa et al., 2016; IFFO, 2013).

2.2.3 Production of renewable energy

The marine renewable energy production sector includes activities related to offshore wind, wave, tidal, thermal and other ocean energy production, as well as the transmission of electricity and communications. Overall, these activities generated EUR 869 million in GVA and employed an estimated 185 000 people in 2017 (Douglas-Westwood Limited, 2005; COGEA et al., 2017; EC, 2019e) (Table 2.1).

([1]) Maximum sustainable yield is the highest catch that can be safely taken year after year while maintaining the fish population size at maximum productivity (EC, 2011).

For wind energy, most offshore wind farms are located in the North Sea and the Baltic Sea (GWEC, 2017; WindEurope, 2019). The sector shows increasing trends in offshore wind farm abundance, size, capacity and distance from shore. Projections for 2020 predict 43 000 MW of total installed capacity of offshore wind, generating roughly 3 % of the EU's total electricity consumption (EC, 2014b). Offshore wind grew 18 % in 2018 and is expected to keep on growing, reaching up to 100 GW in 2030, according to the most ambitious scenario (Table 2.1) (WindEurope, 2019). Tidal, wave, thermal and other ocean energy is harnessed using technologies and built infrastructure that capitalises on the kinetic, temperature and salinity properties of the ocean (Eurostat, 2018a). Unlike other renewable energies, ocean energies are predictable, dependable and capable of producing a constant supply of electricity (Schweitzer, 2015). Although contentious, some projections predict that the installed ocean energy capacity in the EU will reach 3 600 MW by 2020 (EU, 2016), while others predict 665 MW by 2020 (JRC, 2016). As offshore renewable energies continue to grow, more and longer cables and pipelines will be needed to reach the more distant offshore wind farm sites (COGEA et al., 2017).

The generation of ocean energies can prevent other uses due to their demand for space, and can impact marine ecosystems, including by the introduction of electromagnetic energy, the physical loss and disturbance of seabed habitats and killing marine species. The latter is due to the construction and operation of the relevant infrastructure (e.g. turbine bases, barrages for tidal energy, or the laying down of subsea cables and pipelines), which can impact marine species by, for example, establishing barriers, emitting noise pollution, providing pathways for invasive species, and endangering marine mammals via rotating tidal turbines or entanglement in lines (Frid et al., 2012; Langhamer, 2012; Schweitzer, 2015; Eurostat, 2018a). Wave and tidal energy structures induce changes to the prevailing hydrographical conditions (e.g. wave exposure), which can then alter the flow of sediments and the feeding conditions for coastal bird species and fish (Frid et al., 2012). However, such constructions can also provide some benefits, including the creation of new habitat areas, the extension of feeding times for both bird and fish species, and closing the area to trawling (associated with the presence of submerged cables and pipelines) (Frid et al., 2012; Vaissière et al., 2014; Carter and Burnett, 2015; NIRAS, 2015).

2.2.4 Maritime transport

The maritime transport sector includes activities related to transport infrastructure development and maintenance, restructuring of seabed morphology (maintenance of shipping lanes), and shipping. Overall, these activities generated EUR 80 277 million in GVA and employed an estimated 1 294 000 people in 2017 (EC, 2019e) (Table 2.1).

Transport infrastructure relates to activities in ports, such as cargo handling and warehousing and storage, as well as related service activities. With more than 1 200 commercial ports in the EU's 23 coastal Member States, these key nodes of the global trade network handle around 75 % of the EU's cargo trade with third countries and over 33 % of intra-EU freight transport (ECA, 2016). In 2017, roughly 3 961 million tonnes of goods and commodities were handled in EU ports, while passenger visits amounted to over 414 million (EEA, 2016b; Eurostat, 2019b, 2019c).

Short sea shipping (covering relatively short distances within a continent, in contrast to intercontinental, cross-ocean deep sea shipping (EC, 1999), is the main maritime transport mode for the EU coastal Member States, with over 1 864 million tonnes of goods handled in the EU in 2017, a slight increase (0.5 %) from 2016 (EC, 2015a; Eurostat, 2019d). Overall, the sector has remained relatively stable, but it is expected to increase by about 2 % annually in the Baltic Sea and in the Mediterranean Sea, while the North Sea and, more widely, the North-East Atlantic Ocean are expected to have the lowest increases in short sea shipping in the future (Table 2.1) (EC, 2015a).

Although vital for economic and social well-being, the maritime transport sector puts pressure on marine abiotic natural capital, including preventing other uses and impacting marine ecosystem capital (Oral et al., 2008). The construction and modification of ports can cause physical loss of coastal habitats, as land reclamation and land use can seal or smother/destroy coastal habitats (Boteler et al., 2012; Dalgaard et al., 2015). The operation and maintenance of ships can introduce anti-fouling paints, marine litter and other emissions into marine ecosystems, and can produce low-frequency underwater noise and emit air pollutants, such as carbon dioxide, nitrogen oxides, sulphur oxides and particulate matter (Oral et al., 2008; HELCOM, 2010b; Boteler et al., 2012; Viana et al., 2014; Dalgaard et al., 2015). Maritime transport can cause biological pressure by, for example, introducing non-indigenous species (Piet et al., 2011; Dalgaard et al., 2015; EEA, 2015b).

2.2.5 Tourism and leisure

The coastal tourism and leisure sector include activities related to the establishment and running of infrastructure, as well as to accommodation, transport, the retail sale of goods and other expenditure. The latter three sub-sectors generated EUR 69 423 million in GVA and employed an estimated 2 267 000 people in 2017 (EC, 2019e) (Table 2.1). Tourist expenditure in those sub-sectors is associated with beach and coast-based activities, such as swimming and coasteering, and water-based or sporting activities, such as sailing, scuba-diving, recreational fishing, cruising and marine wildlife watching (EC, 2019e).

As the coastal tourism infrastructure sub-sector is linked to various other sectors (e.g. construction, hospitality and port management), it is difficult to estimate the GVA and employment numbers associated with it (hence no information is provided in Table 2.1).

The EU received over 482 million of over 1 240 million international tourist arrivals worldwide (EU and non-EU tourists) in 2016 (WTO, 2018; Eurostat, 2018b). Coastal areas are very popular tourist destinations and are where nearly half (46 %) of all nights spent in tourist accommodation tend to occur (Onofri and Nunes, 2013). Coastal tourism is expected to grow in the coming years as more people, both within the EU and internationally, spend increasing portions of their income travelling (Table 2.1). Expected visitors to coastal areas are estimated to increase by 2-3 % in 2020, with increases in coastal tourists ranging between 504 million and 531 million people (Ecorys, 2013; EC, 2016b). Global growth projections for the cruise shipping industry expect 30 million passengers for 2019, with increasing interest from younger generations (CLIA, 2019).

Growth in the industry will require additional public service support and physical infrastructure in and around the EU's coastline to cope with more visitors (e.g. roads, airports, hospitals, hotels, sanitation and waste disposal, port facilities, restaurants and supermarkets).

Pressures generated by coastal tourism and leisure activities include physical disturbance and loss of seabed habitats as well as the disturbance of coastal and marine species. The development of coastal tourism infrastructure can occur on previously undisturbed areas, replacing natural habitats with artificial surfaces (WWF, 2018) and thereby impacting species dependent upon such areas. Coastal tourism is a key source of coastal litter, while cruise tourism contributes to marine-based litter (Interwies et al., 2013; Carić and Mackelworth, 2014). Marine litter has been shown to have multiple negative effects on marine biodiversity, ranging from its ingestion by species and their entanglement in it to their consumption of microplastics and the toxic substances released from the degradation of plastics (Dias, 2016). Coastal tourism also generates underwater noise, from both recreational boating and cruise ships, which disturbs the social behaviour of marine mammals and threatens their lives through accidental collisions (Rako et al., 2013; Carić and Mackelworth, 2014). Other pressures from coastal tourism include emissions of waste and pollutants to seawater (e.g. from waste water treatment plants) and air emissions from cruise ships (Carić and Mackelworth, 2014; NOAA, 2018).

2.2.6 Public sector

The public sector includes activities related to military operations; research, survey and education; land claim; canalisation and other watercourse modification; coastal defence and flood protection; offshore structures; and waste treatment and disposal. Overall, these activities generated EUR 31 305 million in GVA and employed an estimated 372 000 people in 2017 (EC, 2019a, 2019e) (Table 2.1).

The security and defence sector include defence and training operations in the marine environment. It is expected that the current declining trend in government expenditure will be reversed in the coming years due to recent geo-political developments (Table 2.1) (EC, 2019e). The same increasing trend is expected for education and research in the domain of marine and maritime sciences (Table 2.1) (MareNet, 2003). The EU dedicated over EUR 238 million for maritime research under the Horizon 2020 programme for the funding period 2018-2020 (EC, 2018b).

Public coastal protection consists of measures to protect the EU's coasts from floods and erosion, such as dune and cliff stabilisation through construction of seawalls, dikes, revetments and bulkheads (Mangor et al., 2017), as well as the use of nature-based solutions, such as restoring coastal wetlands due to their role in reducing coastal flooding (Möller, 2019). Rising extreme sea levels linked to anthropogenic climate warming and continued socio-economic development in coastal zones will lead to an increasing future flood risk along the EU coastline, requiring increased public expenditure to minimise it (Table 2.1). Flood defence structures need to be installed or reinforced to withstand increases in rising extreme sea levels that range from 0.5 m to 2.5 m by 2100 to keep future coastal flood losses constant relative to the size of the economy. Otherwise, and in the absence of further investments in coastal adaptation, the expected annual damages of EUR 1.25 billion under present climate conditions is projected to increase by two to three orders of magnitude by the end of the century, ranging between EUR 93 billion and EUR 961 billion (in today's money). The magnitude of the difference in the projections is due to not only the climate scenario but also the socio-economic scenario used (Vousdoukas et al., 2018).

Waste management focuses on measures taken by public authorities in order to prevent untreated or partially treated urban waste water being discharged directly into the marine environment, such as compliance with the EU Urban Waste Water Treatment Directive (EU, 1991). However, these measures are not always implemented and/or successful (ECJ, 2018). Thus, the sector faces several challenges, such as insufficient capacity at peak times of the year, inadequate treatment types (ECJ, 2018) and control (or lack thereof) of contaminants (EEA, 2018a). Waste water effluent contains pharmaceutical residues, as treatment plants are not designed to remove the increasing amount of pharmaceuticals contained in waste water (Hofman, 2019). Other challenges include control of micropollutants, impacts of anthropogenic climate change on waste water treatment, the correct pricing of water services and lack of public understanding (ÖWAV, 2019). Regarding micropollutants, waste water effluent also contains microplastics (Kay et al., 2018) and so does sewage sludge (the by-product of waste water treatment) (Kay et al., 2018; UKWIR, 2019). The latter can be used as a fertiliser and would, thus, remain in the aquatic environment through agricultural land run-off, etc. (Kay et al., 2018).

Public sector activities can put pressure on marine abiotic resources, including preventing other uses, and have an impact on marine ecosystem capital. The latter is affected by, for example, changing wave exposure; emitting pollution, including underwater noise; causing physical loss and disturbance of seabed habitats, changing suspended solids and siltation rates; producing litter; being a barrier to species movement; causing death or injury by collision; creating visual disturbance; introducing or spreading non-indigenous species, and introducing microbial pathogens. Relating to security and defence, one major concern is dumped munitions, e.g. from the First World War and from the 1950s and 1960s, potentially leaking toxic substances into the marine environment.

2.3 The blue economy can be sustainable only when Europe's seas are clean, healthy and productive

There are clear linkages between human activities, pressures, marine ecosystems, marine ecosystem services and the benefits we get from these services (White, et al., 2013; Gomez et al., 2017; Ivarsson et al., 2017). Pressures on Europe's seas, from sea- and land-based human activities, are driven by our socio-technical systems, which require continuous inputs of marine (and other) ecosystem services and marine (and other) abiotic flows to run (Figure 2.4). In addition, the running of these systems gives rise to undesirable outputs, such as polluting emissions, waste and energy (e.g. sound), which also put pressure on and impact marine ecosystems, including through anthropogenic climate change (EEA, 2017) and atmospheric deposition (EEA, 2018a) (Figure 2.4).

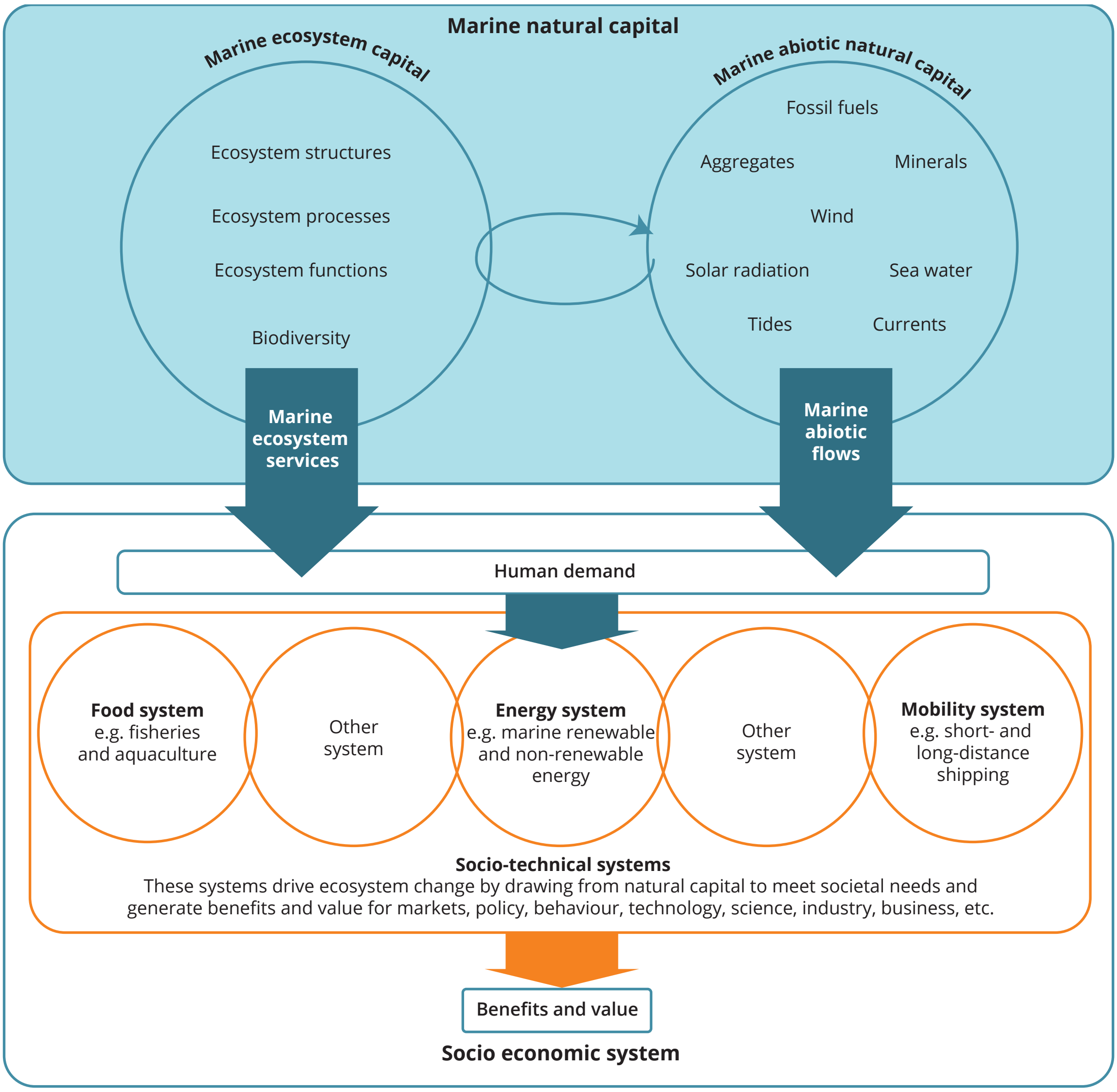
All these inputs and outputs can lead to physical, chemical and biological impacts on marine ecosystems, i.e. to ecosystem change (Figure 2.1; Figure 2.4), degrading their condition and eroding their resilience. In contrast, the sustained supply of marine ecosystem services is based on the self-renewal of marine ecosystems, which occurs naturally if marine ecosystems are used, or affected, within their ecological limits. The degradation of marine ecosystem structures, processes and functions impairs marine ecosystem capacity for service supply. As a result, the marine ecosystem services, and associated benefits, upon which people and the economy depend are not sustained over time (Figure 2.1; Figure 2.2; Table A1.1, Box A1.1) (Culhane et al., 2019).

The European Commissioner for Environment, Maritime Affairs and Fisheries, Karmenu Vella, stated in 2018, 'The EU's blue economy is consistently growing over the last decade and the potential for the future is promising. With investments in innovation and through responsible ocean management, integrating environmental, economic and social aspects, we can double the sector in a sustainable way by 2030' (EC, 2018a).

Because maritime activities depend on the natural capital held in Europe's seas, it is vital that they all use this capital sustainably, so that marine **ecosystem** capital, on which a subset of these activities depends, can be maintained. It is important to note that a greater range of pressures are exerted on marine ecosystems indirectly by human activities using marine abiotic natural capital than by those activities using marine ecosystem services directly (Table 2.1) (EEA, 2015b). Therefore, to be sustainable, as required by the EU 2020 strategy (EC, 2010), the blue economy needs to be compatible with having fully functioning marine ecosystems, i.e. marine ecosystems in a condition capable of both sustaining economic activities at sea that rely on marine living resources and maintaining ecosystem resilience. This can only be achieved by decoupling the use of marine natural capital from the impacts on marine ecosystem capital.

The sustainable use of natural capital and the maintenance of ecosystem capital are enshrined,

Figure 2.4 The constituents of marine natural capital in a socio-economic context



Notes: • 'Ecosystem change', caused by the inputs and outputs from running our socio-technical systems, includes change resulting from the use of natural capital other than marine, i.e. that held in terrestrial and freshwater environments — even if not shown in the right-hand side of the figure (but shown in Figure 2.1).

Source: Modified from EEA (2015b).

to a greater or lesser extent, in several pieces of EU legislation and policy. This is the case for high-level policy, such as the EU biodiversity strategy (EC, 2011), in particular its target 2, and the Seventh Environment Action Programme ([2]) (EC, 2013).

This is also the case for policy instruments that are specific to marine ecosystems, such as the MSFD, the Water Framework Directive (WFD), the Birds Directive and the Habitats Directive, as well as the integrated maritime policy, implemented, for example, through the common fisheries policy (CFP) and the Maritime Spatial Planning Directive (EEA, 2015b, 2019f). These instruments can require that the marine biota, habitats and/or ecosystems are in a certain condition (e.g. 'good') and/or that the pressures upon them

([2]) The Seventh Environment Action Programme employs a different terminology to that used in EU-level reference guidance documents on natural capital, e.g. Maes et al. (2013), and also here, e.g. in Figure 2.1, as it uses the term 'natural capital' as a synonym for 'ecosystem capital'.

stay within certain limits. In addition, several of these instruments, such as the WFD, the MSFD and the CFP, promote the management of human activities in the marine environment following an ecosystem-based approach rather than the traditional narrow focus on single sectors, pressures or certain marine biota and/or habitats (Box 1.1).

The general degradation of marine ecosystems observed in the *State of Europe's seas* (EEA, 2015b) continues (EEA, 2018a; IPBES, 2018; IPCC, 2019; IUCN, 2019). This is confirmed in the summary of assessments included in *Marine messages II*. It means that the way we use the natural capital held in Europe's seas does not appear to be sustainable, as has previously been concluded (EEA, 2015b). Past maritime activities have contributed to this situation by causing, for example, loss and disturbance of seabed habitats and the widespread overexploitation of commercial fish and shellfish stocks. These impacts are many and challenge the sustainability of the blue economy that the EU and its Member States call for.

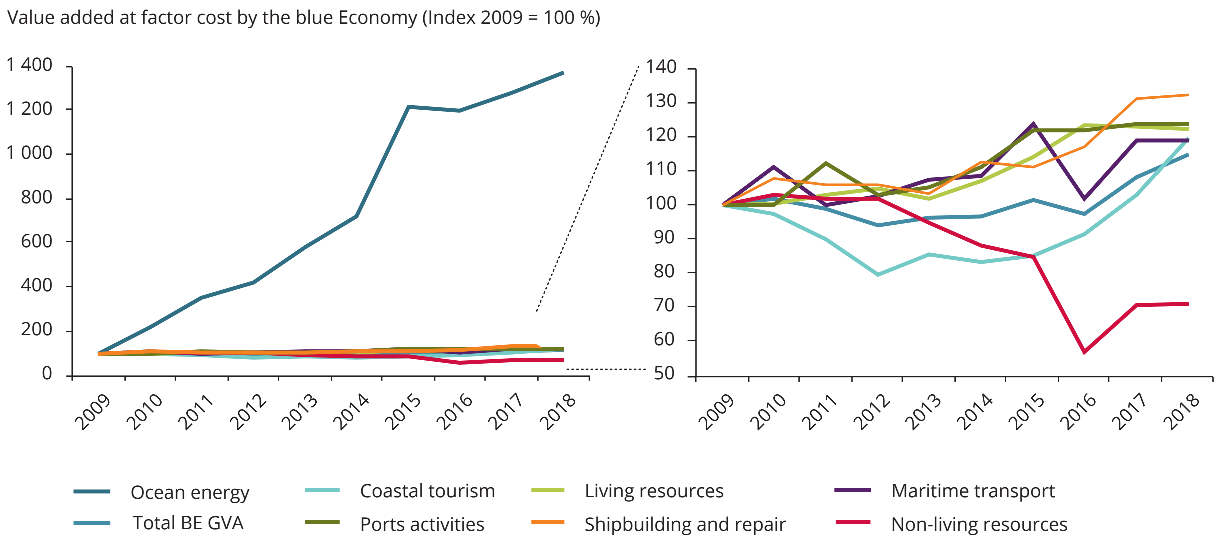
More and more industries and people have been turning their attention to the natural capital held in Europe's seas. There has been a generally increasing trend in their use by some maritime (sub)sectors in the period 2009-2017, such as finfish aquaculture, wind energy production and coastal tourism (Figure 2.5), and this growth is expected to continue for several (sub)sectors (Table 2.1). For example, the deployment of offshore wind energy has increased 10-fold since 2009 and is expected to quadruple between 2020 (up to 24.5 GW) and 2030 (up to 100 GW) in the most ambitious scenario (WindEurope, 2019).

If the blue economy is to double in the next decade (EC, 2018a), the number of activities as well as their overall size and intensity are expected to further increase. As current challenges and competition for resources and space increases, so will the pressures and their combined effects on the marine environment and its ecosystems. This is likely to exacerbate the, generally, current poor condition of marine ecosystems, increasing the degradation of ecosystem structures, processes and functions and further impairing their capacity to supply ecosystem services. In addition, increased demands and impacts on marine ecosystems will, ultimately, undermine their stability and resilience. This is unless the management of maritime activities respects the current ecological limits of marine ecosystems in the context of an ecosystem-based approach. Achieving sustainability would, inter alia, require that:

1. Maritime sectors contribute to halt the degradation of marine ecosystems and help their recovery.

2. The maintenance and expansion of those sectors using marine ecosystem services needs to be commensurate with an understanding of the sustainability of the ecosystem capacity to supply them (Culhane et al., 2019).

Figure 2.5 Trends in the EU blue economy by sector, 2009-2017



Notes: Names of sectors are strictly those from the Directorate-General for Maritime Affairs and Fisheries (DG MARE) annual blue economy reports, which are defined slightly differently from those used in *Marine messages II*.

Source: European Commission (EC, 2019a, 2019e).

3. Those sectors using marine abiotic resources and other abiotic marine outputs should not operate in a way that impairs marine ecosystem capacity for service supply.

These premises could be met through making ecosystem-based management a reality, which can be supported by maritime spatial planning. Using the ecosystem services approach can help in this context, by providing a shared perspective when having to resolve conflicting uses of Europe's seas, including accommodating the needs of the marine ecosystem itself (Granek et al., 2010; EEA, 2015b; Celtic Seas Partnership, 2016; Ivarsson et al., 2017; Veretennikov, 2019).

The next chapter will investigate the current condition of Europe's marine ecosystems.

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3 Marine ecosystems are degraded

Key messages		
Past trends (10-15 years)		Marine biodiversity remains under threat in Europe's seas. A high proportion of marine species and habitats' assessments continue to show an 'unfavourable conservation status' or a status that is 'unknown', despite the Habitats Directive having entered into force in 1994. Management efforts targeting individual marine species and habitats have led to improvements in their conditions in some EU marine regions, but this fragmented success does not offset the combined effects of multiple pressures from human activities on Europe's seas.
Outlook to 2030		EU Member States need to ensure full implementation of existing political commitments if the EU is to halt the loss of marine biodiversity by 2030. The underlying drivers of degradation of marine ecosystems are not changing favourably, and the pressures and effects of anthropogenic climate change are set to continue.
Prospects of meeting policy objectives for 2020	2020	Europe is not on track to achieve 'good' condition for marine species, habitats and ecosystems and 'favourable conservations status' for protected species and habitats in all EU marine regions by 2020.
Robustness	There is large variation in the availability of data across species and marine regions regarding conservation status and data gaps remain. The available outlook information is limited, so the assessment of outlooks relies primarily on expert judgement.	

Europe's seas cover more than 11 million km^2, and range from shallow, semi-enclosed seas to vast expanses of the deep ocean. They host a wide, highly diverse range of coastal and marine ecosystems and have a large variation in their habitats and species. For example, the Mediterranean Sea is one of the world's hot spots for biodiversity. Its highly diverse ecosystems host up to 18 % of the world's macroscopic marine biodiversity (Bianchi and Morri, 2000), i.e. at least 17 000 species (Coll et al., 2010). In comparison, the Bothnian Bay (which is smaller than the Mediterranean Sea) in the Baltic Sea holds only approximately 300 species due to its low salinity (HELCOM, 2018c).

Whether a marine ecosystem hosts 300 or 17 000 species, these species fill all the available ecological niches. The species interact and depend on each other through food web dynamics or competition for space, or through mutual synergies that provide shelter or foraging areas. Combined they are connected through an intricate dynamic 'web of life' — a web that is the foundation for the capacity of the marine ecosystem to provide ecosystem services and benefits for humanity. These connections are at the core of ecosystem-based management (EBM) (Box 1.1). When the individual strings of the web are disturbed through interaction with human activities, it may cause undesirable changes. The ability to absorb the disturbance caused by such changes is 'ecosystem resilience' (Box 3.1).

The challenge is to maintain ecosystem resilience within the boundaries under which humanity has evolved and thrived. For this reason and given the complexity of interactions between the individual components, both the individual pieces and the overall complexity of ecosystem resilience needs to be addressed (albeit in a simplified manner). This chapter looks into the very core of ecosystem resilience, i.e. the status of species and habitats, and the condition of marine ecosystems.

With the Marine Strategy Framework Directive (MSFD), the EU set out a vision for achieving clean, healthy and productive seas. Key to achieving this ambition is to understand the connections between humans and ecosystems. While 'cause and effect' is well understood between some individual elements (e.g. human activities, pressures, impacts, species, habitats), understanding the connections becomes increasingly complex as more elements are considered. However, one thing all these elements have in common is that they 'exist' or interact 'somewhere', i.e. there is a strong spatial dimension in any solution to achieving the MSFD vision (Box 1.1).

Box 3.1 Ecosystem resilience

Ecosystem resilience can be defined as the capacity of an ecosystem to absorb disturbance without collapsing into a qualitatively different state that is controlled by a different set of ecological processes. In practice, ecosystem resilience builds on three characteristics: (1) an ecosystem's capacity to resist change; (2) the amount of change an ecosystem can undergo while still retaining the same controls on structure and function; and (3) an ecosystem's ability to reorganise following disturbance. Resilience thus relates to characteristics that underpin the capacity of ecosystems to provide ecosystem services and benefits.

Source: EEA (2012).

It follows that the overview of the condition of individual species groups (Table 3.1) needs to be supplemented by a spatial description of ecosystem condition (as first demonstrated by the Helsinki Convention (HELCOM, 2010a). This description establishes the necessary connections between human activities, pressures and the overall ecosystem condition (Figure 3.1).

3.1 Biodiversity loss in Europe's seas has not been halted

By recognising the dependency of humanity on biodiversity, the EU adopted the 2006 action plan to halt the loss of biodiversity by 2010 (EC, 2006). When this goal was not reached, only becoming more urgent in the meantime, the EU extended it with the biodiversity strategy to 2020 (EC, 2011). The difficulty is not only how to answer the question of whether the EU has managed to halt the loss of marine biodiversity but also how to answer it in a consistent manner.

More than 600 indicators exist for biodiversity in Europe's seas. These originate from the Regional Sea Conventions, independent research, EU projects and national monitoring (Teixeira et al., 2016), although not all are suitable for the purpose of assessing marine biodiversity at the EU level. However, by both looking at existing regional assessments and deploying a set of more novel indicator-based assessment methodologies, it has been possible to assess the current condition of marine biodiversity in Europe's seas (Table 3.1).

Despite the mix of qualitative and quantitative approaches and levels of certainty, the message is clear — the EU has not succeeded in halting the loss of marine biodiversity by 2020. This general conclusion is supported by the recent IPBES report for Europe and Central Asia, which states, 'based on different assessments considered the European Union's marine ecosystems could therefore not be considered to be in a healthy state' (IPBES, 2018). In fact, from the regional assessments, only bony fish have an improving state in some areas, namely the North Sea and parts of the Baltic and Celtic Seas (OSPAR, 2017c; HELCOM, 2018c). At the same time, some parts of Europe's seas remain in 'good' condition (24 % of assessed areas; Figure 3.1).

3.2 Biodiversity condition is problematic in large areas of Europe's seas

Multi-metric indicator-based tools are increasingly used in marine assessments and have been widely described in the literature. These tools include BEAT+ (Figure 3.1), which has been designed to provide an assessment of the spatial variability of a range of biodiversity components by combining existing biodiversity indicators (Vaughan et al., 2019).

The BEAT+ tool itself is anchored in earlier versions of the tool developed and tested by HELCOM (2010a) and the EU-funded Devotes project (Uusitalo et al., 2016; Nygård et al., 2018). The indicators used for assessing biodiversity conditions across Europe' seas range from planktonic organisms over benthic communities to fish, seabirds, reptiles and marine mammals — and each indicator is represented by two numerical values, a figure representing biodiversity and a figure representing agreed target values (e.g. from HELCOM, the OSPAR Commission, maximum sustainable yield (MSY), etc.).

Data coverage is in general good in the North-East Atlantic Ocean and the Baltic Sea, due to the work done by HELCOM and the OSPAR Commission. However, there is room for improvement in the Black Sea and the Mediterranean Sea, in terms of data availability, indicator development and monitoring. Despite variations in data availability, the condition of biodiversity has been assessed on a European scale, and 84 % of the areas assessed are classified as problem areas. Approximately 4 million km^2 of Europe's seas (33 %) were not assessed due to lack of data.

Table 3.1 Overall biodiversity condition and trends in Europe's Seas

		North-East Atlantic (OSPAR)	Baltic Sea (HELCOM)	Mediterranean Sea (UNEP-MAP and GFCM ([1]))	Black Sea (BSC and GFCM ([2]))	European Seas: Art. 17 Habitats Directive ([4])	European Seas: IUCN Red List ([5])	European Seas: Living Planet Index (LPI)	European Seas: BEAT+ Worst case BQR ([8])
Species groups	Seals	Moderate/mixed; improving	Poor; improving	Insufficient data (limited data)	Insufficient data	Bad; stable/mixed	Poor; improving	Moderate decline	Poor
	Cetaceans	Moderate/mixed	Poor	Poor (limited data)	Insufficient data	Insufficient data (limited data)	Insufficient data (limited data)	Improving (limited data)	Insufficient data
	Birds ([3])	Bad; strong decline	Poor; moderate decline	Poor (limited data)	Insufficient data (limited data)	N/A	Poor; moderate decline (limited data)	Stable/mixed	Bad
	Bony fish ([7])	Moderate/mixed; improving	Moderate/mixed	Poor (limited data)	Poor (limited data)	N/A	Good; stable/mixed	Improving	Moderate/mixed
	Sharks and rays ([6])	Poor	Poor	Bad (limited data); moderate decline (limited data)	Bad (limited data)	N/A	Poor; moderate decline	Stable/mixed (limited data)	Insufficient data
	Reptiles	Insufficient data (limited data)	N/A	Insufficient data	Insufficient data	Bad; strong decline	Bad; strong decline	Insufficient data	Insufficient data
	Cephalopods	Insufficient data (limited data)	N/A	Insufficient data (limited data)	N/A	N/A	Insufficient data	Insufficient data	Insufficient data
	Other invertebrates	Insufficient data (limited data)	Insufficient data (limited data)	Insufficient data (limited data)	Insufficient data	Bad; stable/mixed	Insufficient data (limited data)	Insufficient data	Insufficient data
Habitats	Pelagic	Insufficient data (limited data)	Poor	Insufficient data (limited data)	Insufficient data (limited data); moderate decline (limited data)	N/A	Insufficient data	Insufficient data	Poor
	Benthic	Poor	Poor	Insufficient data (limited data)	Stable/mixed	Bad; moderate decline	Insufficient data	Insufficient data	Bad
Ecosystem	IPBES current and past trends ([9])	Poor; moderate decline	Bad; moderate decline	Bad; strong decline	Poor; strong decline				

	Condition: Good	Moderate /mixed	Poor	Bad	Insufficient data	Trend: Improving	Stable/ mixed	Moderate decline	Strong decline
	(blue)	(yellow)	(orange)	(dark red)	(grey)	↑	○	↘	↓
Limited data/ regional coverage	(light blue)	(light yellow)	(light orange)	(pink)	(light grey)	↑ (grey)	○ (grey)	↘ (grey)	↓ (grey)

N/A = Not applicable

Notes: ([1]) Based on the United Nations Environment Programme-Mediterranean Action Plan (UNEP-MAP) quality status report assessment 2018 (UNEP-MAP, 2018); ([2]) Black Sea Commission. Note that the biodiversity assessment has not yet been published; ([3]) Status based on percentage of species; ([4]) Habitats Directive Article 17 reporting 2013 (2019 is due); ([5]) Red List Index on mammals and seabirds (extracted from Rodrigues et al. (2014) and IUCN (2019); ([6]) This covers sharks, skates and rays, which are affected significantly by by-catch in fisheries; ([7]). Mainly from indicators derived from fisheries data; ([8]) BEAT+ integrative biodiversity assessment tool (Vaughan et al., 2019); ([9]) *The regional assessment report on biodiversity and ecosystem services for Euro pe and Central Asia* (IPBES, 2018).

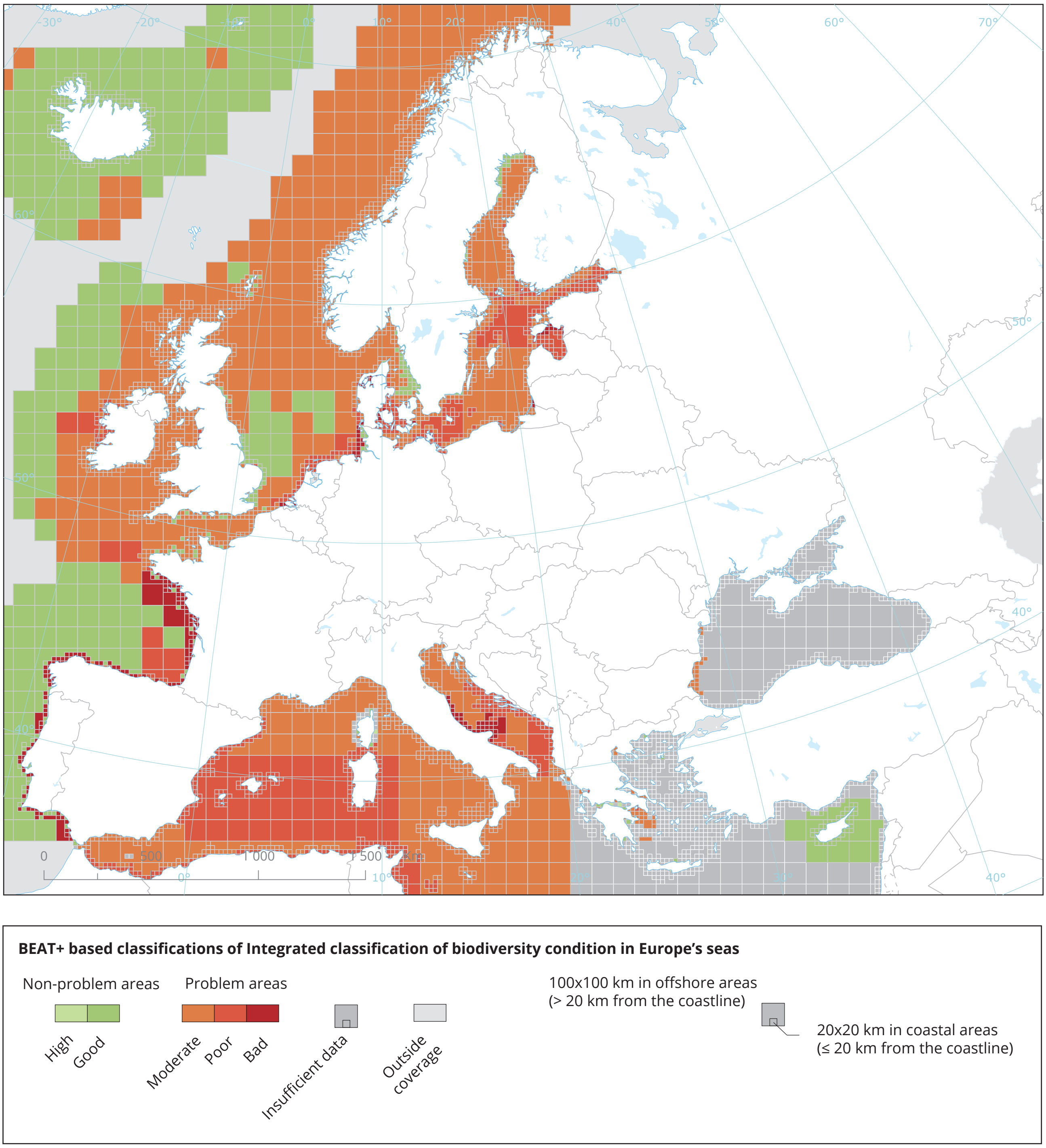
GFCM, General Fisheries Commission for the Mediterranean; IUCN, International Union for Conservation of Nature; BQR, Biodiversity Quality Ratio; IPBES, Intergovernmental Science-Policy Platform on Biodiversity.

The Mediterranean Sea is showing poor condition mainly due to overfishing. The main 'non-problem areas' lie around the Iberian Peninsula, parts of the Norwegian and Icelandic coasts, the central part of the North Sea (due to recovery of fish stocks) and the northern Baltic Sea. However, data availability on trends in and the condition of most biodiversity components is limited in offshore waters. This highlights the need for more and continued monitoring and development of reliable indicator thresholds. The percentages of assessed areas classified as 'problem' and 'non-problem' areas within different sub-regions can be seen in Annex 2 (Table A2.1).

3.3 Marine species remain under pressure

Apart from looking at the overall condition of marine biodiversity, it remains important to maintain a focus on the individual characteristics of resilience in order to inform specific management measures (Box 3.2). This includes species, groups of species, habitats and structures such as sea floor integrity and food webs, to mention but a few. So, what are the condition of and trends in major marine species groups within Europe's seas (Table 3.1)? Elements of this section are from the EEA report *The European environment — state and outlook 2020* (EEA, 2019f).

Figure 3.1 Integrated classification of biodiversity condition in Europe's seas



Notes: These classifications are not directly related to those of status in relevant EU water, marine and nature directives. This is because, inter alia, the tool uses (1) a precautionary approach based on the 'one out, all out' principle when integrating indicators, (2) all available EU and regional-level indicator-based biodiversity information, and (3) EU and regional threshold values (assessment criteria). This is rather than just using the status aggregation rules, the information that may have been reported, and the quality thresholds under those directives.

Source: Vaughan et al. (2019). See Annex II.

The condition of the populations of commercially exploited fish and shellfish species that could be assessed across Europe's seas presented a contrasting picture in the period 2015-2017 (EEA, 2019e). A significant number of the assessed stocks in North-east Atlantic Ocean and Baltic Sea populations had improved in 2017. 82.3 % and 62.5 % of these stocks, respectively, showed a fishing mortality rate and/or reproductive capacity compatible with biomass levels above those capable of producing MSY (Table 4.1).

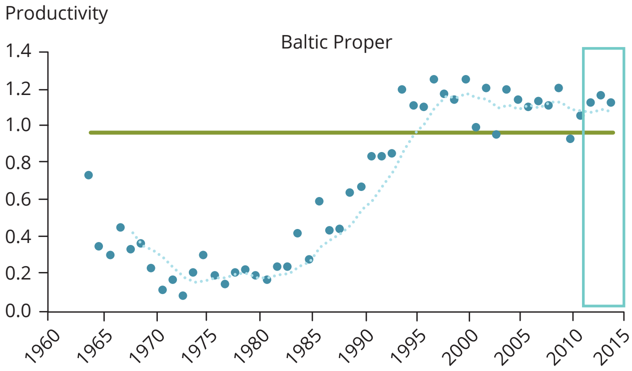
However, the condition of some of stocks in those regions did not improve (EEA, 2019e). For example, Greater North Sea and eastern Baltic cod stocks had reached a very critical stage by 2018, which means that exploitation of the Greater North Sea stock should be reduced by 63 % (ICES, 2019). Fishing for cod in the Baltic Sea was banned for the rest of 2019 through emergency measures (EC, 2019b).

The condition of assessed stocks in Mediterranean Sea and Black Sea populations remained critical (FAO, 2018; Jardim et al., 2018; UNEP-MAP, 2018), with only 6.1 % and 14.3 % of these stocks, respectively, being fished sustainably in 2016 (Table 4.1). In contrast, strong regulation to reduce fishing mortality has brought bluefin tuna, a Mediterranean top predator, from the brink of collapse (in 2005-2007) to possibly reaching sustainable levels for fishing mortality and reproductive capacity in 2022 (FishSource, 2018) based on (ICCAT, 2017a, 2017b).

Average European seabird population trends are either stable or declining. Approximately 33 % are slightly declining and another 22 % are regarded as 'threatened' (BirdLife International, 2015). In the Norwegian Arctic Ocean, the Greater North Sea and the Celtic Sea, there has been an overall drop of 20 % in seabird populations over the last 25 years for more than a quarter of the species assessed (OSPAR, 2017c). On a positive note, there are examples of recovery of individual species as a result of targeted management efforts, e.g. the banning of dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs). This includes the white-tailed eagle in parts of the Baltic Sea (HELCOM, 2018b) (Figure 3.2).

Marine mammals are all protected by EU legislation or global policy, but their status is not fully understood due to complexities in monitoring. This has resulted in 72 % of Member States' reports on their status (ETC/BD, 2012) and 44 % of International Union for Conservation of Nature (IUCN) assessments being 'data deficient' (Temple and Terry, 2007). Some seal populations are relatively healthy and increasing in numbers or reaching carrying capacity, e.g. harbour

Figure 3.2 White-tailed eagle productivity in the Baltic Sea



Note: Mean annual productivity of white-tailed eagle (*Haliaeetus albicilla*), estimated as the number of nestlings per occupied territory in coastal sub-populations of the Baltic Proper and the Gulf of Bothnia (based on data from Sweden). The green line illustrates the threshold value of the HELCOM core indicator. The blue box identifies the assessment period 2011-2015.

Source: HELCOM (2018b).

seals in the Kattegat, although they are decreasing in other areas (OSPAR, 2017b; HELCOM, 2018a). However, despite the increase of the population of grey seals in the Baltic Sea and in the OSPAR region, their nutritional condition and reproductive status is not good in the Baltic Sea (HELCOM, 2018a). In the Mediterranean Sea, the number of monk seals appears to be stabilising, although this species is still at risk due to its small population size (Notarbartolo di Sciara and Kotomatas, 2016).

Recent studies of populations of killer whales (*Orcinus orca*) show the adverse effects of PCBs on their reproduction, threatening 50 % of the global population. This may cause the disappearance of killer whales from the most contaminated areas within 50 years, despite PCBs having been banned for 30 years. These waters include areas in the North-East Atlantic Ocean around the United Kingdom and in the Mediterranean Sea around the Strait of Gibraltar (Desforges et al., 2018). In contrast, populations of minke whale, harbour porpoise and white-beaked dolphin appear to be stable (since 1994) (OSPAR, 2017b).

Seabed habitats are under pressure across EU marine regions, with over 65 % of protected seabed habitats reported as being in 'unfavourable' conservation status 20 years after the entry into force of the Habitats Directive (ETC/BD, 2012; EEA, 2015c). In another example, 86 % of the assessed seabed in the Greater North Sea and Celtic Seas shows evidence of physical disturbance by bottom-touching fishing gear (OSPAR, 2017a). In the Baltic Sea, only 44 % and 29 %, respectively, of the soft-bottom seabed habitat area in coastal waters and in the open sea were in 'good' status (HELCOM, 2018c). Some of the bottom-living molluscs on the Norwegian coast are recovering in response to banning tributyltin (TBT), e.g. the common dog whelk (Schøyen et al., 2019).

3.3.1 Vulnerable species — visible indicators of resilience loss

When populations are in decline, and the causes of those declines are not diminishing, then the greatest risk is that the species may become extinct or lose ecological relevance. To avoid losing sight of these species when aggregating data for all species, specific assessments and indicators are needed to assess rare and threatened species (ICES, 2018). The IUCN Red List assessments have been developed to identify the state and future trends in populations or species at risk (IUCN, 2019).

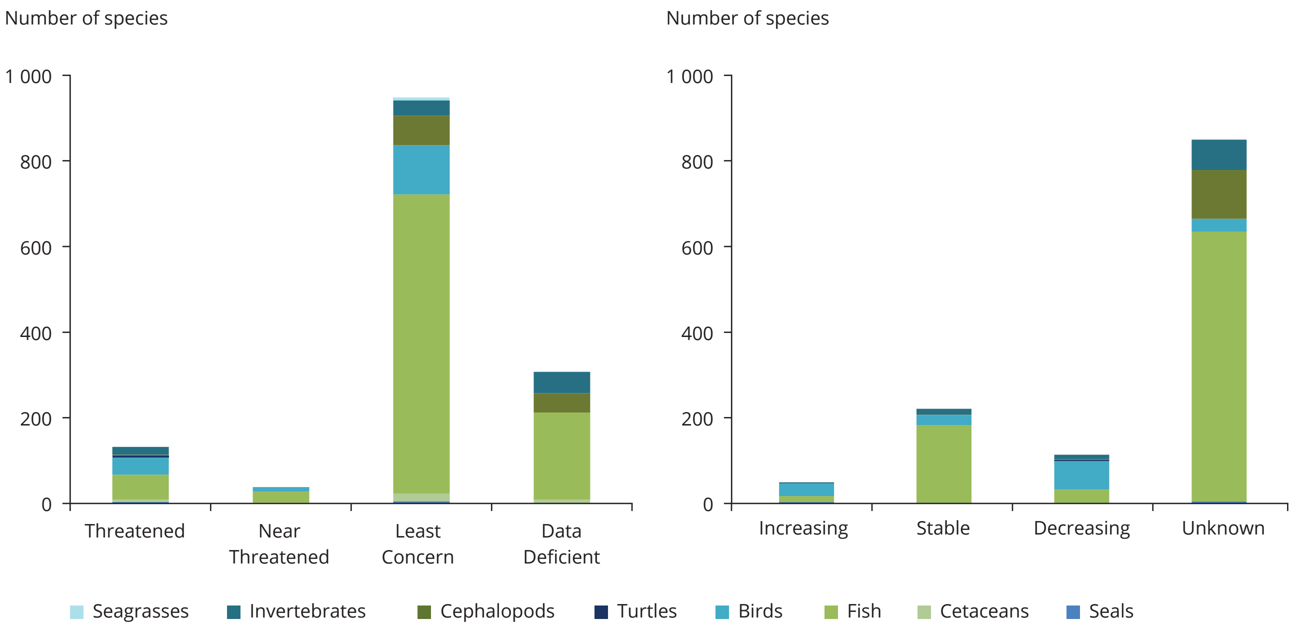
To better understand the rate of biodiversity loss, and to help report on Aichi Biodiversity Target 12 (CBD, 2018), two aggregated indices have been proposed: the Red List Index (RLI) to assess extinction risk (IUCN, 2019) and the Living Planet Index (LPI) for population trends (WWF and ZSL, 2015; IPBES, 2018). The RLI is calculated for all birds and mammals, and shows that birds have a declining index value across all European marine regions. The Red List assessments for Europe show that, of the 1 196 marine species assessed, 9 % are threatened, while 3 % are 'near-threatened'. Birds, mammals and turtles are particularly at risk, with over 20 % of species being threatened (Figure 3.3).

In measuring marine abundance trends, the trend in the LPI for European marine fauna is relatively stable compared with the trends in developing countries (WWF and ZSL, 2015), although threatened species are performing less well (Figure 3.4). However, the global loss of marine fauna is taking place at a faster rate than for land species, for which the populations of some species have declined by up to 49 % in just 40 years (WWF and ZSL, 2015). If human demand for the seas' resources increase to match historical exploitation on land, marine extinctions may increase, but opportunities still exist to prevent wholescale defaunation of the seas (McCauley et al., 2015). Ensuring that measures, such as marine protected areas deliver conservation benefits remains a cost-effective management option (Box 3.2).

3.4 Ecosystem condition is problematic in large areas of Europe's seas

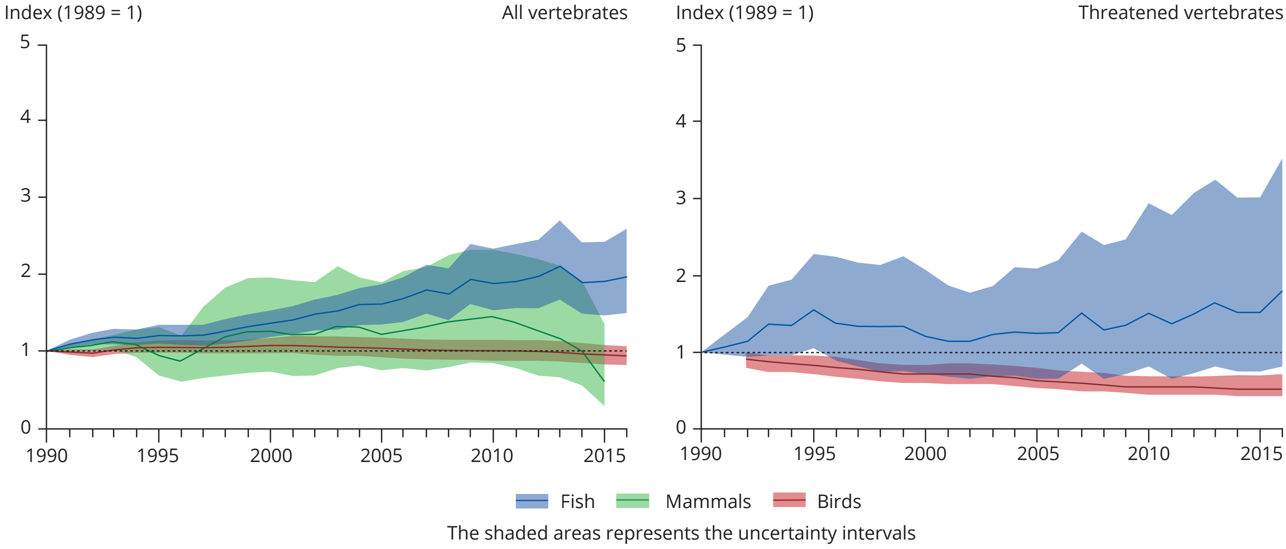
Marine messages II refers to 'clean, healthy and productive' as being the desired condition of Europe's seas, as this is the vision put forward in

Figure 3.3 Summary of status of and trends in threatened marine species



Sources: Birdlife international (2015), Nieto et al. (2015), Bo et al. (2017), EC and IUCN (2018) and IUCN (2019).

Figure 3.4 Living Planet Index calculated for main marine vertebrate groups



Note: Only long-term trend data for birds, fish and mammals are shown. Birds have now been declining overall since 2009, while fish are showing a strong positive trend. Sea mammals have variable trends but have been in sharp decline since 2009 (all species).

Sources: Data collected by EEA (Vaughan et al., 2019). Model from the Zoological Society of London (ZSL) (Freeman, 2019), used for Living Planet Assessment (WWF and ZSL, 2015; IPBES, 2018).

the MFSD (EU, 2008b). This implies, that 'clean' also means 'non-toxic' (and under limited physical, hydro-morphological and physico-chemical disturbance), and that 'healthy' also means 'functioning' and 'resilient'. Therefore, 'good condition' is used here when referring to these three qualities of Europe's seas together, or just 'condition' when assessing whether they are being met.

As discussed for biodiversity, a quantitative, indicator-based, spatial description of the current ecosystem condition is thus needed to further embrace resilience thinking (Box 3.1) and EBM (Box 1.1) of Europe' seas.

Therefore, *Marine messages II* has developed, tested and applied a new multi-metric indicator-based assessment tool named 'European Marine Ecosystem (Health) Tool' (MESH+). The MESH+ tool builds on the EEA assessment tools developed and applied in the context of assessing the degree of contamination (CHASE+), eutrophication (HEAT+) and biodiversity (BEAT+) in Europe's seas (EEA, 2018a, 2019c; Vaughan et al., 2019). MESH+ makes use of the same data sets and threshold values used in these assessments but recombines these in a new framework that addresses 'ecosystem condition'.

On the EU scale, 1 456 000 km^2 (about 20 %) of the assessed areas are classified as non-problem areas, while 5 657 000 km^2 are identified as being problem areas in the context of ecosystem condition (Map 3.1; Table 3.2).

In the Baltic Sea, most of the areas assessed are identified as problem areas (387 000 km^2), while 13 000 km^2 are classified as non-problem areas. The data coverage is good, and the results are in line with recent HELCOM assessments (HELCOM, 2010a, 2018c). The key reason for the impaired conditions is inputs of polluting substances, i.e. nutrients and contaminants.

In the Black Sea, the assessment has been carried out for only 157 000 km^2 out of 476 000 km^2, due to limited data availability. Of the assessed areas, 130 000 km^2 are identified as problem areas and 27 000 km^2 as non-problem areas. The key reason for the impaired conditions are inputs of polluting substances, especially nutrients and contaminants.

For parts of the Mediterranean Sea, especially the eastern parts, the assessment faced data issues. However, 60 % has been assessed, and 115 000 km^2 have been identified as non-problem areas, while 1 404 000 km^2 have been identified as problem areas. In this case, the key reasons for the impaired conditions are overfishing and inputs of polluting substances.

In the North-East Atlantic Ocean, the largest of the regional seas in Europe, 73 % of 6 858 000 km^2 have been assessed. Non-problem areas covered 25.8 % or 1 302 000 km^2, while problem areas covered 74.2%. The key reasons for the impaired conditions are overfishing and inputs of polluting substances, especially contaminants and, in some areas, also nutrients.

Box 3.2 Marine protected areas in Europe's seas

Marine protected areas (MPAs) and networks of MPAs are a key measure for protecting Europe's marine biodiversity (for definition see EEA (2015a). Approximately 75 % of EU MPAs are sites designated under the EU Habitats Directive (EU, 1992) and the EU Birds Directive as part of the Natura 2000 network of protected sites. The remaining sites are designated under national legislation (Agnesi et al., 2017).

From 2012 to 2016, the EU almost doubled its network of MPAs. By 2018, it had reached Aichi Biodiversity Target 11 of designating at least 10 % of its sea area as MPAs (UN, 2015), albeit with some variation between the marine regions. Five out of ten EU marine sub-regions are still short of reaching 10 % coverage of MPAs, especially in offshore areas (EEA, 2018b). A priority is to close this gap and ensure that the MPA network is coherent and representative, adequately covering the diversity of the constituent ecosystems (as required by Marine Strategy Framework Directive Article 13.4) — this could include the inclusion of commercially exploited and by-caught species as conservation objectives in designations. Another key objective is to ensure that management efforts deliver true benefits for marine biodiversity.

However, the real challenge is to ensure that the network delivers the best possible benefits for marine biodiversity as a whole, rather than just for vulnerable species and habitats. This includes actions such as accurately assessing the degree to which MPAs and the network as a whole are achieving their intended purpose — protecting marine biodiversity.

Fully protected European MPAs (e.g. no-take reserves) have been documented to deliver significant improvements in densities of species, species richness, body size and biomass. However, less than 1 % of European MPAs can be considered to be marine reserves (Fenberg et al., 2012). There is currently no evidence that less protection delivers conservation goals. Actions should also include the removal of the key pressures from the sites to allow recovery of the species and habitats that they contain and to ensure that the MPAs can act as a sanctuary zone for biodiversity from which the broader marine ecosystem can benefit as progression is made towards 'good environmental status'. It has been demonstrated that European MPA networks are being more affected than non-protected areas by commercial fisheries. The abundance of some sensitive species (sharks, rays and skates) decreased by 69 % in heavily trawled areas (Dureuil et al., 2018).

This question the true benefit of the EU MPA network for marine biodiversity and shows that management efforts need to be strengthened, to prove, for example, that they actually deliver benefits to marine biodiversity compared with areas outside the network.

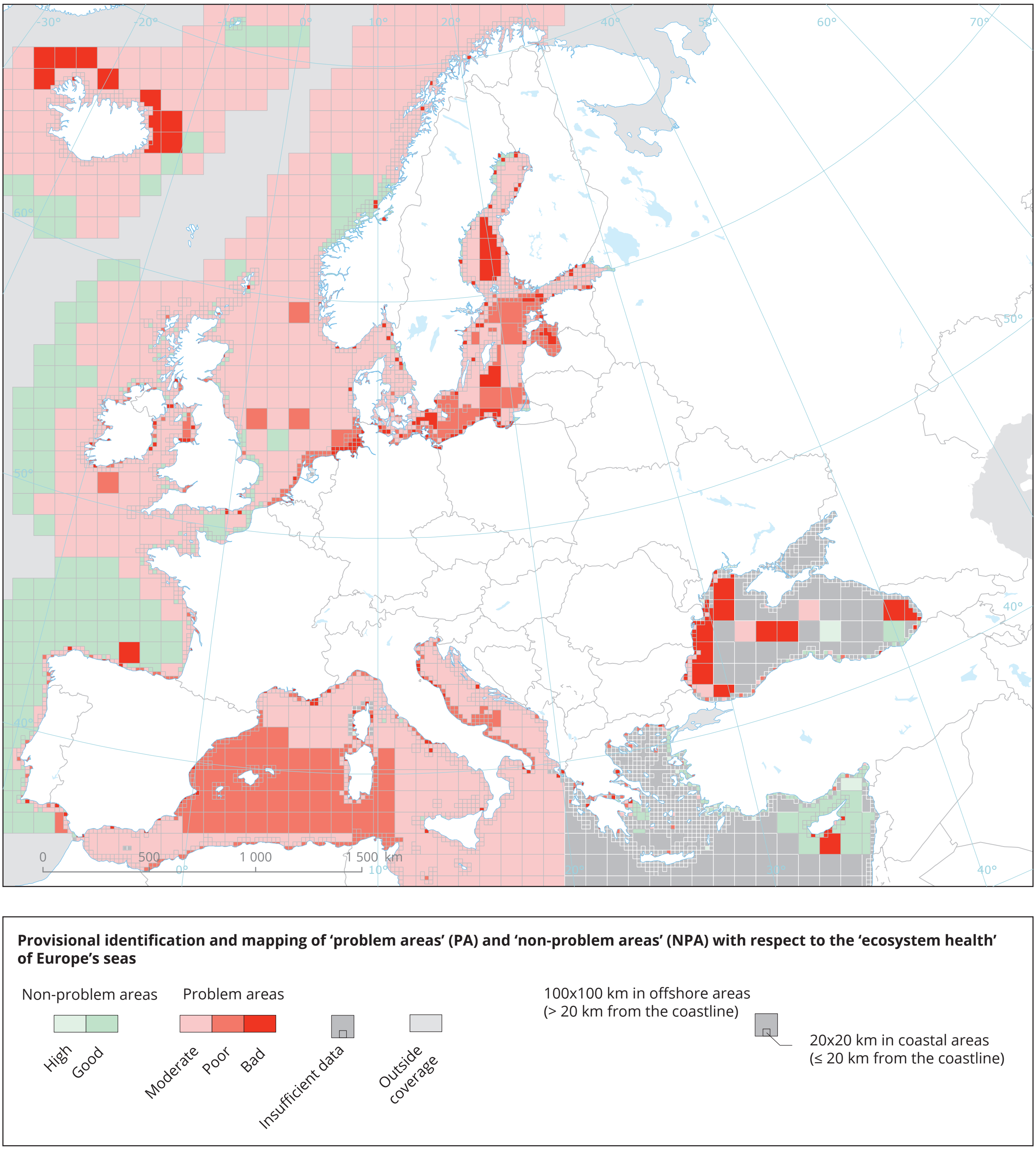
The procedure, according to Article 11 of the common fisheries policy (2013), to implement fisheries management measures in MPAs does not ensure the efficient management and regulation of fisheries activities that have a negative impact on protected habitats and species in designated Natura 2000 sites. The requirement of a 'joint recommendation' of Member States with fisheries interest in these areas often has the consequence that commercial fisheries interests are favoured over nature conservation requirements.

Table 3.2 Summary of MESH+ classifications in the Baltic Sea, Black Sea, Mediterranean Sea and North-East Atlantic Ocean

	Baltic Sea	Black Sea	Mediterranean Sea	North-East Atlantic Ocean	Total
Total area (km²)	400 000	476 000	2 530 000	6 858 000	10 264 000
Assessed	100 %	32.9 %	60.10 %	73.4 %	69.3 %
NPA_{High}	0 (0 %)	12 000 (7.5 %)	13 000 (0.9 %)	0 (0 %)	25 000 (0.3 %)
NPA_{Good}	10 000 (2.4 %)	15 000 (9.5 %)	102 000 (6.7 %)	1 286 000 (25.5 %)	1 413 000 (19.9 %)
$PA_{Moderate}$	208 000 (52 %)	33 000 (21.2 %)	935 000 (61.5 %)	3 488 000 (69.2 %)	4 664 000 (65.6 %)
PA_{Poor}	116 000 (29.1 %)	3 000 (1.7 %)	445 000 (29.3 %)	130 000 (2.6 %)	694 000 (9.8 %)
PA_{Bad}	66 000 (16.5 %)	94 000 (60 %)	25 000 (1.6 %)	133 000 (2.6 %)	318 000 (4.5 %)
% PA	97.60 %	82.90 %	92.40 %	74.50 %	79.80 %

Note: NPA, non-problem area; PA, problem area.

Map 3.1 Provisional identification and mapping of problem areas (PA) and non-problem areas (NPA) with respect to the 'ecosystem health' of Europe's seas



Note: The non-problem area/problem area classifications are not directly related to those of status in relevant EU water, marine and nature directives. This is because, inter alia, the tool uses (1) a precautionary approach based on the 'one out, all out' principle when integrating indicators, (2) all available EU and regional-level indicator-based information, and (3) EU and regional threshold values (assessment criteria).

Attempts to classify ecosystem health or environmental state/condition on large scales are scarce, probably due to issues with data access and agreed threshold values. However, a few attempts have been made in the Baltic Sea (HELCOM, 2018c) and on a Europe-wide scale (Borja et al., 2019). Although these two examples can be characterised as demonstrations rather than baseline studies, they both prove that integrated assessments can be made based on existing data. An interesting finding in the study by Borja et al. (2019) is that using around 40 indicators could be enough to obtain robust assessments. When applying MESH+ on a European scale, assessment units covering more than 3 711 000 km^2 (52.2 % of the area assessed) have more than 40 indicators showing consistent classification results. Furthermore, 1 325 000 km^2 (18.5 %) were classified based on 20-39 indicators, and 2 088 000 km^2 (29.3 %) were based on 1-19 indicators.

The mapping of problem areas and non-problem areas with respect to ecosystem health using MESH+ builds on a very large data set and threshold values available from EU legislation, the Regional Sea Conventions and the International Council for the Exploration of the Sea (ICES). Despite this, the assessment of ecosystem health could and should be improved using more and better indicators and associated threshold values, especially regarding biodiversity.

The next chapter will describe the multiple human pressures causing impaired ecosystem condition in Europe's seas in order to include key characteristics of ecosystem resilience other than biodiversity, e.g. stressors and disturbance regimes.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4 Europe's seas are affected by multiple pressures

Key messages		
Past trends (10-15 years)		Where regional cooperation has been established and implemented consistently, negative trends in certain pressures are beginning to be reversed, for example, levels of nutrients and contaminants or the introduction of non-indigenous species. Pollution caused by eutrophication and contaminants is still a concern in parts of Europe's seas. Of the commercially exploited fish and shellfish stocks across Europe's seas, 89.5 % and 100 %, respectively, cannot be assessed at the EU level in terms of whether they meet two or three out of the three primary criteria that are used to define the Marine Strategy Framework Directive's (MSFD's) 'good environmental status' objective. Of the assessed commercially exploited fish and shellfish stocks across Europe's seas, 55.2 % meet at least one out of two primary criteria used to define the MSFD's 'good environmental status' objective for commercial fish and shellfish species. Widespread physical disturbance of the sea floor continues in coastal waters due to, especially, bottom trawling. Changes in ocean warming, ocean acidification and oxygen content indicate that significant systemic changes are taking place in EU marine regions, which erode marine ecosystem resilience and hence the resilience to the climate crisis. Reaching agreed goals to limit the extent of the climate crisis is one of the essentials for preserving the resilience of marine ecosystems.
Outlook to 2030		Achieving 'good condition' for Europe's seas is a prerequisite for fulfilling international commitments such as Sustainable Development Goal (SDG) 14.1 by 2030. Doing so will require political resolve, increased coordination among stakeholders and policy integration.
Prospects of meeting policy objectives/targets for 2020	2020	Europe's seas are not on track to achieve 'good condition' in relation to key pressures, such as contaminants, eutrophication, non-indigenous species and marine litter, by 2020.
Robustness	We have come up with the first pan-European spatial assessment of the combined effects of several multiple pressures from human activities on marine ecosystems. There is large variation in data availability across species and marine regions, and data gaps remain. Monitoring of key pressures could be improved and threshold values for various pressures could be established. Recent reporting under the MSFD (2019) may increase data availability for most pressures.	

Throughout history the ocean has been considered as a source of rich, bountiful resources capable of absorbing all human waste and exploitation. This perception is no longer true. The first signs of overexploitation were seen in extinctions of oyster beds and some island birds and crashes in whale and seal populations. This was followed by pollution effects in coastal seas and economic catastrophes caused by fish stock collapses (Jackson et al., 2001).

These patterns of overexploitation and pollution continue today, with the added threat of anthropogenic climate change causing abrupt changes to alternative, less desirable states (Möllmann et al., 2011; IPCC, 2018; IRP, 2019). These changes may be irreversible within policy-relevant timescales. Therefore, management solutions to achieve clean, healthy and productive seas do not only have to look at the individual parts of marine ecosystems but also at the combined effects of multiple stressors causing the disturbance.

This chapter presents the distribution and intensity of the pressures arising from human activities in Europe's seas and estimates how much these can potentially affect the marine ecosystems. Apart from describing the combined effects of several pressures from human activities, it also touches upon individual pressures of sea-based origin and land-based origin.

Therefore, it mirrors the dual approach applied to marine species and ecosystems to describe some of the links between human activities and marine ecosystems. Understanding these connections spatially can help to adapt the ecosystem-based approach to the management of human activities. Ultimately, it can inform how to balance EU policy visions for the marine environment with those for the blue economy — i.e. coupling the efforts to restore ecosystem resilience to social-ecological systems rather than to either social systems or the ecosystems.

4.1 Combined effects of human activities on Europe's seas

The Marine Strategy Framework Directive (MSFD) aims to couple social and ecological systems by enshrining ecosystem-based management (EBM). This includes an analysis of the predominant pressures and impacts, including the main combined and synergetic effects, i.e. connecting the sum of effects from human activities to overall ecosystem condition within an entire EU marine/maritime region (Article 8).

Given the current, generally poor condition of marine ecosystems (Table 3.1; Figure 3.1) (OSPAR, 2017c; HELCOM, 2018c), it is highly relevant to better understand this condition and link it to the causes. Inspired by previous attempts (Halpern et al., 2008; HELCOM, 2010a; Andersen et al., 2015, 2017), *Marine messages II* has aimed to demonstrate that it is possible to provide a spatial description of the combined effects of multiple pressures from human activities at the scale of Europe's seas that is based on the indicative list of ecosystem elements, anthropogenic pressures and human activities provided by MSFD Annex III.

Despite various gaps in data coverage, institutional barriers (e.g. lack of easy access to harmonised spatial information of human activities, no institutional-led process that adequately covers all marine/maritime spatial information in the context of delivering all relevant EU policies) and methodological challenges (sensitivity and confidence assessments), it is indeed feasible to start mapping the combined effects of multiple pressures from human activities in a coherent manner (Figure 4.1, panel A). This exercise also allows the ranking of both the most widespread pressures and the ecosystem components most impacted, based on the spatial description (Figure 4.1, panel B).

The exercise is based on (1) mapping human activities, (2) describing their pressures in a spatial context, (3) mapping ecological elements, i.e. species and habitats, (4) describing their vulnerability to the set of pressures, and (5) combining the information in order to establish the connections needed to inform EBM. The results could be improved through better data coverage and a consistent, coordinated approach to marine/maritime spatial information. To further understand the origin of the pressures, the following sections will look into sea-based and land-based pressures.

4.2 Sea-based pressures impact marine habitats and species

Activities taking place at sea cause pressures that need to be managed (e.g. reduced, prevented) both at sea and on land. Such pressures include continuous and impulsive noise, physical loss of and disturbance to seabed and water habitats, extraction of marine species, by-catch of marine species and the introduction of non-indigenous species.

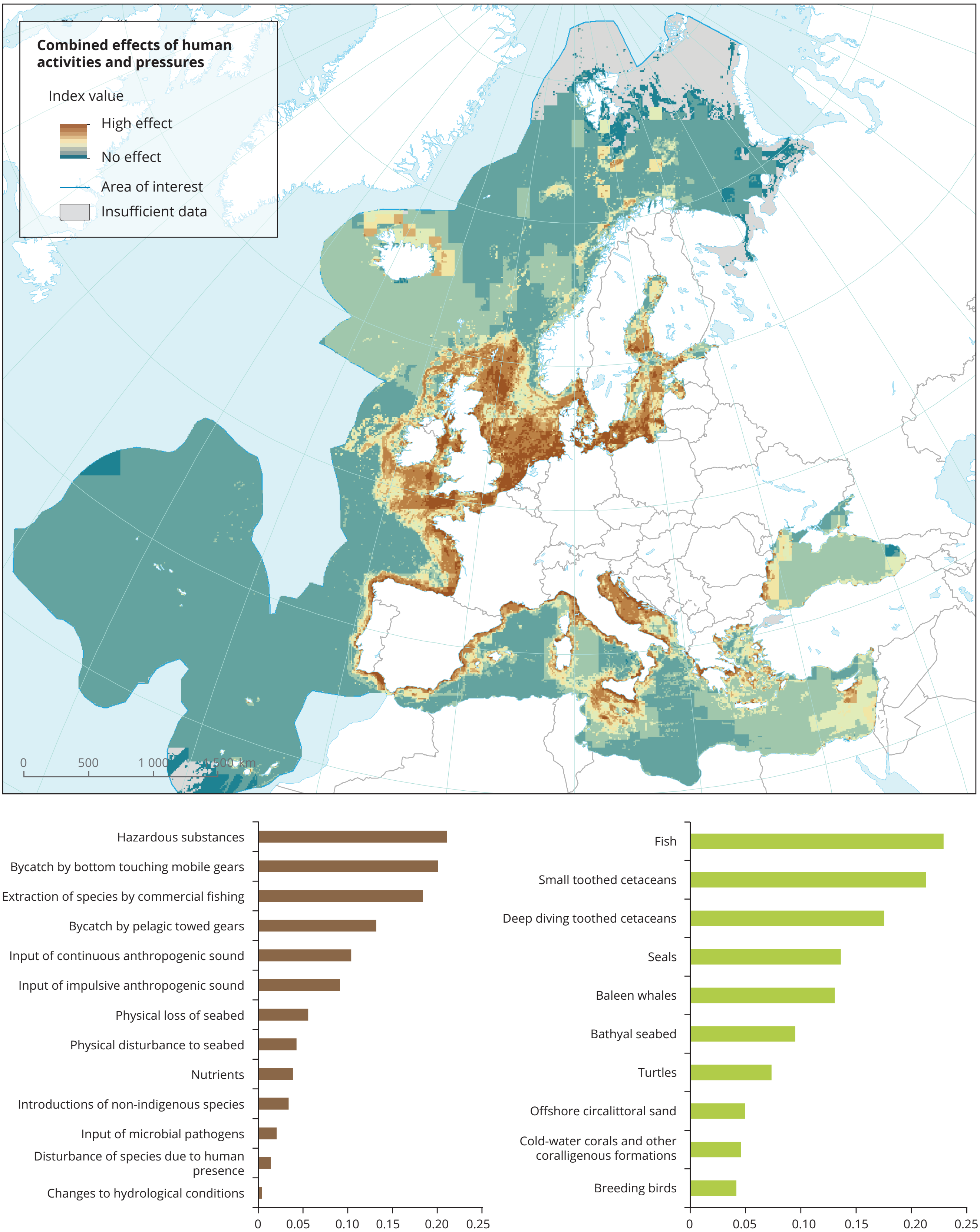
Sea-based pressures have potentially the highest effects (i.e. impacts) in the continental shelf, because the relatively shallow seas allow a high concentration of several human activities at the same time, such as fisheries, exploitation of the seabed and energy production. As these areas host rich seabed habitats, the combined effects of those pressures on the marine ecosystem are relatively higher than the area beyond the shelf (Figure 4.2, panel A). The analysis indicates that the North Sea, the Bay of Biscay and the Adriatic Sea are as affected by high pressures and their effects as the narrower shelf of the Iberian Peninsula and rest of the Mediterranean Sea.

Among all sea-based pressures, the most widespread combined effects arise from underwater noise, the by-catch of pelagic (water column) and demersal (on or near the seabed) species and physical disturbance of seabed habitats (Figure 4.2; panel B). These pressures affect the following marine ecosystem components (i.e. species (sub)groups) the most: fish, small-toothed cetaceans (e.g. dolphins), deep-diving toothed cetaceans (e.g. sperm whale), seals, baleen whales, turtles, cold water corals and similar, and birds (Figure 4.1, panel B).

4.2.1 Fishing causes multiple effects in wide areas

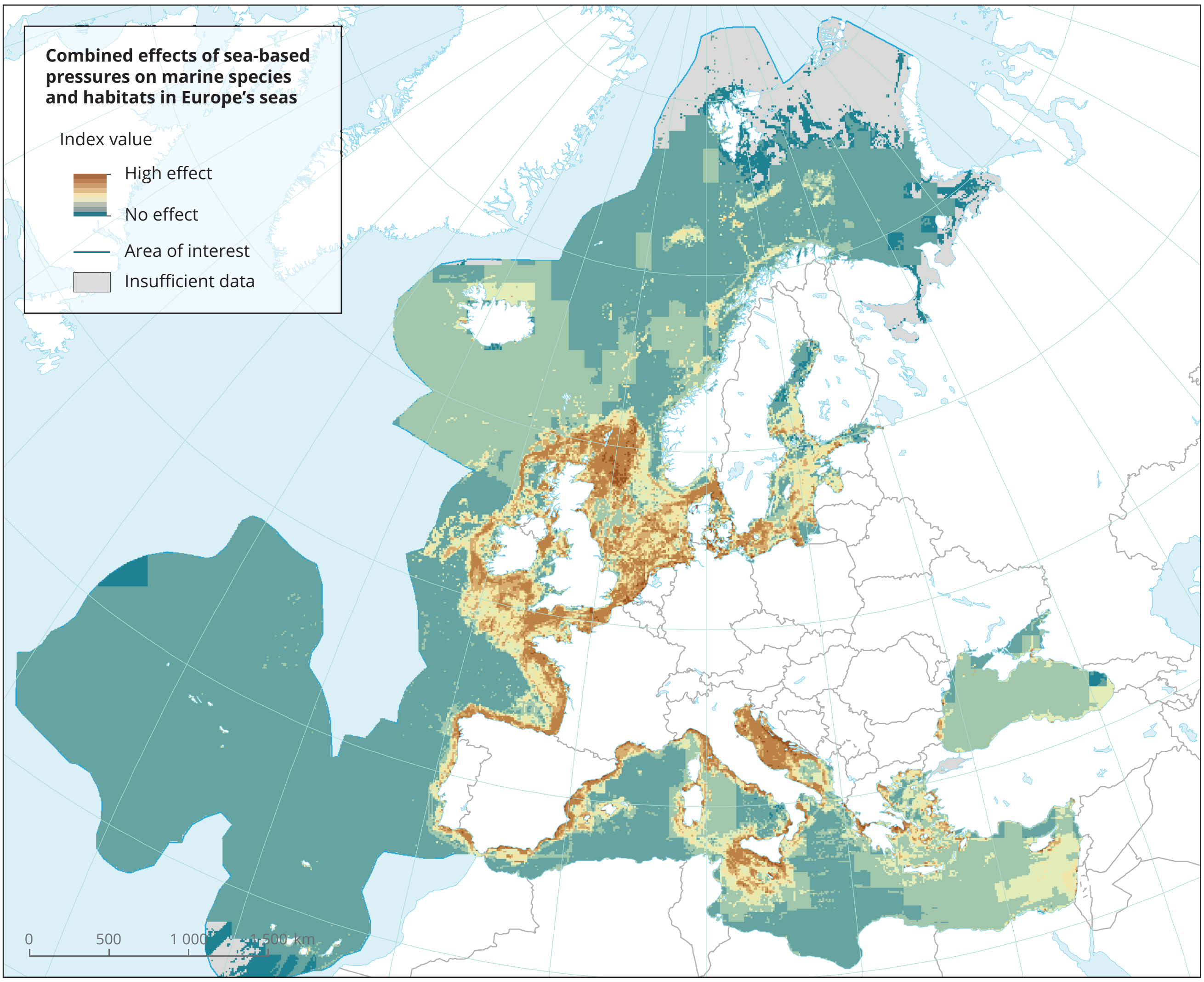
Fishing for pelagic and demersal fish and shellfish is a widespread use of Europe's seas, which has a high impact on the marine environment (Micheli et al., 2013; FAO, 2016; OSPAR, 2017a; HELCOM, 2018c). Impacts include overexploitation of targeted species (FAO, 2018; Froese et al., 2018), physical disturbance of seabed habitats (OSPAR, 2017a), by-catch (Lewison et al., 2014)

Figure 4.1 Combined effects of human activities and pressures (top) and the ranking of key ecosystem components affected by them (bottom) in Europe's seas



Notes: The combined effect assessments (CEA) index uses the intensity of anthropogenic pressures (normalised), the distribution of habitats and species and the sensitivity of habitats and species to the pressures and calculates a potential additive effect of the pressures in 10 km × 10 km marine areas. Ranking of effects is calculated as a combination of two variables — spatial area of the pressure and potential effects that are estimated based on sensitivity of ecosystem components. Ranking of 'Extraction of species by commercial fishing' includes extraction of all commercial species in corresponding spatial area and sensitivity of species. 'Bycatch by bottom touching mobile gear' and 'Bycatch by pelagic towed gears' occur in areas that may overlap, but sensitivity scores are different - one is addressing benthic species, and another is addressing pelagic species. The full method description is given by ETC/ICM (2019).

Figure 4.2 Combined effects of sea-based pressures on marine species and habitats in Europe's seas (top) and spatial coverage of the sea-based pressures in three marine zones (bottom)



	Coastal strip	Shelf	Beyond shelf
Continuous noise	86 %	97 %	96 %
Physical disturbance	79 %	43 %	3 %
Non-indigenous	53 %	22 %	4 %
Extraction of fish	27 %	37 %	4 %
Bycatch demersal	26 %	35 %	3 %
Bycatch pelagic	18 %	20 %	3 %
Physical loss	23 %	2 %	0 %
Impulsive noise	11 %	17 %	3 %

Note: See note in Figure 4.1.

Source: ETC/ICM (2019).

and impacts on the structure and functioning of the marine ecosystem (Jackson et al., 2001).

Overexploitation of commercial fish and shellfish stocks continues across Europe's seas. The fishing mortality rates (i.e. fishing pressure) and reproductive capacities (i.e. spawning stock biomass) of all commercially exploited stocks across all EU marine regions need to be compatible with having population biomass levels that are above those capable of producing maximum sustainable yield ([1]) (MSY) by 2020 as part of fulfilling the MSFD's 'good environmental status' (GES) objective for descriptor 3 on 'commercially exploited fish and shellfish'. However, 44.8 % of the assessed stocks do not meet either of the two GES (primary) criteria, although there are significant differences between regions. It should also be noted that it is only possible to assess 10.5 % of the exploited stocks against both of the criteria, and 39.3 % against at least one of them (Table 4.1).

The North-East Atlantic Ocean and the Baltic Sea have been showing progress towards achieving the 2020 goal, due to improved management decisions (Zimmermann and Werner, 2019). Thus, only 17.7 % and 37.5 % of the North-East Atlantic Ocean and Baltic Sea assessed stocks, respectively, did not meet any of the above-mentioned GES primary criteria in 2017 (Table 4.1). In contrast, 93.9 % and 85.7 % of the Mediterranean Sea and Black Sea assessed stocks, respectively, did not meet any of the above-mentioned GES primary criteria in 2016 (Table 4.1). Therefore, these seas remain highly overfished (FAO, 2018) and there have been no visible effects of the common fisheries policy (CFP) since 2003 (Jardim et al., 2018).

Table 4.1 Environmental status of commercially exploited fish and shellfish stocks in relation to meeting two of the primary criteria that define the MSFD's 'good environmental status' objective for descriptor 3 on 'commercially exploited fish and shellfish'

Stocks in relation to meeting two of the primary criteria defining the MSFD's GES objective: achieving (1) a fishing mortality and (2) a reproductive capacity compatible with having population biomass levels above those capable of producing MSY	North-East Atlantic Ocean	Baltic Sea	Black Sea	Mediterranean Sea	EU
Percentage of stocks for which it is possible to assess whether **both** of the GES primary criteria are met out of all exploited stocks	16.0	5.0	0	0	**10.5**
Percentage of stocks for which it is possible to assess whether **at least one** of the two GES primary criteria are met out of all exploited stocks	36.4	40.0	77.8	41.8	**39.3**
Percentage of assessed stocks meeting **both** the GES primary criteria	44.1	12.5	0	0	**26.7**
Percentage of assessed stocks meeting **either** of the two GES primary criteria	38.2	50.0	14.3	6.1	**28.5**
Percentage of assessed stocks meeting **at least one** of the two GES primary criteria	82.3	62.5	14.3	6.1	**55.2**
Percentage of assessed stocks **not** meeting **either** of the two GES primary criteria	17.7	37.5	85.7	93.9	**44.8**

Notes: The MSFD includes a third primary criterion to determine GES in relation to descriptor 3 on 'commercially exploited fish and shellfish' (i.e. on the age and size structure of the populations of fish/shellfish (cf. EU, 2017a)), but, at present, there is no agreed EU-level method to assess it, hence it is not included here.

The first two rows are based on the total number of commercially exploited fish/shellfish stocks landed across Europe's seas (295 stocks). Out of these, some stocks can be assessed using any of the two GES primary criteria for descriptor 3 (116 stocks), some by standards other than GES (52 stocks), and some are not assessed at all (127 stocks).

The last four rows are based on the number of commercially exploited fish/shellfish stocks for which one and/or two of the primary criteria used to determine GES for descriptor 3 can be assessed (116 stocks).

Data gaps remains for many stocks.

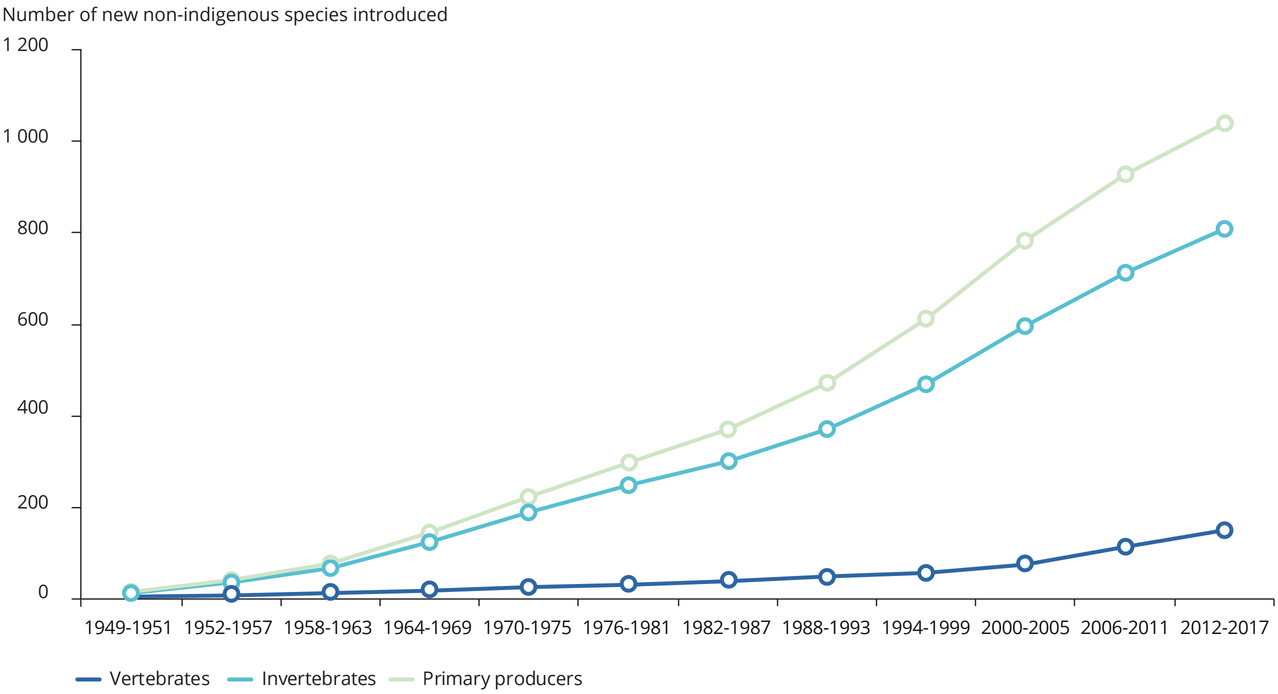
For more detail and full methodology, please refer to EEA (2019e).

Getting an overview of the spatial, benthic footprint of EU fisheries remains very difficult. However, 86 % of the assessed seabed in the Greater North Sea and Celtic Seas shows evidence of physical disturbance by bottom-touching fishing gear. 58 % of the area is highly disturbed, and the recoverability of seabed habitats is questionable (OSPAR, 2017a). Fishing pressure affects threatened habitats, such as sea-pen and burrowing megafauna communities and seagrass beds. At the scale of Europe's seas, 79 % of the coastal strip area and 43 % of the shelf area are estimated to be physically disturbed (by different pressures) (Figure 4.2). 35 % of the shelf area is disturbed by fisheries alone (ETC/ICM, 2019).

Most forms of fishery produce by-catch of non-target species: marine mammals, turtles, seabirds, sharks, rays and skates, other fish species and benthic biota (Lewison et al., 2014). A global study has shown that by-catch is the main reason for population decline for 93 % of marine mammal species (Avila et al., 2018). By-catch is the main pressure for all of the threatened species of sharks, rays and skates in Europe's seas, where 32-53 % of all species are threatened (Nieto et al., 2015). By-catch is a threat for dolphins and benthic sharks in both the Black Sea and the Mediterranean Sea. There is a large by-catch of seabirds in the Iberian coast, Greater North Sea and the Baltic Sea (Žydelis et al., 2009, 2013; Anderson et al., 2011; Lewison et al., 2014). The Mediterranean Sea is a hot spot for the by-catch of turtles (Saidi et al., 2012; Wallace et al., 2013). Overall, by-catch of marine mammals, seabirds and non-commercial fish remains a major threat (OSPAR, 2017c; HELCOM, 2018c).

The EU has not yet met the politically agreed targets for commercially exploited fish and shellfish species, whether defined by the CFP (EU, 2013), the EU biodiversity strategy to 2020 (EC, 2011) or the MSFD. In short, all the populations of these species across all EU marine regions are still required to achieve the MSFD GES objective for descriptor 3 on 'commercially exploited fish and shellfish' by 2020. Achieving these targets and reducing sea floor impacts from fishing gear are among the biggest challenges (apart from limiting the extent of the climate crisis) facing the governance of Europe's seas.

Figure 4.3 **Cumulative number of non-indigenous species in Europe's seas in 5-year periods between 1949 and 2017**



Note: The analysis is made at the pan-European level and is shown in 5-year periods. Numbers are shown for vertebrates, invertebrates and primary producers.

Source: EEA (2019g).

4.2.2 The number of non-indigenous species continues to increase in Europe's seas

Marine non-indigenous species have established in Europe's seas since early human migrations (Figure 4.3). Of the 1 223 non-indigenous species identified in Europe's seas, 1 039 (81 %) were introduced in the period 1949-2017 (EEA, 2019g). Looking only at EU waters, the number in 2012 was less, with 824 species (Katsanevakis et al., 2014). Most of the species are harmless or localised in their distribution. About 87 species are invasive, and they spread in Europe's seas, often competing with native species and disrupting ecosystem structure and functioning (Katsanevakis et al., 2014).

4.2.3 Underwater noise is a threat

Adverse effects of underwater noise on marine biota have been known for a long time, but their estimation — by operational monitoring of sound levels or activities causing noise — has been difficult (Tasker et al., 2010; Van der Graaf et al., 2012). Based on mapping of maritime traffic in Europe's seas, a recent assessment estimates that 91 % of the area is exposed to continuous shipping noise and 10 % is exposed to high shipping density. Impulsive noise from impact piledriving from construction, seismic exploration with airguns, explosions and high-frequency sonar systems is spatially more restricted but is still found in 8 % of Europe's sea area. Although the level of adverse effects cannot be depicted from the coverage, it is clear that noise is the most widely spread human-induced pressure. The current gap in the knowledge of ecosystem effects will probably soon be solved when national and regional sound monitoring results are integrated and the results compared with ecosystem vulnerability (Tasker, 2016).

4.2.4 Marine litter causes harm to marine species and ecosystems

Marine litter is present in all marine ecosystems. Accumulation of plastics, metals, cardboard and other waste material on shores, the seabed and surface waters has been observed from all the European marine regions (Zampoukas et al., 2010; Pham et al., 2014; Siegfried et al., 2017). Plastics constitute up to 95 % of the waste that accumulates on shorelines, the sea surface and the sea floor. The majority of the plastic litter items are packaging, fishing nets, small pieces of unidentifiable plastic or polystyrene (Pham et al., 2014). Litter pollution harms marine animals through entanglement, clogging of digestive systems (via ingestion) and physiological alterations. Potential effects at the population/food web level are not well investigated (Rochman et al., 2013). Land-based sources contribute the largest proportion of litter, which is mostly transported by rivers or directly discharged from coastal activities, e.g. tourism. The main marine sources of litter are fisheries, aquaculture and shipping.

4.3 Land-based pressures impact Europe's seas downstream

Land-based pressures include pollution from the catchment area and the coast, loss of seabed habitats due to coastal development, and disturbance of sensitive species and habitats as a result of human presence. Spatially, the pollution by nutrients and hazardous substances is more widely spread than the human-induced physical disturbance and physical loss, which are both more common in coastal waters than offshore (Figure 4.4).

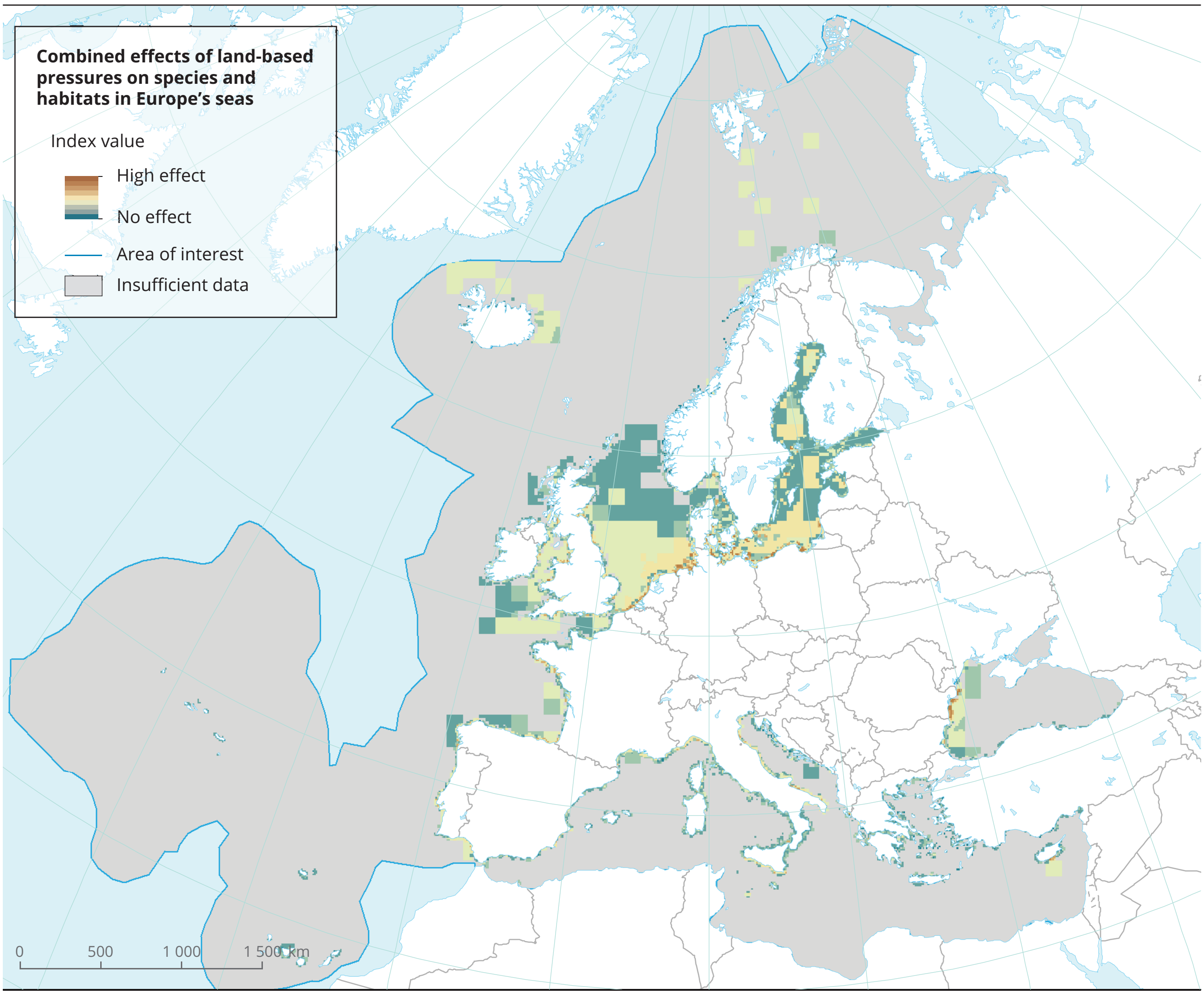
Two of the major pressures are eutrophication caused by inputs of nutrients and organic matter and contamination caused by discharges, losses and deposition of persistent organic pollutants, heavy metals and radioactive substances. Although some of the pollution inputs originate from atmospheric deposition (some hazardous substances and nitrogen oxides) and sea-based activities (i.e. shipping, oil and gas extraction and resuspension of sediments caused by bottom-touching activities), the land-based inputs are the main source of pollution.

Combined effects from land-based pressures are most extensive in the Baltic Sea, coastal areas of the Black Sea, and the southern North Sea. In the Mediterranean and wide areas of the North-East Atlantic Ocean, the continental shelf is narrow and polluting substances disappear into oceanic depths; pollution in these areas is visible only in estuaries, bays and shallower areas (e.g. the northern Adriatic Sea).

4.3.1 Eutrophication — signs of recovery, but reductions in inputs are still required

Eutrophication is a process fuelled by the enrichment of water by nutrients, i.e. nitrogen and phosphorus, leading to increased growth and biomass of algae, changes in the balance of organisms and degradation of the water quality. The consequences of nutrient enrichment and eutrophication are undesirable if they appreciably degrade ecosystem condition and the sustained supply of marine ecosystem services (Ferreira et al., 2011).

Figure 4.4 **Combined effects of land-based pressures on species and habitats in Europe's seas (Map) and frequency of assessment units indicating pressure (*) (Table)**



	Baltic Sea	Black Sea	Mediterranean	NE Atlantic
Eutrophication	87 %	52 %	16 %	13 %
Nutrients	98 %	31 %	42 %	6 %
Direct effects	97 %	92 %	7 %	6 %
Indirect effects	69 %	48 %	10 %	1 %
Hazardous substances	96 %	91 %	87 %	75 %
Water	94 %	79 %	98 %	95 %
Biota	77 %	58 %	32 %	43 %
Sediment	89 %	99 %	89 %	92 %
Hydrographic alterations	16 %	3 %	14 %	6 %
Species disturbance	40 %	22 %	38 %	26 %

Notes: (*) Pressure is assumed if eutrophication or hazardous substances indicate a less than good state.

Source: TC/ICM (2019).

Areas where undesirable effects, such as elevated nutrient concentrations, high phytoplankton biomass, changes or even loss of benthic communities and low oxygen concentrations, have recently been documented on a European scale and are classified as problem areas with respect to eutrophication (EEA, 2019c). Problem areas are caused by nutrients being in the wrong place(s), often in shallow coastal water bodies with long residence time(s). There are region-specific differences in the susceptibility to elevated nutrient concentrations, for example both the Baltic Sea (HELCOM, 2018c) and the Black Sea have a high sensitivity due to their limited exchange with connecting seas.

There are variations in data availability within and between the different regional sea regions (EEA, 2019c). From a total of 2 401 776 km^2 assessed, 1 836 672 km^2 were classified as non-problem areas (76.5 %) and 562 923 km^2 as problem areas (23.5 %) (Figure 4.5). Data availability is in general good in most coastal waters, probably because of monitoring activities anchored in the Water Framework Directive (WFD). For open waters, data availability is good in the Baltic Sea, North Sea and western parts of the Black Sea. In some areas, lack of access to assessment criteria (target values) prevents classification and identification of problem areas. The percentages of assessed areas classified as problem and non-problem areas within different sub-regions can be seen in Annex II (Table A2.2).

All regional seas have problem areas. Some, such as the Baltic Sea, have more than others (it represents 70 % of the total problem areas in Europe; Figure 4.5). To address the problem and to abate eutrophication, there must be a focus on the root causes, i.e. inputs of nutrients. The way forward in lowering the number of problem areas on a European scale is to make additional reductions in discharges, losses and emissions of both nitrogen and phosphorus.

Significant efforts have already been made to reduce nutrient inputs. EU directives, such as the WFD and the MSFD, and regional action plans set out the direction, but in particular the Nitrates Directive, the Urban Waste Water Treatment Directive and the Industrial Emissions Directive are and will be instrumental in achieving cleaner and healthier seas that are unaffected by eutrophication. Signs of recovery have been seen, for example in the Adriatic Sea (Mozetič et al., 2010), in the Baltic Sea (Andersen et al., 2017), in the Black Sea (Yunev et al., 2017), in Danish coastal areas (Riemann et al., 2016) and in the North Sea (OSPAR, 2017c).

These examples show that the cure is well known and that it works, despite time lags in coastal waters and upstream catchments. Thus, this documentation should encourage other Member States or the Regional Sea Conventions to effectively implement relevant action plans and legislation and to continue the work to increase the number of non-problem areas in Europe with respect to eutrophication.

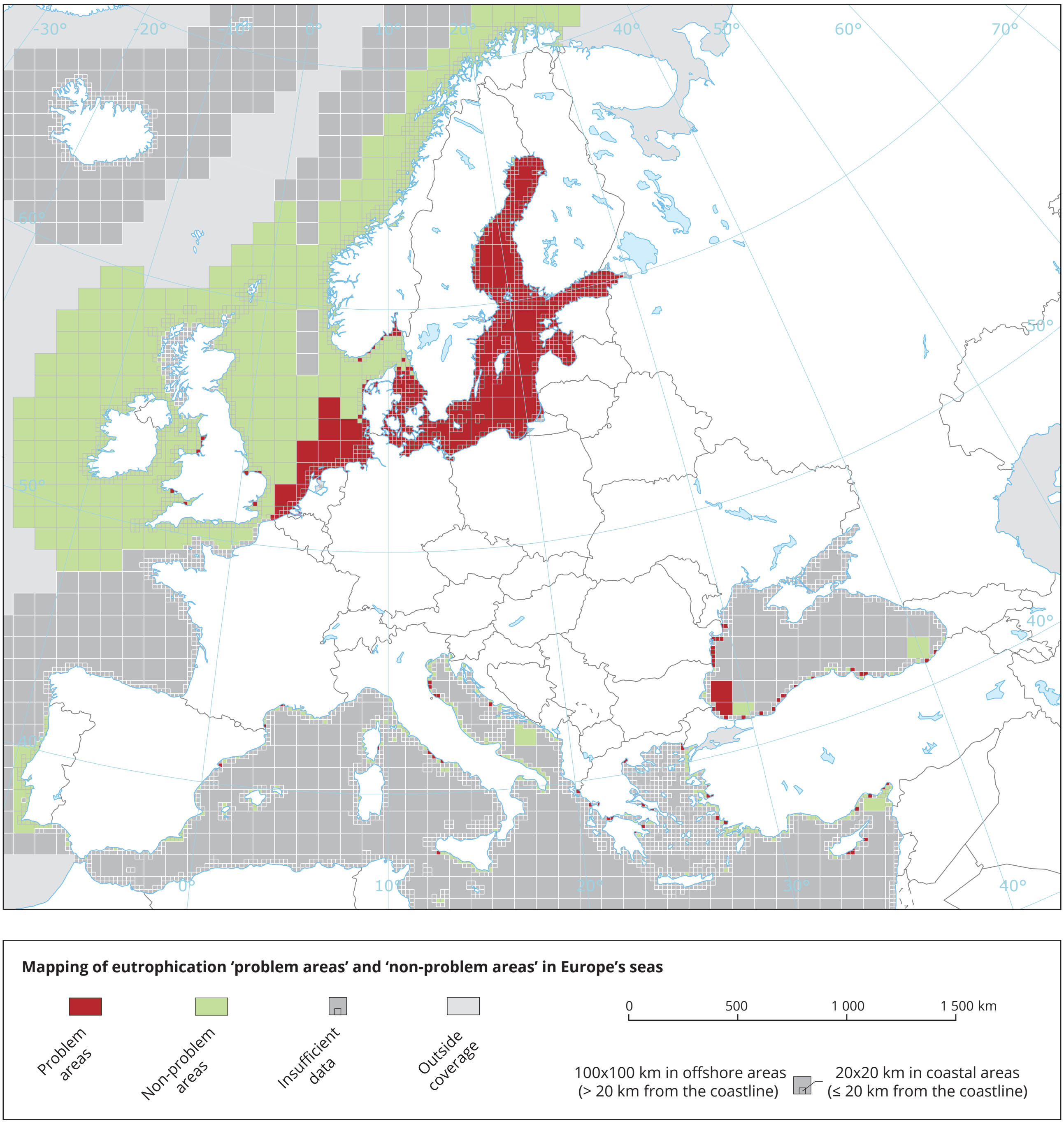
4.3.2 Concentrations of contaminants above politically agreed threshold values are widespread

Human activities may result in discharges, losses and emissions of contaminants such as heavy metals and man-made chemicals — and these substances may end up in the seas around Europe. Contaminants are accordingly widespread in the marine realm in seawater, in sediment and in living organisms, where they may have negative effects.

Areas with elevated concentrations of contaminants and/or undesirable effects of contaminants have been documented and mapped on a European scale, identifying problem areas and non-problem areas with respect to contaminants (using the CHASE+ tool) (EEA, 2018a). A total of 1 481 710 km^2 of seas have been assessed. All regional seas are covered by this thematic assessment of contaminants. Out of these, 1 186 247 km^2 (80.1 %) have been classified as being problem areas with respect to contamination (Figure 4.6). The likelihood of being in a healthy condition, i.e. being identified as non-problem areas, varies among regional seas — the percentage of non-problem areas in the Baltic Sea, the Black Sea, the Mediterranean Sea and the North-East Atlantic Ocean is 3.7 %, 9.2 %, 12.7 % and 25.0 %, respectively (Figure 4.6). The percentages of assessed areas classified as problem and non-problem areas within different sub-regions can be seen in Annex II (Table A2.3).

The data availability is better than anticipated, particularly for coastal waters. The lack of commonly agreed assessment criteria for some substances and matrices has restricted the number of substances included in the classifications and thus the subsequent identification of problem areas. However, given the data available, the degree of contamination seems to differ between the Baltic Sea, the Mediterranean Sea and the North-East Atlantic Ocean (EEA, 2018a). For the Black Sea, the results seem to be related to the substances being monitored as well as to the limited spatial coverage.

Figure 4.5 Mapping of eutrophication problem areas and non-problem areas in Europe's seas



Note: These non-problem area/problem area quality classifications are not directly related to those of status in relevant EU water, marine and nature directives. This is because, inter alia, the tool uses (1) a precautionary approach based on the 'one out, all out' principle when integrating indicators, (2) all available EU and regional-level indicator-based eutrophication information, and (3) EU and regional threshold values (assessment criteria). This is rather than **just** using the status aggregation rules, the information that may have been reported and the quality thresholds under those directives.

Source: Based on EEA (2019c). See Annex II.

Although Europe's seas are still contaminated, it is also clear that for many individual substances, progress has been observed (OSPAR, 2017c; HELCOM, 2018c; EEA, 2018a). Declining concentrations of known individual substances or groups of substances, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), organotins, polybrominated diphenyl ethers (PBDEs) and radioactive materials, can be found in many areas. This may, according to the EEA (2018a), be a direct effect of the advanced and comprehensive policy and regulatory frameworks that have been put in place to reduce contaminants in Europe's environment, as well as of the subsequent preventative actions taken by Member States and industries. Similar findings are observed for European freshwater ecosystems.

This improvement may indicate that some effective measures have been implemented (EEA, 2018a). Such reductions can have a positive and visible impact on ecosystem features.

4.4 Climate change — pushing marine ecosystems to their limits

Human-forced climate change through emissions of greenhouse gases is a global challenge that is driving environmental changes and producing undesirable consequences for ecosystems and dependent human societies (EEA, 2017). It both adds additional stress and exacerbates other pressures on marine ecosystems by influencing the otherwise 'stable' physico-chemical parameters of the ocean (i.e. temperature, pH (ocean acidification) and oxygen content), in other words, the current rate of change is beyond what organisms and ecosystems have experienced in an evolutionary timescale. When those change faster than normal, it can have consequences for life on Earth. Such rapid changes in one or more of these parameters have been linked to the previous five major extinction events (Barnosky et al., 2011). Other impacts from anthropogenic climate change on marine ecosystems, which erode their resilience, such as sea level rise or increased storm frequency, are not discussed here.

4.4.1 Ocean warming changes ecosystems

Since 1850, average sea surface temperature (SST) has increased by 0.6 °C (IPCC, 2019). This ocean warming has been evident since 1980, and has been particularly rapid since 1998 (Cheng et al., 2017), with the ocean absorbing 93 % of Earth's additional heat (Gattuso et al., 2015). These changes are also observed in Europe's seas (EEA, 2016a). Increases in SST lead to changes in species' distribution ranges, abundance and seasonality, and it affects marine food webs (IPCC, 2019).

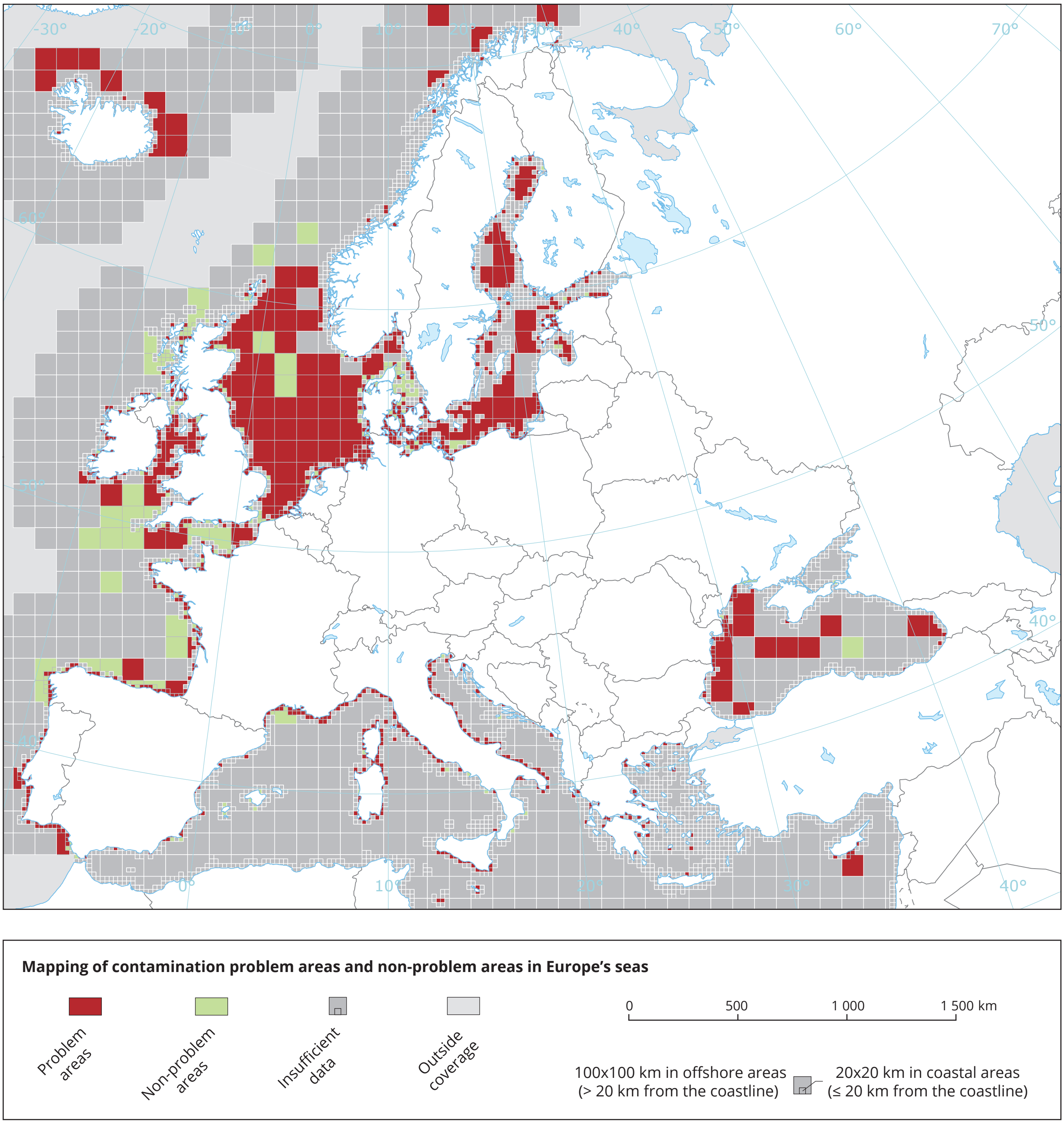
For example, the replacement of cold water species with warm water species — e.g. in fish in the North-East Atlantic Ocean — is already happening (Pinnegar et al., 2013) (Figure 4.7). Similar changes have also been observed for water birds, which, over recent decades, have shifted their overwintering distribution northwards and eastwards out of the United Kingdom (MCCIP, 2013). In addition, changes in the distribution of copepods in the North-East Atlantic Ocean have been observed (Reid et al., 2010). It has also been documented that the seasonality of some species has changed, for example spawning occurs earlier for species such as mackerel and sole (MCCIP, 2013). Temperature changes also occur in deeper or stratified areas, impacting benthic communities, but this is not covered here.

Of more immediate concern are extreme events as illustrated by marine heat waves. These can cause immediate shifts in the distribution of (mobile) species, drive regime shifts and cause local extinctions, indicating that many, including temperate, marine ecosystems may not be resilient to extreme events (Wernberg et al., 2016). One of the first documented mass mortalities in rocky benthic communities originated from the north-western Mediterranean Sea during the summer of 2003. Here, several thousand kilometres of coastline were affected by a marine heat wave with temperatures of 1-3 °C above the climatic values (mean and maximum), and the mass mortality (up to 80 % of the population) of at least 25 species of soft corals (e.g. sea fans) and sponges was observed (Garrabou et al., 2009). Marine heat waves are predicted to increase as a result of further anthropogenic climate warming (IPCC, 2018).

4.4.2 Ocean acidification influences all levels of the food web

Ocean surface pH has declined from 8.2 to below 8.1 (note that pH is expressed on a logarithmic scale; 0.1 pH unit equals 30 % change in acidity) during the industrial era (EEA, 2019d), with the ocean capturing 28 % of the anthropogenic CO_2 emissions since 1750 (Gattuso et al., 2015). Ocean acidification affects marine organisms in multiple ways, including early stage survival and growth. For example, based on samples from the Mediterranean Sea, the planktonic coccolithophore *Emiliania huxleyi* has shown a decrease in average weight in the period 1993-2005 in response to ocean acidification (Meier et al., 2014). Different

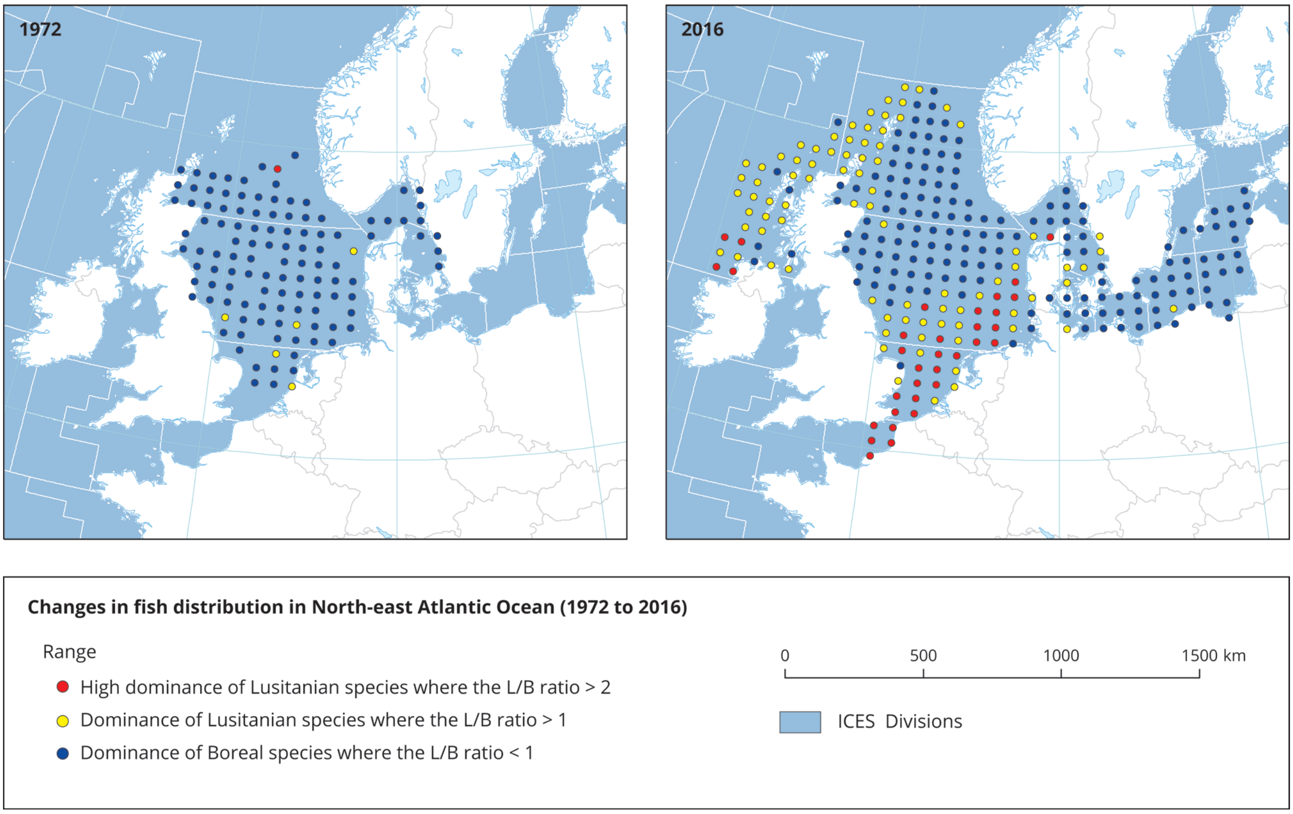
Figure 4.6 Mapping of contamination problem areas and non-problem areas in Europe's seas



Note: These non-problem area/problem area classifications are not directly related to those of status in relevant EU water, marine and nature directives. This is because, inter alia, the tool uses (1) a precautionary approach based on the 'one out, all out' principle when integrating indicators, (2) all available EU and regional-level indicator-based contaminants information, and (3) EU and regional threshold values (assessment criteria). This is rather than **just** using the status aggregation rules, the information that may have been reported and the quality thresholds under those directives.

Source: EEA (2018a). See Annex II.

Figure 4.7 Changes in fish distribution in the North-East Atlantic Ocean, 1972-2016



Notes: Lusitanian (Iberian)/boreal (northern) species ratios (EEA, 2019b).

species exhibit different responses, with potential significant changes to phytoplankton community structures and thus marine food webs (Dutkiewicz et al., 2015). Similarly, 'severe levels of shell dissolution' have been observed in pteropods in the Southern Ocean (Bednaršek et al., 2012). Therefore, the elements of the basic layers of the marine food webs are already showing decreased productivity and structural stress.

Higher trophic levels are also impacted. In more acidic and food-limited conditions, cod larvae in the North-East Atlantic Ocean experience decreased functionality and impairments of organs, as they spend more energy on growth and ossification of the skeletal elements (Stiasny et al., 2019).

In 2005, Orr et al. predicted that conditions that are detrimental to marine organisms in high latitude marine ecosystems could develop within decades. It has been estimated that diatoms contribute up to 40 % of the primary production in the ocean (Tréguer et al., 2018). The pH of the oceans is anticipated to decline by 0.07 to 0.31 pH units over the next 100 years (Gattuso et al., 2015).

4.4.3 The seas are losing oxygen

Oxygen is essential for most life. Since 1960, the oxygen content has declined by 2 % in the global ocean, due to both a decrease in deep ocean ventilation and a decline in oxygen solubility as a result of temperature increases and increased microbial respiration at higher temperatures (Schmidtko et al., 2017; Breitburg et al., 2018). By 2100, it is estimated that dissolved oxygen in the ocean will have declined globally by 1-7 % (Schmidtko et al., 2017). It is estimated that the volume of anoxic oceanic water has quadrupled and that the extent of the oxygen minimum zones has expanded since 1960 (Gilbert, 2017; Breitburg et al., 2018).

In coastal waters, extreme declines in oxygen are often linked to excessive nutrient inputs. Both natural permanent and seasonal oxygen depletion occurs in the Baltic Sea and Black Sea. The lower water layers of the Black Sea are permanently anoxic, but the depth of the surface oxygenated layer has decreased from 140 m in 1955 to less than 80 m in 2016 (Capet et al., 2016; von Schuckmann et al., 2016). In the Baltic Sea, a 10-fold increase in hypoxia happened during the 20th century, i.e. from 5 000 km^2 to > 60 000 km^2 (Carstensen et al., 2014). In the coastal zone, hypoxia has been steadily increasing since the 1950s (Conley et al., 2011). However, significant reductions in nutrient loads into the Baltic Sea in the last couple of decades have slowed the expansion of hypoxia, but the trend is not yet reversed (Carstensen, 2019).

In conclusion, faster than normal long-term changes in temperature, ocean acidification (pH) and oxygen content are now observed across the global ocean (Bindoff et al., 2013). Beside these gradual changes, there are localised, temporal extreme events. The combined effects of anthropogenic climate change 'will likely push' marine ecosystems and individual species to the very limits of their resilience, if not beyond their critical survival thresholds (Gilbert, 2017; IPCC, 2019).

The last chapter will address these challenges by providing a set of solutions for a better future for Europe's seas.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5 Emerging solutions for the future of our seas

Key messages

- We have proven that marine ecosystem condition is directly linked to the combined effects of multiple pressures from the human use of Europe's seas and have come up with a way of identifying the limits for the sustainable use of our seas.
- Up until now, the EU has not managed to decouple the use of Europe's seas from marine ecosystem degradation. The way that we use the natural capital held in our seas does not appear to be sustainable, as already concluded in the EEA's 2015 report *State of Europe's seas*.
- But the EU still has a chance to restore some marine ecosystem resilience piece by piece, which would increase resilience to the climate crisis and to other pressures; although there is an urgent need to act now.
- Past EU and regional policy implementation allows the identification of a set of lessons for restoring marine ecosystems, which should be used when coming up with actions and solutions to achieve clean, healthy and productive seas. General actions to do so are (1) closing the implementation and knowledge gaps, and (2) steering policy implementation towards operationalising ecosystem-based management.
- Several solutions for halting the loss of marine biodiversity and starting to restore some marine ecosystem resilience, while allowing for the sustainable use of Europe's seas, are obvious and readily available under the umbrella of these general actions; they just need to be implemented. These solutions would also support making the ecosystem-based management of Europe's seas more operational.
- Moving towards a 'good condition' for Europe's seas is feasible within the existing EU policy framework by 2030 with political resolve, increasing coordination among stakeholders and policy integration. This needs to start by reducing pressures on marine ecosystems.

At present, the world is destroying or degrading its ecosystems at an unprecedented and accelerated rate. This general trend is also the norm for marine ecosystems, despite some encouraging exceptions. This means that global and EU 2020 policy objectives aiming to halt this negative trend are unlikely to be met and that post-2020 action is currently being discussed at both levels.

The current, generally poor condition of Europe's seas reflects the combined effects of multiple past and present pressures caused by a broad range of human activities. It means that the way we use the natural capital held in our seas does not appear to be sustainable, as already concluded by the EEA (2015b). Marine ecosystem resilience is being worn away piece by piece by the multiple stressors that are degrading and depleting marine ecosystems and, thus, the seas' overall capacity to supply the services upon which we depend.

Most assessed areas have one or more hazardous substances above agreed thresholds, with new substances being developed constantly; eutrophication and related anoxic sea bottoms are widespread in some coastal and offshore areas; non-indigenous species are present in all EU marine regions and continue to arrive; extensive bottom-trawling continues to physically ruin sea floor integrity; the Mediterranean Sea remains the most overfished sea in the world, which degrades the food web within it; marine litter is of growing concern; and noise is present across all coastal areas. Moreover, anthropogenic climate change exacerbates the impacts of the other stressors, potentially leading to abrupt, non-linear and irreversible changes in the current ecosystem regimes.

Overall, each EU marine region faces different challenges, but no region has so far managed to decouple human use from marine ecosystem condition to achieve sustainability. No marine region has yet delivered the legal obligations of achieving 'favourable conservation status' for all its vulnerable marine species and habitats or 'good' marine ecosystem condition, which means that 'good environmental status' across all of Europe's seas, as required by the Marine Strategy Framework Directive (MSFD), is unlikely to be achieved by 2020. Key species groups are in decline, including sharks, rays, turtles and some seabirds, and the composition of fish communities is undergoing rapid change. Meanwhile, our use of the seas is growing and the EU maritime economy is expected to double by 2030. This raises the question of how we balance the climatic and biodiversity crises with our expectations for a sustainable blue economy.

While the crises may seem almost insurmountable in their complexity, there is hope for the future of Europe's seas. Many historical toxic substances have been banned and their concentrations in the environment are decreasing; nutrient inputs have, in some areas, been reduced significantly; introductions of new non-indigenous species seem to be slower than previously; single-use plastics are starting to be phased out, and measures have been put in place to reduce marine noise. And the global community seems more conscious of the climate crisis than ever before, with many actions being taken to reduce emissions of CO_2 and other greenhouse gases.

Slowly, but surely, marine ecosystems are responding with small, fragmented signs of recovery. Seagrasses and invertebrates are reappearing where eutrophication has been reduced; the bluefin tuna has returned to the North Sea after being absent for half a century; the Baltic white-tailed eagle and dog whelks are recovering; some fish stocks in the North-East Atlantic Ocean and the Baltic Sea are recovering; and populations of the Mediterranean monk seal appear to be stabilising.

Therefore, some of the answers to the crisis should be found not only in late lessons from early warnings but also in the emerging lessons from marine ecosystem recovery. These lessons indicate that the EU still has the potential to start restoring marine ecosystem resilience.

Today's challenge is to translate this need for action into clear, integrated policy priorities and pragmatic solutions to further guide the operational governance of Europe's seas over the next policy cycle(s). A key priority should be restoring some marine ecosystem resilience, while ensuring the sustainable use of the sea. The final sections of *Marine messages II* translate the findings of the report into a set of solutions, several of which may be obvious but do not seem to be sufficiently applied. These solutions aim to make ecosystem-based management (EBM) of human activities in the marine environment (Box 1.1) more concrete. This is what is needed to deliver the EU policy vision of clean, healthy and productive seas in practice.

5.1 Lessons from marine ecosystem recovery

The EU has established the most comprehensive marine policy frameworks in the world, resulting in significant, sometimes decade-long, efforts being made by Member States to protect and enhance Europe's seas, including using them sustainably (Table 1.1). The achievements so far in fulfilling these objectives have been illustrated throughout this report and elsewhere (OSPAR, 2017c; HELCOM, 2018c). Analysing these achievements leads to a set of obvious lessons to take into account when acting to overcome the outstanding challenges for Europe's seas (Table 5.1). These lessons should, thus, be used when acting to deliver clean, healthy and productive seas, rather than 'reusing' policy ambitions from one EU policy cycle to the next.

5.2 Acting now for the future of Europe's seas

Table 5.1 shows a set of ready-to-apply general actions to support making the achievement of clean, healthy and productive seas a reality: (1) close the implementation gap; (2) close the knowledge gap; and (3) steer policy implementation towards operational EBM.

5.2.1 Close the implementation gap

As documented by the policy framework put in place, the EU has enough scientific knowledge to identify the challenges facing Europe's seas and to translate the need to overcome them into political visions and objectives. However, the EU has, so far, not managed to decouple the use of natural capital from the degradation of marine ecosystems, i.e. this use is still not sustainable (Box 5.1). This means that these visions and objectives are not being fulfilled. There are several potential reasons for this.

One could be that somewhere within the institutional set-up and implementation process, at the EU, regional and national levels, there is a tension between how different policies or institutions interpret such goals and/or a gap between policy visions and the achievement of objectives through the necessary management measures.

A possible way forward to close this gap would be for the responsible public institutions across different policies (e.g. environmental protection, fisheries, maritime transport, agriculture and waste management) to act in a truly coordinated manner and use the same information platform (so that, for example, marine monitoring can properly inform whether the use of the sea is sustainable). This could help to achieve a better implementation of existing policy and legislative commitments for Europe's seas.

Such coordination could be supported by establishing a **stronger integrative and participatory process**

Table 5.1 Nine lessons from marine ecosystem recovery

Lesson to be acted on	Detail	Action
Trust that policy-based management measures can work	One-to-one measures addressing well-known problems work when implemented fully. Thus, reducing individual pressures and targeting the protection/recovery of individual species/species groups and/or habitats to rebuild some ecosystem resilience piece by piece in cases where cause-effect is direct and known is still a possibility.	Close the policy implementation gap
Evaluate the appropriateness of policy-based management measures	Measures to manage human activities in the marine environment put in place as a result of policy to protect marine ecosystems and biodiversity, or to mitigate pressures upon them, should focus on the predominant stressors and be systematically and periodically evaluated to ensure that they are fit for purpose (and revised if they are not).	
Avoid delays and partial fulfilment of marine policy objectives	Marine policy objectives need to be attained on time and in full, rather than being 'redistilled' into new policy cycles when not met, in order to avoid further delays in marine ecosystem recovery.	
Make the most of the scientific knowledge available when setting marine policy objectives	Europe has a strong scientific tradition, with more than 100 years of observations available to inform decision-making. There is enough adequate scientific evidence to act now to prevent further degradation of Europe's seas and promote their recovery. Full use of the best available scientific knowledge when setting targets or thresholds for the state of marine ecosystems, or the pressures acting upon them, is vital to prevent their continued degradation and limit the challenges faced by future generations.	Close the knowledge gap
Data gaps continue to exist across nature, the environment and living resources. Fill EU-level data gaps through improved monitoring and reporting	Data gaps still exist and need to be closed in order to better inform, plan and act in the future. The information collected and made available by countries at the EU level and the resolution of that information as well as EU-level data harmonisation and quality should be optimised and targeted, so that EU-level assessments can better track progress towards meeting EU policy targets. Establish an EU-supported and coordinated fit-for-purpose monitoring programme for the environment, nature and living resources for each marine region.	
Further integrate and ensure coherence across all EU policies	Policy visions for healthy, clean and productive seas need to be better aligned with expectations for the exploitation of marine, freshwater and terrestrial resources. Full integration within and across all policies using natural capital would better support the maintenance of marine ecosystem capital and the sustained supply of ecosystem services.	Steer policy implementation towards operational EBM
Take into account that the recovery of marine species, habitats and ecosystems takes time and requires sustained efforts	Recovery of marine species, habitats and ecosystems takes time. There can be decades between the realisation of a problem and a policy intervention over actual implementation of management measures to full recovery. It will always be better to prevent damage than to try to reverse it.	
Ensure that policy on the use of marine natural capital does prevent the degradation of marine ecosystem capital	Decoupling the use of marine natural capital from marine ecosystem degradation, as promoted by EU policy, needs to become a reality. Without addressing current pressures adequately, adding more pressures through, for example, increased deployment of maritime activities could push marine ecosystems beyond their limits.	
Understand that working together delivers results	Cooperating at various geographical scales (local, national, regional and EU level) and across scientific disciplines, businesses and countries, and with citizen's is what works to reverse marine ecosystem degradation. This includes increasing the public's 'ocean literacy'.	

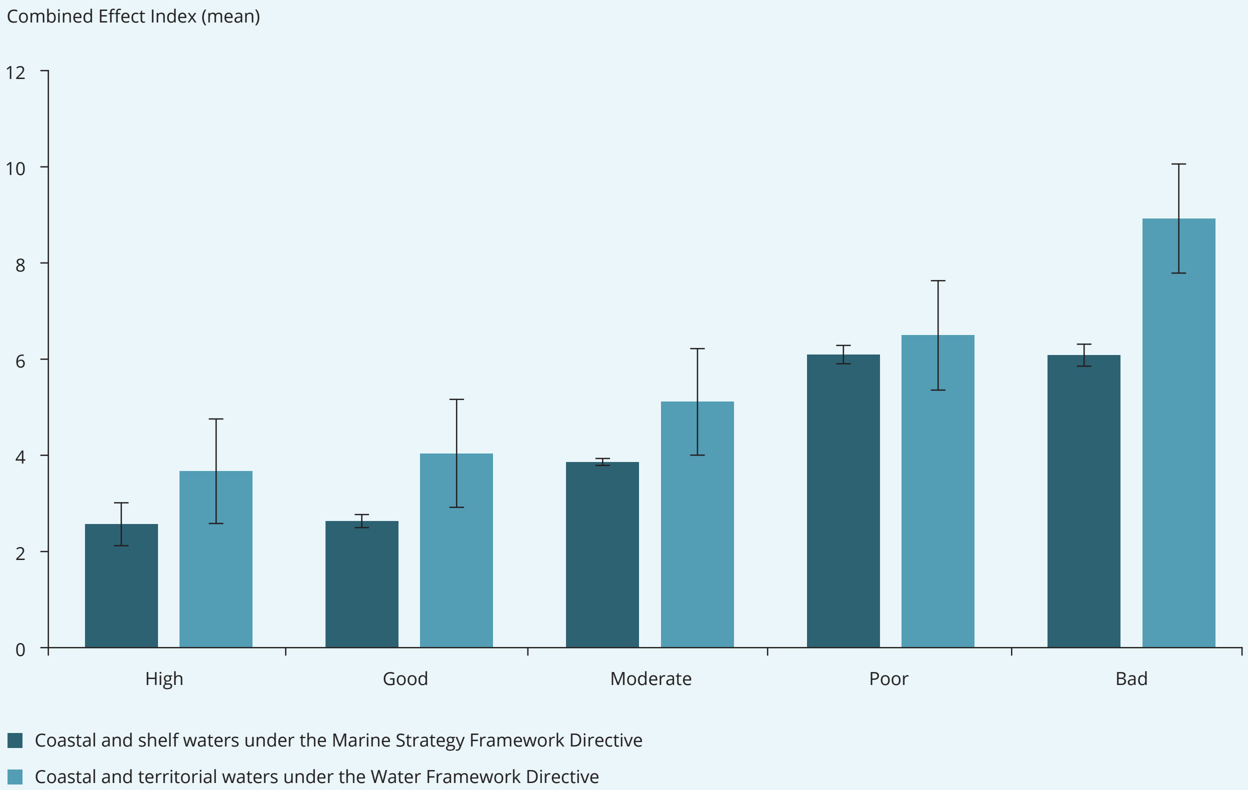
for delivering across different policy objectives. Then, in order to help close the implementation gap, the **targets measuring progress towards these objectives should be strictly based on scientific evidence targets** (rather than, for example, fishing quotas not always being set according to scientific advice) (Carpenter, 2018). In addition, these objectives and targets should be set within a **realistic timeframe** (which may be over several policy cycles, e.g. Box 5.3), so that the relevant management measures can actually deliver. These measures should undergo a **systematically and periodical evaluation** of progress.

Box 5.1 The condition of Europe's seas is a direct function of the intensity of human activities

Traditional approaches to the management of human activities influencing the EU's seas have had a high level of focus on individual species, habitats and individual pressures and sectors, while more systemic approaches have remained elusive in practice. Aiming to make ecosystem-based management (EBM) (Box 1.1) more operational, we have now established the link between human use of the sea and the pressures exerted upon marine ecosystems and their condition, and we have assessed this condition in a spatial context. This work shows that there is a direct link between the combined effects of multiple pressures on marine ecosystems (Figure 4.1) and their condition (Map 3.1). It means that the combined effects of multiple pressures from human activities could be used as a proxy for marine ecosystem condition under certain premises. It also means that the way forward to improve marine ecosystem condition is to decouple the combined effects of multiple pressures from human activities from ecosystem degradation.

The darker blue bars show the condition of coastal and shelf waters, as defined by the Marine Strategy Framework Directive (MSFD), is dependent on the pressures affecting them, while the lighter blue bars show the same dependency for the 'ecological' and/or 'chemical' status of coastal (up to 1 nautical mile from shore) and territorial (up to 12 nautical miles from shore) waters, as defined by the Water Framework Directive (WFD). These links between condition and impacts can be considered a ground-truthing of the pressure index (Figure 4.1), regarding both the assessment method and the quality classifications of 'ecological status' formally reported under the WFD. The approach builds on information collected under the MSFD, the WFD, the common fisheries policy (CFP), the Birds Directive and the Habitats Directive, as well as initiatives under the integrated maritime policy (e.g. the European Marine Observation and Data Network (EMODnet)) and others. It would allow bridging between the different approaches used to assess the condition of the marine waters under the WFD and MSFD.

Therefore, the spatial tools describing the combined effects of multiple pressures (Figure 4.1) and the multi-metric indicator-based tools used in this work (Map 3.1; Figure 3.1; Figure 4.5; Figure 4.6) provide a spatial decision-making platform developed within the EBM concept. This platform can be used to discuss and decide on sustainable uses of the sea and efforts towards restoring marine ecosystem resilience. Thus, for example, it allows the determination of what pressure reductions would be needed to fulfil a certain ecosystem condition in a specific area, as required to achieve, for example, MSFD good environmental status (GES). **It, ultimately, allows the identification of the limits for the sustainable use of Europe's seas**.



Lack of progress should trigger the instalment of further measures. Doing all this does not require new policies/legislation but an empowerment of public institutions, so that they adequately address politically agreed commitments.

This increased empowerment would ensure that adequate funding is available to deliver the individual objectives by the agreed deadline. The recent environmental implementation review estimated that the environmental implementation gap costs around EUR 55 billion per year (EC, 2019c) — a figure that is likely to increase if the capacity of marine ecosystems to supply services degrades any further. It is beyond the scope of this report to delve deeper into what adequate financing means — although decoupling the use of the sea from ecosystem degradation would be a **win-win** situation for both nature and European society.

5.2.2 Close the knowledge gap

If the EU is to make the required change to achieve clean, healthy and productive seas, while allowing for their sustainable use, it needs **data and information** to facilitate the change now and in the future. This is in regard to **closing the information gaps** in the implementation of existing legislation, but also in regard to better informed EBM. This will require not only **better use of existing data** but also **new data**. This includes making use of **novel ways** that are available for collecting, analysing and presenting information, while ensuring that existing gaps are closed. But to achieve real progress, the EU and its Member States need to have **better knowledge** overall. This includes becoming better at **evaluating the measures** put in place to manage human uses of Europe's seas, i.e. to check whether progress stays in line with expectations and to be able to react if not. A condition for this is to make **evidence-based decisions** for setting environmental targets and threshold values to determine 'good' ecosystem condition.

When looking across Europe's seas there are a lot of data collected at the national level, in particular in coastal waters. There is also a range of EU-supported data collection initiatives in place for marine areas. However, these are not always coordinated within regions or designed to support marine and maritime policies. The information is also not always easily available for EU-level assessments. As a result, gaps remain within and between regions in the thematic areas looked at, and there is a high level of 'unknowns' across formal reporting (Box 5.2). Such issues make a consistent EU-level assessment and evaluation of different thematic topics more difficult than necessary.

Where information has been collected consistently over an extended period and within a common monitoring framework for an entire marine region (large-scale

Box 5.2 Dichotomy between required knowledge components and funding mechanisms

The EU supports a variety of data collection initiatives, such as the European Marine Observation and Data Network (EMODnet), the data collection framework on fisheries, the EU strategy for marine and maritime research and Copernicus, to mention but a few. However, when it comes to direct support of the implementation of EU legislation, there appears to be a disconnect between policy needs and the information available (e.g. see Table 4.1).

A large proportion of the formal EU nature/environmental/resource legislative reporting still includes many instances of 'unknown', 'not assessed', etc., despite there having been decades of implementation efforts. For example, 'conservation status' under the Habitats Directive is reported as 'unknown' for 42 % of marine species assessments for coastal waters and 54 % and 83 % for shelf and open ocean waters, respectively (EEA, 2015b). Similarly, for a high proportion of commercially exploited fish and shellfish, i.e. 60.7 %, it is not even possible to assess whether they meet at least one of the two criteria for assessing the Marine Strategy Framework Directive's (MSFD's) good ecological status (GES) for which EU-level assessments are available (Table 4.1). Worse still, there is no available information at all to assess (1) whether those GES criteria are met for any stocks in the Macaronesian marine (sub)region; and (2) whether the third primary GES criterion on fish stock age and size structure is met at the EU level. Similarly, EMODnet has been designed to deliver data and data products that underpin the implementation of the MSFD. However, of the 37 case studies provided on the use of EMODnet data, not a single one refers to EMODnet data products that are being used for MSFD implementation (EMODnet, 2017).

Therefore, a dichotomy between policy requirements/obligations and marine knowledge and available funding continues to exist. A solution would require an improvement of existing structures or a novel institutional reorganisation to implement a joint, fit-for-purpose, EU-supported environment/nature/ living resource monitoring programme and the related infrastructure. The key elements are that the initiative delivers the data and information needed to implement EBM as defined by the EU policy framework and that it allows for appropriate EU responses to future systemic challenges.

ecosystem) and is used for decision-making, it has enabled monitoring of progress towards recovery (Figure 3.2). It has also contributed to a better understanding of the systemic challenges faced (e.g. Figure 4.7) and has informed the measures needed to achieve recovery (Box 5.3).

Given the urgency and complexity of the crisis faced, the time has come to move away from petty information exchange challenges and embrace the strong scientific heritage that resides within Europe. Indeed, the time has come to harvest the good lessons learned from the common fisheries policy's (CFP's) data collection framework and the way that Copernicus is organised.

The latter has delivered solid information to, for example, enable the recovery of fish stocks in the North-East Atlantic Ocean. The time has come to better align project-based, ad hoc funding towards a more consistent, long-term, EU-supported and -coordinated monitoring programme for the environment, nature and living resources in each marine region, as was done so successfully for parts of the fisheries management. A fit-for-purpose monitoring programme designed to systematically inform the components of the CFP, the integrated marine policy (IMP) and the nature directives, and placed within an EU organisation is needed. If done systematically, it could enable the EU to act more effectively and plan for the complex 'systemic' challenges faced.

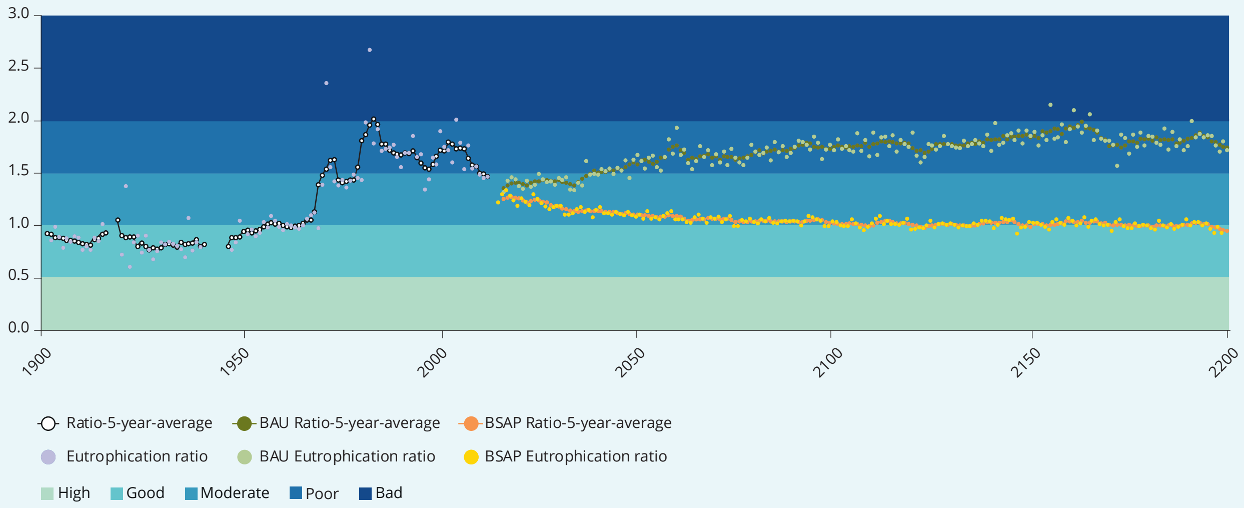
A starting point could be a better alignment of funding under the IMP (or the CFP), i.e. the European Maritime and Fisheries Fund, to directly support both the blue economy and the achievement of the MSFD's GES at the same time. This could focus on closing the gap between the information made available under

Box 5.3 The value of long-term data for informing the future

Europe has a strong scientific heritage, which, for some marine areas, has provided environmental observations covering more than 100 years. Such data sets not only enable taking a historical view of past ecosystem conditions but also show how this condition has evolved over the course of the last century as human activities have accelerated. When combined with modern modelling approaches, this type of data set can become very useful for the development of evidence-based targets to prevent further environmental degradation and to promote recovery.

Based on a combination of monitoring data for the period 1901-2012 and numerical modelling for the period 2013-2200, the long-term eutrophication status and the likelihood of meeting agreed policy objectives in the Baltic Sea can be assessed. At the same time, the power of large monitoring data sets in combination with scenario modelling can be demonstrated.

The best-case scenario represents an implementation of the HELCOM Baltic Sea Action Plan (BSAP) from 2007, whereas in the worst-case scenario (business as usual, BAU) no actions are taken and agricultural activities are intensified in countries of the south-eastern parts of the Baltic Sea drainage basin. A key point is that implementation of the BSAP and the related management measures will eventually result in a Baltic Sea unaffected by eutrophication.



Source: Based on Andersen et al. (2017) and Murray et al. (2019).

EMODnet and the formal reporting under the MSFD. Such an initiative could link existing national monitoring programmes that focus on establishing a consistent long-term component to close persistent information gaps within and across regions, i.e. at an EU level. The policy alignment could also include strengthening the evaluation of selected, existing measures, e.g. the effectiveness of marine protected areas (MPAs), or link measures such as maritime spatial planning and achieving GES. The improved alignment could, thus, alleviate the existing tension between these instruments by helping all stakeholders to close the knowledge gap as required when planning for future needs.

5.2.3 Steer policy implementation efforts towards an operational systems approach

When trying to steer towards a systemic approach aiming to achieve long-term sustainability, one needs to realise the various **temporal and spatial scales** involved in achieving current targets and future visions. **Recovery** of marine species, habitats and ecosystems **takes time**. There can be decades from the realisation of a problem, through the required policy intervention(s), to the actual implementation of management measures and full recovery (Box 5.3).

Another element is to better align policy visions for clean and healthy seas with the expectations for the exploitation of marine, freshwater and terrestrial resources, given all impacts on the marine environment. Therefore, **full integration within and across all policies** influencing natural capital would better support the maintenance of marine ecosystems, allowing for future sustainable use. To achieve such integration, **cooperating at various geographical scales** (local, national, regional and EU-level), ***across scientific disciplines, businesses and countries and with citizens*** is more relevant than ever for halting ecosystem degradation.

5.3 Solutions to achieve clean, healthy and productive seas are readily available

The three general actions to support making the achievement of clean, healthy and productive seas a reality can be further specified in a series of practical solutions that fit within an EBM context.

5.3.1 Characterising solutions

These solutions link to the implementation of EU marine policy, both environmental and economic, and are ready to apply (Table 5.2). Although several are well known, or obvious, for their positive effects on the marine environment, the current, generally poor condition of marine ecosystems across Europe's seas indicates that they are not yet sufficiently implemented.

There are three overall premises for these solutions:

- All EU policy objectives should be checked against their effectiveness in contributing to delivering life and the growth of people and economies within the 'planetary boundaries'.
- Human activities with the potential to impact marine species, habitats and ecosystems need to be compatible with achieving the objectives of the corresponding EU environmental legislation, i.e. the WFD, the MSFD, the Birds Directive and the Habitats Directive, rather than with the derogations and exceptions also included in this legislation (or its non-compliance). They should be authorised through a strict reversed burden of proof, whereby operations should not take place until compliance with the objectives of these directives is proven.
- The implementation of existing EU policy objectives aiming, directly or indirectly, to protect and enhance marine species, habitats and ecosystems should be fully enforced.

The list of solutions is not exhaustive but comprises a set of examples paving the way towards 2030, and they do not consider the EU's global footprint. Several of these examples may appear drastic, but they just reflect the magnitude of the current degradation of marine ecosystems and their services. Some of these solutions may only be temporary. Profound changes are needed in the way we use Europe's seas to prevent their further degradation, restore their resilience and achieve their sustainable use. These changes involve an unprecedented level of socio-economic adaptation, such as in terms of production and consumption, which needs to be accommodated in the framework of the current transitions to sustainability.

Nevertheless, these solutions build on current structures that, so far, have failed to decouple sea use from marine ecosystem degradation. Given the

Table 5.2 Examples of ready-to-apply solutions to achieve clean, healthy and productive seas

Topic	Solutions
Species	• Apply spatial measures to protect both common and vulnerable species, e.g. MPAs, ship speed reduction corridors, and not only those species within the scope of EU nature protection legislation. • Stop fisheries by-catch of non-target species such as turtles and dolphins.
Seabed habitats	• Rewild seabed habitats in x % of the area (of the national marine waters) in each EU marine region (and not only in MPAs), including nursery/foraging areas for fish and other migratory species, by e.g. restricting human activities causing physical loss and physical disturbance, and restoring degraded seabed habitats.
Marine protected areas	• Close remaining gaps (offshore, deep sea) within existing MPA networks. • Ensure all MPAs have adequate management plans and evaluate their effectiveness. • Increase MPA effectiveness by designating a significant proportion (x %) of the MPA network in which: the operation of extractive activities, e.g. fishing and mining, is severely restricted; no activity is allowed, i.e. establish reserves/no-take sites to rebuild ecosystem resilience.
Non-indigenous species	• Maintain or restore marine food webs, by ensuring an abundance of top predators, and still-natural habitats to avoid open 'ecological niches', as these can promote proliferation of non-indigenous species.
Commercially exploited fish and shellfish stocks	• Adhere to science-based quotas for the commercial exploitation of fish and shellfish stocks for which there is sufficient information to do so, and do not allow exploitation of data-limited stocks. • Improve stock monitoring and assessment to enable setting science-based quotas for all commercially exploited stocks. • Allocate more fishing opportunities to low impact fleets and gear. • Ban the most harmful fishing practices, including bottom trawling in coastal areas. • Dedicate adequate resources to stop illegal, unreported and unregulated fishing in EU waters. • Remove or prevent harmful fishing subsidies.
Nutrients	• Minimise losses of nutrients from agriculture and other land uses in upstream catchments, especially in vulnerable areas such as river valleys, to improve ecosystem condition downstream. • Use and implement science-based, region-wide nutrient reduction targets. • Reduce direct discharges into the sea by, for example, avoiding intensive fish farming in shallow and enclosed coastal and other vulnerable areas.
Contaminants	• Optimise all possibilities for the reduction of contaminants at source to minimise losses into the sea, by keeping strengthening and supporting the REACH system, so that it delivers on the substitution of hazardous substances in pesticides and other products. • Reduce direct discharges into the sea where relevant and feasible by, for example, updating waste water treatment to treat important contaminants that are currently not treated, such as pharmaceuticals.
Marine litter	• Dedicate adequate resources to enforce the ban on single-use plastics and the proper disposal of vessel garbage (e.g. plastic containers, nets) at sea, which is linked to the use of port facilities. • Ensure that the REACH system and the WFD surface water monitoring cover microplastics. • Reduce direct discharges into the sea by: banning micro-/nanoplastics in hygiene, cosmetic and other relevant consumer products; intercepting plastics at river mouths and improving waste water treatment to ensure that water effluent and sewage sludge are micro-/nanoplastic free.
Noise	• Optimise all possibilities for limiting marine noise, such as ship speed reductions, using quieter alternatives to piledriving and seismic surveying, and limiting military training to specific areas.
Climate crisis	• All efforts to stay within an increase of 1.5 °C remain top priorities. • Restore seabed habitats with a high capacity for CO2 capture, such as seagrass meadow, biogenic reefs and soft-bottom invertebrate communities, to historical levels to re-establish such capture.
Knowledge	• Establish an EU-supported, long-term joint data collection framework for environment and nature to ensure the necessary time series, data harmonisation and closure of gaps in EU-level information to improve assessments of policy effectiveness and help plan and act for the future. • Promote ocean literacy within the EU to ensure the responsible behaviour of society towards the seas.
Funding sustainability	• Dedicate a balanced proportion of the European Maritime and Fisheries Fund to supporting all components under the IMP with a view to ensuring the long-term maintenance/restoration of marine ecosystems. It may require the development of supportive legislation.
Monitoring	• Introduce a fit-for-purpose policy monitoring programme designed to systematically inform the components under the CFP, the IMP and the nature directives with regard to methods, timing and baselines.

increase in maritime activities expected in the next decade, more advanced solutions will be needed to ensure that, in the future, the EU operates within the limits of Europe's seas. We need solutions that apply an approach that can simultaneously address anthropogenic climate change, biodiversity loss and the overuse of natural resources by bringing all the individual pieces together. A good place to start is with the current EU policy framework.

5.3.2 Operationalising solutions

The solutions identified to deliver the EU policy vision of clean, healthy and productive seas in practice must build upon existing governance structures. They must be seen as a way of making EBM (Box 1.1) more concrete. Thus, within the marine and maritime policy acquis (Table 1.1), the EU has taken the first important step towards EBM. This has been done to achieve integration, in this case between all aspects of the system, although its operationalisation is not yet a reality. It requires a different mindset to encompass multiple uses/sectors/activities and the combined effects of their pressures on marine ecosystems and their capacity for service supply (Crain et al., 2009). This includes handling resilience as well as multiple management objectives and the trade-offs that occur between ecological, social and economic factors at the scale of EU marine regions (Knights et al., 2014). This is a big challenge compared with addressing a single sector or pressure, individual species or habitats, or single marine ecosystem services. Moving away from single interests to embracing many in a structured manner requires a new mindset for all involved at local, national, regional and EU levels.

Key to accommodating all these interests, with the 'common good' in mind, includes evolving and applying a pragmatic, structured approach to EBM. The spatial and indicator-based tools used throughout this report deliver a novel, albeit advanced, methodology for supporting such a process. They operate within the current policy framework regarding the use of and established targets for environmental condition. They could be further applied to provide different scenarios for condition versus use, e.g. to help inform discussions of whether future use in a given region stays within the boundaries of the seas.

However, the tools do not deliver the stakeholder process or the full spatial dimension of the implementation aspects to achieve 'good' condition. For this, a holistic approach to maritime spatial planning (MSP) needs to be implemented, i.e. MSP that contributes to sustainable development and supports the achievement of 'good environmental/ecological/conservation' status across entire ecosystems and/or marine sub-regions, while balancing all stakeholder interests within these ecological limits. Therefore, the tools used in this report could be combined with a flexible, adaptive MSP zoning approach (Cameron and Askew, 2011), guided by spatial requirements for both human use and nature conservation (see examples in Table 5.2). This could be key for making EBM more operational in EU waters. Using the ecosystem services approach would also help, as this provides a shared perspective on the uses of the sea (Section 2.3).

5.4 So, what will the future hold for Europe's seas?

Marine messages II shows that many areas across Europe's seas are not in 'good' ecosystem condition and that disturbing systemic changes are occurring because of the combined historical and current effects of human use. Past trends demonstrate continued ecosystem degradation whereby human use of the sea has not been decoupled from impacts on ecosystem condition. These areas have limited, if any, extra capacity for increased use if they are to continue to deliver the ecosystem services upon which Europe depends. Predicting the future remains precarious at the best of times — however, as shown throughout this report, there is enough quantitative information available to indicate that urgent, meaningful action is needed.

Thus, despite the observed instances of marine ecosystem recovery, the sheer scope of the climate (IPCC, 2019), biodiversity (IPBES, 2018, 2019) and resource (IRP, 2019) crises indicates that the need for urgent action remains if we are to stay within the ecological limits of our seas. The findings of this synthesis, and others (OSPAR, 2017c; HELCOM, 2018c; Jardim et al., 2018; Lotze et al., 2019), support the understanding that these crises are also affecting Europe's seas, despite the comprehensive policy framework already in place (Table 1.1). Further degradation of Europe's marine ecosystem structures, processes and functions is to be avoided if we want to sustain their capacity to supply the services and associated benefits upon which we depend. This is a must to avoid the potential impacts on our prosperity and quality of life (Box A1.1).

Therefore, Europe stands at a crossroads — a crossroads where it needs to make the choice between its political aspiration of achieving clean, healthy and productive seas and delivering this vision. In the end, it remains a political choice to complement long-term visions with fully fledged sustained support for their implementation. The EU can still make the choice to halt the loss of marine biodiversity and start restoring some marine ecosystem resilience piece by piece, while allowing for the sustainable use of its seas. We stress that this all needs to start by decoupling the use of the sea from ecosystem degradation and, thus, reducing pressures on marine ecosystems (Box 5.1).

The recovery of several vulnerable marine species, common marine species groups and even marine habitats in direct response to informed management actions and measures indicates that the EU is still able to start restoring some of the lost resilience of its marine ecosystems. This could happen piece by piece by reducing individual pressures and targeting the protection/recovery of individual species/species groups and/or habitats in cases in which the cause and effect is direct and known. Such a piece-by-piece approach is a way of supporting the overall restoration of marine ecosystem resilience, which is needed for the sustained supply of marine ecosystem services and the associated benefits they deliver to people. Realising this chance requires, among other things, applying management measures that have been solely informed by science; reducing the single and multiple pressures acting upon specific marine species and habitats; adequate implementation of policy-based restoration objectives; and enough time, often measured in decades, to allow for full recovery.

The observed instances of marine ecosystem recovery also show that, when the EU applies an evidence-based approach as the foundation for the management of human activities in Europe's seas, such recovery and, thus, increased marine ecosystem resilience is achievable. This should not be incompatible with the sustainable use of the sea nor with Europe's seas being clean, healthy and productive.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Abbreviations

BAU	Business as usual
BSAP	Baltic Sea Action Plan
CEA	Cumulative effect assessments
CFP	Common fisheries policy
CICES	Common International Classification of Ecosystem Services
Devotes	Development of innovative tools for understanding marine biodiversity and assessing good environmental status
DG MARE	Directorate-General for Maritime Affairs and Fisheries
DDT	Dichlordiphenyltrichlorethane
EAP	Environment Action Programme
EBM	Ecosystem-based management
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
EMODnet	European Marine Observation and Data Network
ETC	European Topic Centre on Inland, Coastal and Marine Waters
EU	European Union
GES	Good environmental status
GFCM	General Fisheries Commission for the Mediterranean
GVA	Gross value added
HELCOM	Baltic Marine Environment Protection Commission — Helsinki Commission
ICES	International Council for the Exploration of the Sea
IMP	Integrated maritime policy
IOGP	International Association of Oil and Gas Producers
IPBES	Intergovernmental Science-Policy Platform on Biodiversity

IUCN	International Union for Conservation of Nature
LPI	Living Planet Index
MESH+	European Marine Ecosystem (Health) Tool
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive
MSP	Maritime spatial planning
MSPD	Maritime Spatial Planning Directive
MSY	Maximum sustainable yield
NPA	Non-problem area
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PA	Problem area
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
REACH	Registration, evaluation, authorisation and restrictions of chemicals
RLI	Red List Index
SDG	Sustainable Development Goal
SST	Sea surface temperature
TAC	Total allowable catch
TBT	Tributyltin
UNEP-MAP	United Nations Environment Programme Mediterranean Action Plan
WFD	Water Framework Directive

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Annex 1

Table A1.1 Categories of marine ecosystem services, their description and what holds the ecosystem capacity to supply them

Marine ecosystem service category	What holds the ecosystem capacity to supply the services?
Provisioning	
Provisioning marine ecosystem services are all biota and biotic materials constituting tangible outputs from marine ecosystems. They can be exchanged or traded as well as consumed as foodstuffs (e.g. fish) or used by people in, for example, manufacturing and the production of energy.	Marine biota (their biomass or other biotic outputs, e.g. shells) acting as 'ecosystem structures' holds the capacity to supply these services. For example, a wild fish, as an ecosystem structure in itself, holds the capacity to supply the 'seafood and other nutritional outputs from wild animals' service (Figure 2.2).
Regulation and maintenance	
Regulation and maintenance of marine ecosystem services are all the ways in which marine biota and ecosystems control or modify the biotic and abiotic parameters defining the environment of people (i.e. all aspects of the 'ambient' environment). These marine ecosystem outputs are not consumed, but they affect the performance of individuals, communities and populations.	The 'processes' and 'functions' that marine biota carry out within the ecosystem tend to be what holds the capacity to supply these services. For example, the filtration of waste nutrients by benthic invertebrates, such as mussels, holds the capacity to supply the 'anthropogenic waste and toxicant treatment via biota' service. However, there are some instances in which this capacity is held in marine biota (their physical presence) that act as 'ecosystem structures'. For example, macroalgae, such a kelp forest, being in place and breaking the energy of waves before they reach the shore, hold the capacity to supply the 'erosion prevention and sediment retention' service (Figure 2.2). Marine biota and/or ecosystem processes/functions: • can mediate (neutralise or remove) waste and toxic substances that result from human activities, and this mediation has the effect of detoxifying the marine environment; • contribute to maintaining coastal landmasses and water currents, reducing, for example, the intensity of floods and preventing erosion; • contribute to the provision of sustainable human living (i.e. physical, chemical and biological) conditions.

Table A1.1 Categories of marine ecosystem services, their description and what holds the ecosystem capacity to supply them (cont.)

Marine ecosystem service category	What holds the ecosystem capacity to supply the services?
Cultural	
Cultural marine ecosystem services include all non-material marine ecosystem outputs that have physical, experiential, intellectual, representational, spiritual, emblematic or other cultural significance.	Marine biota (e.g., their physical presence, existence, image) acting as 'ecosystem structures' tends to be what holds the capacity to supply these services. For example, the capacity to supply the 'existence' service is held by all marine biota (and their habitats) and reflects an intrinsic value of marine biodiversity. However, there are some instances in which this capacity is held in ecosystem 'processes' or 'functions' involving certain biotic groups. For example, the sea smell is a by-product of the metabolism of phytoplankton, under certain conditions, or of bacteria when these degrade phytoplankton (Dodd, 2008), which can enhance human physical and intellectual interactions with marine biota/ecosystems linked to using the 'recreation and leisure' service (Figure 2.2). Marine biota and/or ecosystem processes/functions: • can underpin or enhance recreation and leisure, as well as underpin intellectual, cultural, emotional and artistic development that can depend on a particular condition of marine biota/ecosystems (or where this can enhance it); • can underpin spiritual development and aspects of legacy and can act as cultural or other symbols and have an intrinsic value for people, which can depend on a particular condition of marine biota/ecosystems (or where this can enhance it).

Note: Based on a marine interpretation of the meaning of the 'divisions' and 'sections' within the hierarchy of the Common International Classification of Ecosystem Services (CICES).

Source: Modified from Haines-Young and Potschin (2013, 2018), Maes et al. (2013) and EEA (2015b), using Culhane et al. (2019).

Box A1.1 What's at stake from the degradation and depletion of marine ecosystem capital?

Fulfilling our basic needs would be at stake. Many marine ecosystem services sustain people by providing us with vital direct inputs, such as seafood to eat and oxygen to breathe. However, these vital services are not doing well:

- The 'seafood and other nutritional outputs from wild animals' service across EU marine regions is affected by the current overexploitation of autochthonous commercial fish and shellfish stocks (e.g. not fishing them at MSY) (Culhane et al., 2019). EU catches declined from 1993 to 2013, at an average rate of 2 % annually, coinciding with the decrease in abundance of almost all demersal stocks (Owen and Carpenter, 2018). This decline needed to be offset by stocks from elsewhere in order to meet demand, which is still the case, as 44.8 % of the assessed stocks in EU marine regions remain overfished (EEA, 2019e). The reliance of EU citizens solely on fish/shellfish caught in EU waters is measured by the EU's 'Fish dependence day'. Despite signs of recovery for several stocks in the North-East Atlantic and the Baltic Sea (EEA, 2019e) and some nations being self-sufficient (e.g. Estonia, Sweden), this day has moved earlier in the year by almost a month over 16 years — from 4 August in 2000 to 9 July in 2016 — at the latest available calculation. This means that the EU would consume its domestic fish and shellfish supply in just over half a year (Owen and Carpenter, 2018).

- The 'oxygen production' service could potentially be affected by reductions in the abundance and diversity of phytoplankton (microalgae) linked to the climate crisis (Sekerci and Petrovskii, 2018) and to eutrophication (EEA, 2019c). Given that marine ecosystems supply about 50 % of the oxygen in the air we breathe (Lalli and Parsons, 1993), which is mainly generated by phytoplankton (Behrenfeld, 2001), those reductions would lower its productivity, jeopardising the service (Dutkiewicz et al., 2015; Boyce et al., 2010; Moore et al., 2018).

Our well-being would be at stake. Many (other) marine ecosystem services relate to our well-being, i.e. to us being, for example, comfortable, healthy, relaxed and happy. The following are examples of these services:

- 'Global climate regulation', as noted, contributes to the habitability of our ambient environment (Culhane et al., 2019) and would also be impacted by the above-mentioned reductions in phytoplankton productivity, given that these organisms play a key role in carbon sequestration too (see review in (Basu and Mackey, 2018)).

- The 'waste nutrient removal and storage' service type, for example, contributes to providing clean seawater for us to swim in (Culhane et al., 2019). Phytoplankton, again, plays a key role in the supply of this service through nutrient sequestration (Sigman and Hain, 2012; Basu and Mackey, 2018), which means that the service could also be eventually impacted if phytoplankton numbers keep going down.

Our livelihoods and economy would be at stake. Revenue and jobs in those maritime sectors based on exploiting ecological resources, mainly, provisioning, but also a few cultural marine ecosystem services, would be lost if the supply of these services reduces or stops. For example, there would be economic losses as a result of reductions in the following:

- The 'seafood and other nutritional outputs from wild animals' service would suffer economic losses due to the overexploitation of commercial fish and shellfish stocks (as documented by, for example, Carpenter and Esteban (2015) and the World Bank (2017). One study found that recovering stocks to their MSY would deliver 2 million tonnes of additional fish/shellfish per year (enough to meet the annual demand of 89 million EU citizens), EUR 1.6 billion additional gross revenue per year and EUR 800 million additional net profits per year, which could support up to 20 000 new EU jobs. However, this study did not consider all EU marine regions nor non-quota species in the North-East Atlantic region, meaning that the estimated costs of overfishing are likely to be much higher (Carpenter and Esteban, 2015).

- The 'recreation and leisure service', which can be used through tourist activities (Culhane et al., 2019), would suffer economic losses due to the effects of marine litter on tourism. Thus, marine litter impacts on marine biota/ecosystems cause the loss of EUR 350 million and 5 590 employees per year in this sector across the EU (EC, 2019e).

Annex 2

Table A2.1 Summary of BEAT+ classifications in the Baltic Sea, the Black Sea, the Mediterranean Sea and the North-East Atlantic Ocean

	Baltic Sea	Black Sea	Mediterranean Sea	North-East Atlantic Ocean	Total
Total area (km²)	400 000	47 000	2 530 000	6 858 000	10 264 000
Assessed	100 %	1.4 %	58.6 %	73.4 %	67.5 %
NPA_{High}	0 (0 %)	0 (0 %)	1 000 (0.1 %)	0 (0 %)	1 000 (0 %)
NPA_{Good}	4 000 (1.1 %)	0 (0 %)	94 000 (6.3 %)	991 000 (19.7 %)	1 089 000 (15.7 %)
$PA_{Moderate}$	261 000 (65.1 %)	7 000 (100 %)	791 000 (53.4 %)	2 483 000 (49.3 %)	3 542 000 (51.1 %)
PA_{Poor}	130 000 (32.6 %)	0 (0 %)	578 000 (39.0 %)	1 371 000 (27.2 %)	2 080 000 (30.0 %)
PA_{Bad}	5 000 (1.2 %)	0 (0 %)	17 000 (1.1 %)	190 000 (3.8 %)	212 000 (3.1 %)
% PA	98.9 %	100.0 %	93.6 %	80.3 %	84.3 %

Note: NPA, non-problem area; PA, problem area.

Table A2.2 Summary of HEAT+ classifications in the Baltic Sea, the Black Sea, the Mediterranean Sea and the North-East Atlantic Ocean

	Baltic Sea	Black Sea	Mediterranean Sea	North-East Atlantic Ocean	Total
Total area (km²)	400 000	476 000	2 530 000	6 858 000	10 264 000
Assessed	98.8 %	9.3 %	3.7 %	27.2 %	23.4 %
NPA_{High}	0 (0 %)	0 (0 %)	48 000 (50.8 %)	111 000 (6.1 %)	159 000 (6.6 %)
NPA_{Good}	2 000 (0.6 %)	21 000 (47.0 %)	35 000 (37.3 %)	1 620 000 (87.1 %)	1 678 000 (69.9 %)
$PA_{Moderate}$	108 000 (27.3 %)	2 000 (3.7 %)	4 000 (4.7 %)	92 000 (5.1 %)	207 000 (8.6 %)
PA_{Poor}	228 000 (57.4 %)	16 000 (35.3 %)	2 000 (1.7 %)	20 000 (1.1 %)	264 000 (11.0 %)
PA_{Bad}	59 000 (14.7 %)	6 000 (13.9 %)	5 000 (5.4 %)	22 000 (1.2 %)	92 000 (3.8 %)
% PA	99.4 %	52.9 %	11.8 %	7.2 %	23.5 %

Note: NPA, non-problem area; PA, problem area.

Table A2.3 Summary of CHASE+ classifications in the Baltic Sea, the Black Sea, the Mediterranean Sea and the North-East Atlantic Ocean

	Baltic Sea	Black Sea	Mediterranean Sea	North-East Atlantic Ocean	Total
Total area (km^2)	400 000	476 000	2 530 000	6 858 000	10 264 000
Assessed	50 %	26.9 %	3.7 %	15.4 %	14.4 %
NPAHigh	4 000 (2 %)	12 000 (9.2 %)	4 000 (4.7 %)	191 000 (18 %)	211 000 (14.2 %)
NPAGood	3 000 (1.7 %)	0 (0 %)	8 000 (8.0 %)	73 000 (6.9 %)	84 000 (5.7 %)
PAModerate	59 000 (29.6 %)	1 000 (0.9 %)	10 000 (10.4 %)	354 000 (33.4 %)	424 000 (28.6 %)
PAPoor	27 000 (13.6 %)	0 (0 %)	23 000 (23.9 %)	169 000 (16 %)	219 000 (14.8 %)
PABad	107 000 (53.2 %)	115 000 (89.8 %)	50 000 (53 %)	272 000 (25.7 %)	543 000 (36.7 %)
% PA	96.3 %	90.8 %	87.3 %	75.0 %	80.1 %

Note: NPA, non-problem area; PA, problem area.

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