State of Europe's seas

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European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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Authors and acknowledgements

EEA lead authors

Johnny Reker, Constança de Carvalho Belchior and Eva Royo Gelabert.

EEA contributing authors

Annemarie Bastrup-Birk, Trine Christiansen, Rasmus Dilling and Ronan Uhel.

European Topic Centre for Inland, Coastal and Marine Waters (ETC/ICM) contributing authors

Aldo Annunziatellis (ISPRA), Ana Jesus (JNCC), Andrea Palatinus, (IWRS), Argyro Zenetos (HCMR), Benjamin Boteler (Ecologic Institute), Beth Stoker (JNCC), Birger Bjerkeng (NIVA), Caterina Fortuna (ISPRA), Claudette Spiteri (Deltares), Dag Hjermann, (NIVA), Frank Thomsen (DHI), Gerjan Piet (IMARES), Giancarlo Lauriano (ISPRA), Giulia Mo (ISPRA), Hans Mose Jensen (ICES), Harriet van Overzee (IMARES), Jane Hawkridge, (JNCC), Jørgen Nørrevang Jensen, (ICES), Katrina Abhold, (Ecologic Institute), Manuel Lago (Ecologic Institute), Monika Peterlin, (IWRS), Nikos Streftaris, (HCMR), Norman Green, (NIVA), Periklis Panagiotidis (ICES), Sabrina Agnesi (ISPRA), Stefan Trdan, (IWRS), Stefanie Werner (UBA), Terri Kafyeke, (Ecologic Institute), Theo Prins, (Deltares), Ulf Stein (Ecologic Institute).

Other contributing authors

Fiona E. Culhane and Lydia J. White (University of Liverpool).

EEA production

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Summary

Europe's seas are home to a wide variety of marine organisms and ecosystems, and are also an important source of food, raw materials, and energy for people. There is a range of EU policy goals related to managing the use of our seas' natural capital so we can keep on reaping its benefits. For example, there are EU policies related to managing fisheries and offshore energy production, and to protect marine biodiversity. In order to achieve the integration of these different policies, European policymakers agreed on the 2008 EU Marine Strategy Framework Directive (MSFD). The MSFD has three main goals for the state of Europe's seas, and this report seeks to examine whether these goals are being met. Our conclusion is that we are failing to meet two out of these three goals.

This is the first EEA report to undertake an assessment of Europe's seas at an EU-wide scale. The report begins with **Part I**, which discusses 'ecosystem-based management', a concept promoted by the MSFD. Ecosystem-based management means managing human activities in a way that is compatible with the full functioning of marine ecosystems. In **Part II**, the report examines whether the EU is meeting the three goals it set under the MSFD. These goals are for Europe's seas to be (1) 'healthy', (2) 'clean', and (3) 'productive'. We conclude this part indicating that although Europe's seas can be considered 'productive', they cannot be considered 'healthy' or 'clean'. In **Part III**, the report looks into the future and considers whether the use of Europe's seas' natural capital is sustainable. It concludes that a closer coupling between our ambitions for 'Blue Growth' and 'productive' seas on one hand and our ambitions for 'healthy' and 'clean' seas on the other is needed. Thus, our current way of using Europe's seas' natural capital does not appear to be sustainable despite some recent positive results from the implementation of certain policy instruments. Unsustainability threatens the productivity of our seas and, ultimately, our well-being. In order to address this situation we need to make fundamental changes in our lifestyles, leading to living in a way that respects the ecological boundaries of the sea. These changes are key to ensure that we meet the EU's 2050 vision to 'live well, within the planet's ecological limits'.

Part I — Towards ecosystem-based management in Europe's seas

Part I of the report describes the concept of 'ecosystem-based management' of human activities in the marine environment. This concept is enshrined in EU marine and maritime policies. In **Chapter 1**, we give an operational definition of ecosystem-based management. We also provide a description of some of the EU policies governing the management of our activities at sea, with a special focus on the MSFD. MSFD implementation by EU Member States is an important step in applying ecosystem-based management and having 'productive' seas that are also 'healthy' and 'clean', but further efforts are needed to make ecosystem-based management a reality.

These further efforts will require increased integration between EU marine and maritime policies and economics. In **Chapter 2**, we discuss some of the concepts that can assist decision-makers to make this integration happen. For example, we explain how economic concepts such as capital and services apply to marine ecosystems. We further argue that the services provided by the 'biotic' constituent of the sea's natural capital (i.e. marine ecosystem capital) are critical for meeting people's basic needs, and for supporting our well-being and livelihoods.

Part II — Are our seas healthy, clean, and productive?

Part II of the report provides the assessment of the state of Europe's seas. This assessment is based on data and information from numerous published and/or officially reported sources. It focuses on marine species and habitats; the predominant pressures on these species and habitats; and the maritime activities responsible for these pressures. It also provides examples of the effects of different EU policy responses to key issues affecting the state of Europe's seas.

Chapter 3 examines the state of marine species and habitats, which are known by the collective term of 'ecological features'. This chapter looks at ecological features such as seabed and water column habitats, and key biotic groups: invertebrates, fish, turtles, seabirds and water birds, and mammals. It also

examines overall ecosystem functioning, such as food web dynamics. The chapter tentatively concludes that our seas cannot be currently considered 'healthy'. It also concludes that significant efforts are needed to improve our knowledge base on the biodiversity of Europe's seas. This can be done by enhancing coordination between Member States, and by gathering and sharing further information from the regional seas of Europe.

In **Chapter 4**, we examine the pressures that affect Europe's seas. These pressures include physical damage to the seafloor; extraction of fish and shellfish; introduction of non-indigenous species; input of nutrients leading to eutrophication; marine litter, etc. EU policy is having an effect in reducing the more 'traditional' of these pressures, such as those arising from fishing or from nutrient loading. However, there is also an array of non-traditional, 'emerging' pressures, which must now be adequately managed. A further difficulty that must be addressed is the combined, cumulative effect of all these pressures on marine ecosystems. This is an increasingly complex problem and a growing concern, because these cumulative effects lead to altered ecosystem functioning and reduced ecosystem resilience. We conclude that, at present, Europe's seas cannot be considered 'clean'.

In **Chapter 5**, we examine the human activities causing the pressures described in Chapter 4. A significant part of the pressure on marine ecosystems arises from activities at sea. These maritime activities are at the heart of the EU's 'Blue Growth' strategy and include the extraction and production of living resources; transport; energy production; tourism, etc. Maritime activities play an important role in the European economy in terms of gross value added and employment, and most of these activities are expected to increase in the future. We therefore conclude that our seas are currently very 'productive'. However, we warn that past, present and future pressures from human activities are reaching levels that threaten this productivity because of the way they affect the marine ecosystem capital of Europe's seas.

Chapter 6 discusses how the ecosystem-based approach could help decision-makers to manage the activities causing marine pressures in an integrated and thus more effective way. Thematic policy instruments dealing with single 'traditional' issues, such as eutrophication, biodiversity protection, and overfishing are leading to improvements in the state of Europe's seas. However, EU marine and maritime policies have not yet achieved their full potential. In order to address the increasing complexity of the problems faced by our seas, governments must implement these policies in an integrated way. The chapter concludes that applying the ecosystem-based approach would be the way to achieve the desired policy integration. This would require changes to traditional policy and management procedures.

The quality of the EEA's assessments across this report relies on the quality of Member State reporting on their implementation of EU marine policy. While there are some examples of high-quality reporting, there are also substantial gaps in this reporting. We therefore compiled the evidence presented in this report from numerous sources, including policy-linked reported information; established EU data flows; scientific literature; empirical examples; and case studies. Chapters 3, 4, 5 and 6 all argue for more and better-quality information on our seas in order to support improved effectiveness of EU marine policy.

Part III — Our seas, our future

Part III builds on the previous chapters and reflects upon the serious challenges that still face Europe's seas despite the partial improvements that have reduced certain pressures. It argues that we need to identify and respect the ecological boundaries of Europe's seas if we want to maintain their potential to deliver ecosystem services now and in the future.

In **Chapter 7**, we assess whether our use of the natural capital of Europe's seas is sustainable or leads to the degradation and loss of marine ecosystems and their services. Humans have relied upon the sea to support their daily lives for centuries. How long can we keep on doing so? If we focus solely on short-term economic gains, we put ecosystems — and our own basic needs, well-being, and livelihoods — at risk. Unfortunately, it appears that the way we use Europe's seas' natural capital is not sustainable.

In **Chapter 8**, we examine how our policy ambitions for economic growth, in particular from maritime activities, can be aligned with our policy targets of securing 'healthy', 'clean' and 'productive' seas. This alignment will require a fundamental shift in the 'socio-technical' systems that fulfil our societal needs. Achieving such a shift relies on a collaborative response from decision-makers; research institutions; businesses; advocate groups; citizens; and providers of information and knowledge. Thus, we need to build a 'European ocean constituency', committed to embracing the stewardship of our seas. The chapter includes an indicative summary assessment of the status and outlook for our seas on the basis on all information put forward in this report (see Table ES.1). Our assessment shows that Europe's seas cannot be considered 'healthy' nor 'clean' today and are unlikely to become so in the future given the current trends.

Table ES.1 Indicative assessment of key status and outlook for healthy, clean, and productive seas, plus supporting information

Healthy seas?	**Status: ecosystem characteristics**	**5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Seabed habitats				3.2
Water column habitats				3.3
Marine invertebrates				3.4
Marine fish				3.5
Turtles				3.6
Seabirds and waterbirds				3.7
Marine mammals				3.8
Ecosystem processes and functions				3.9, 3.10
Clean and undisturbed seas?	**Status: pressure**	**5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Physical disturbance of seafloor				4.2
Extraction of fish and shellfish				4.3
Non-indigenous species				4.4
Eutrophication				4.5
Contamination				4.6
Marine litter				4.7
Underwater noise and other forms of energy input				4.8
Climate change				4.9
Productive seas?	**Direct dependency on healthy seas**	**Activity 5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Land-based activities	x	-		5.2
Extraction of living resources	√	↗		5.3
Production of living resources	√	↗		5.4
Extraction of non-living resources and disposal of waste	x	↗		5.5
Transport and shipbuilding	x	↗		5.6
Tourism and recreation	√	↗		5.7
Man-made structures	x	↗		5.8
Energy production	x	↗		5.9, 5.10
Research and survey	x	↗		5.11
Military	x	↘		5.12

Legend: Indicative assessment of:

Status and trends of ecosystem and pressures		Information availability and quality	
	Status not good/deteriorating trends dominate		Limited information
	Status or trends show mixed picture		Sufficient information
	Status good/improving trends dominate		Good information
Note	The indicative assessment builds on the information analysed in the relevant sections and expert judgement. The sources of information include EU reporting obligations, EEA indicators, EU and regional reports, and peer-reviewed papers.	Note	The indicative assessment builds on the availability and quality of the information to make comparable and coherent evaluations at EU level and between regional seas.
Productive seas			
x √	An activity is considered dependent on healthy seas if its production depends on biotic natural capital having good status.	↗ ↘	Trends of the activity build on those presented in Table 5.1.

Introduction

Europe's coastal areas and seas of today sustain ecosystems that have been significantly altered by centuries of human exploitation. Historical knowledge shows us that whaling, seal hunting and, later, commercial fishing caused profound changes to marine ecosystems, which have influenced the marine life they can support today. More recent knowledge shows us that human-induced change to marine ecosystems has greatly increased in the past 60 years.

The seas have become busier places, driven by a combination of technological advances and an increase in our society's demand for food, energy, and other resources. Traditional maritime activities such as fishing have become more intensive and widespread, and the rise in global trade has driven an enormous growth in the shipping industry. Entirely new industries have also sprung up in the marine environment, including offshore wind-power and offshore production of oil and gas. Coastlines have changed dramatically, as the growing population density has required a massive increase in the development of infrastructure and housing on Europe's coastal areas.

Old political barriers, for example in the Baltic Sea region, have been broken down providing new opportunities for communities to share Europe's seas. Today's huge super tankers, pipelines, and telecommunication lines across the seas bring the world ever closer. Offshore activities continue to move ever further away from the shore seeking new opportunities for exploitation of natural resources, whether it is for mining, energy, biotechnology, or capturing fish.

Combined, maritime activities have had a positive effect on Europe's economic growth and provided other social benefits. Further substantial investments are being made or planned, paving the way for the future expansion of the 'blue economy'. This 'Blue Growth', as it is called in the EU, will provide opportunities for economic revenue, trade and jobs. These benefits are much needed in a Europe still recovering from the 2008 financial crisis, feeding into the continuous development of our society.

But how has the development of human activities affected the health of our seas and their ecosystems so far? Many of the signs we observe are worrisome. bluefin tunas no longer roam from the entrance of the Baltic Sea to their spawning grounds in the Black Sea. Canarian oyster-catchers no longer forage on isolated beaches on Tenerife. Large predators like marine mammals, sharks and other large fish have been reduced to a shadow of their former selves. Invasive species are also on the rise, hitting particularly hard the Mediterranean Sea. Climate change is already taking a toll in Europe's seas by warming and acidifying its waters. One of the visible consequences of anthropogenic climate change are the shifts in marine species distribution towards more northerly (and thus colder) regions, namely of species with commercial value such as those targeted by fisheries. This climate-induced change in the geography of marine species also affects human international relations, as shown by recent conflict amongst countries sharing fish resources in northern European seas.

Human activities are putting unprecedented pressure on our seas, and the observed signs show that marine habitats and species in all of Europe's marine ecosystems are rapidly changing. Changes to marine ecosystems are inexorably linked to the way we use the sea's natural capital. The resulting biodiversity loss and ecosystem degradation reduce ecosystem resilience. Underminining ecosystem resilience not only affects the health of our seas but also human well-being, by putting at risk the ecosystem potential for delivering services key for meeting our societal needs. Moreover, the human pressures that have contributed to altering marine ecosystems show no sign of disappearing. On the contrary, we will make more demands on the sea's natural capital in the future given our consumption and production patterns in a world with a globalised economy and a growing population.

We must therefore act smarter with the knowledge of today to ensure resilient marine ecosystems and a sustainable blue economy in the long-term. The management of human activities in Europe's seas must follow a holistic approach, one that better protects, conserves and enhances marine ecosystem capital while meeting societal needs. Ecosystem-based management offers such an approach and thus the opportunity to balance the future use of our seas with the boundaries of its bounty and beauty.

This report provides the first European-level analysis of where the EU stands on this pathway to securing healthy oceans and productive ecosystems for the benefit of the current and future generations. The report also offers some of the 'stepping stones' to support Europe towards this goal, in particular its policy ambition of achieving 'good environmental status' of our seas by 2020. In doing so, the report also responds to Europe's stakeholders call for HOPE: 'Healthy Oceans, Productive Ecosystems' ([1]). These stepping stones include providing the conceptual framework for ecosystem-based management (Part I); the current *state-of-affairs* in terms of ecosystem state and the human drivers of ecosystem change (i.e. activities and pressures) in our seas, together with an analysis of the EU policy response (Part II); and, lastly, showing our progress towards assessing marine ecosystem services because this can tell us whether our management of the sea's natural capital is sustainable; as well as the overall conclusions of the report (Part III).

Aims of the report

The main aim of this report is to assess whether Europe's seas can be considered healthy, clean and undisturbed, and productive. These are three core aspects of the EU's main marine policy instrument — the Marine Strategy Framework Directive — and relate to the condition of marine ecosystems and the human drivers of ecosystem change. This assessment also involves identifying the main sustainability challenges affecting our seas, and how the EU is responding to these challenges. Ultimately, the report argues that EU is not on the path to fulfil its ambition of achieving sustainable use of its seas; although it is fully empowered to do so through the current array of policies and knowledge. This report also discusses how a long-term transition to sustainability could then be secured using the available policies and knowledge.

The report has three main goals. Firstly, it seeks to establish a snapshot of the current state of Europe's seas by looking into the main marine ecosystem characteristics, i.e. species, habitats, processes, and functions. This assessment also analyses the pressures and impacts affecting marine ecosystems and the human activities causing these pressures. It further discusses the complexity of the interactions between these different ecological and human elements, and what this means for the management of human activities, and the knowledge needed to support such systemic understanding. By doing this, the report improves our knowledge of the sea's natural capital. It tells us, in particular, about how human use of this natural capital affects the capacity for self-renewal of its biotic constituent — marine ecosystem capital. Understanding the condition of marine ecosystem capital is key to meet people's basic needs, and to support our well-being and livelihoods as it determines the sea's potential to generate marine ecosystem services. In this way, the report shows how the benefits we obtain from the sea are connected to the state of marine ecosystems, highlighting the direct link between our societal well-being and the mostly 'unseen' role of the sea.

The second goal is to assess how this snapshot of the state of our seas can help marine policy. By making an analysis of the current state of Europe's seas, the report provides a 'baseline' reference, against which the implementation of current and future EU policies affecting Europe's seas can be measured. The report therefore also analyses the policy context, and uses the snapshot of the current state of the seas to assess the progress the EU is making towards achieving its main policy objectives. In doing this, the report argues that the EU already has the right tools to address the observed patterns of change in Europe's seas. The key to success is therefore not new tools, but fully implementing the existing tools using long-term solutions, such as those offered by ecosystem-based management.

The success for developing an ecosystem-based management depends on the availability and quality of marine information. High quality information is critical for assessing the state and outlook of the marine environment, and the effectiveness of the policies aiming at its protection, conservation and enhancement. The report therefore touches upon the efforts needed to shape this information into a knowledge platform capable of supporting ecosystem-based management. With unprecedented change occurring in Europe's seas, a coherent knowledge base might soon become our most valuable resource.

This report is primarily aimed at EU, regional and national policymakers and practitioners who are already dealing with marine and maritime issues.

([1]) 'Good environmental status' is the main objective of the Marine Strategy Framework Directive (MSFD). Stakeholders across Europe gathered in 2014 for the Healthy Oceans — Productive Ecosystems (HOPE) Conference to discuss progress since the MSFD adoption in 2008 and issued the 'Declaration of HOPE' as an output.

The report is also aimed at broader interest groups, such as environmental NGOs; the academic and scientific community; business organisations; consultancies; and 'think tanks'.

Technical aspects of the report: analytical framework, information base and timing

The report is made up of several 'building blocks'. It is structured around the DPSIR (Drivers, Pressures, State, Impacts and Response) analytical framework, which has been modified to incorporate key EU policy objectives and methodological standards. This includes requirements coming from the Marine Strategy Framework Directive (MSFD); the Habitats Directive; the MAES (Mapping and Assessment of Ecosystems and their Services) process under the EU Biodiversity Strategy to 2020; and the Integrated Maritime Policy 'Blue Growth' initiative (Figure I.1).

The report also provides suggestions for definitions of key concepts that are important to create a common understanding of what an ecosystem-based approach to the management of human activities on the marine environment (i.e. ecosystem-based management) could entail for Europe's seas. The need for such a common understanding is pressing: these concepts are increasingly present in EU policy discussions, but they often have no formal definition, or a coherent approach to their implementation.

The report builds on the information reported by European Union (EU) Member States under key legal obligations such as the Marine Strategy Framework Directive, the Habitats Directive, and the Common Fisheries Policy. It further substantiates this information with other information sources, namely EU indicators and reports, regional assessments, peer-reviewed scientific papers and other literature.

Nevertheless, the information available for the assessments carried out in this report is still limited and fragmented. Therefore, in order to establish a 'European snapshot', the report also uses local, national and regional examples, case studies, EEA indicators, and other information. Although the report uses local and national examples, it does not discuss the assessments and reporting of individual Member States. Member State reporting and assessments may therefore vary compared to the European (or regional) perspective presented here.

The timing of the report means that it benefits from the information made available by the first EU Member State reporting on the state of Europe's seas (i.e. the Marine Strategy Framework Directive Initial Assessment, Article 8). It also benefits from new information made available under the Birds and Habitats Directives. The report can therefore be used to inform the next implementation and assessment cycles under these directives. For example, it can help to identify better solutions for assessing the Marine Strategy Framework Directive objective of 'good environmental status' (GES) to be maintained or achieved in European marine regions by 2020. The report also comes at a time where regional 'Blue Growth' strategies are being implemented, and maritime spatial plans developed by EU Member States under the Maritime Spatial Planning Directive. It therefore provides key knowledge for those engaged in implementing ecosystem-based management in Europe's seas.

Content and structure of the report

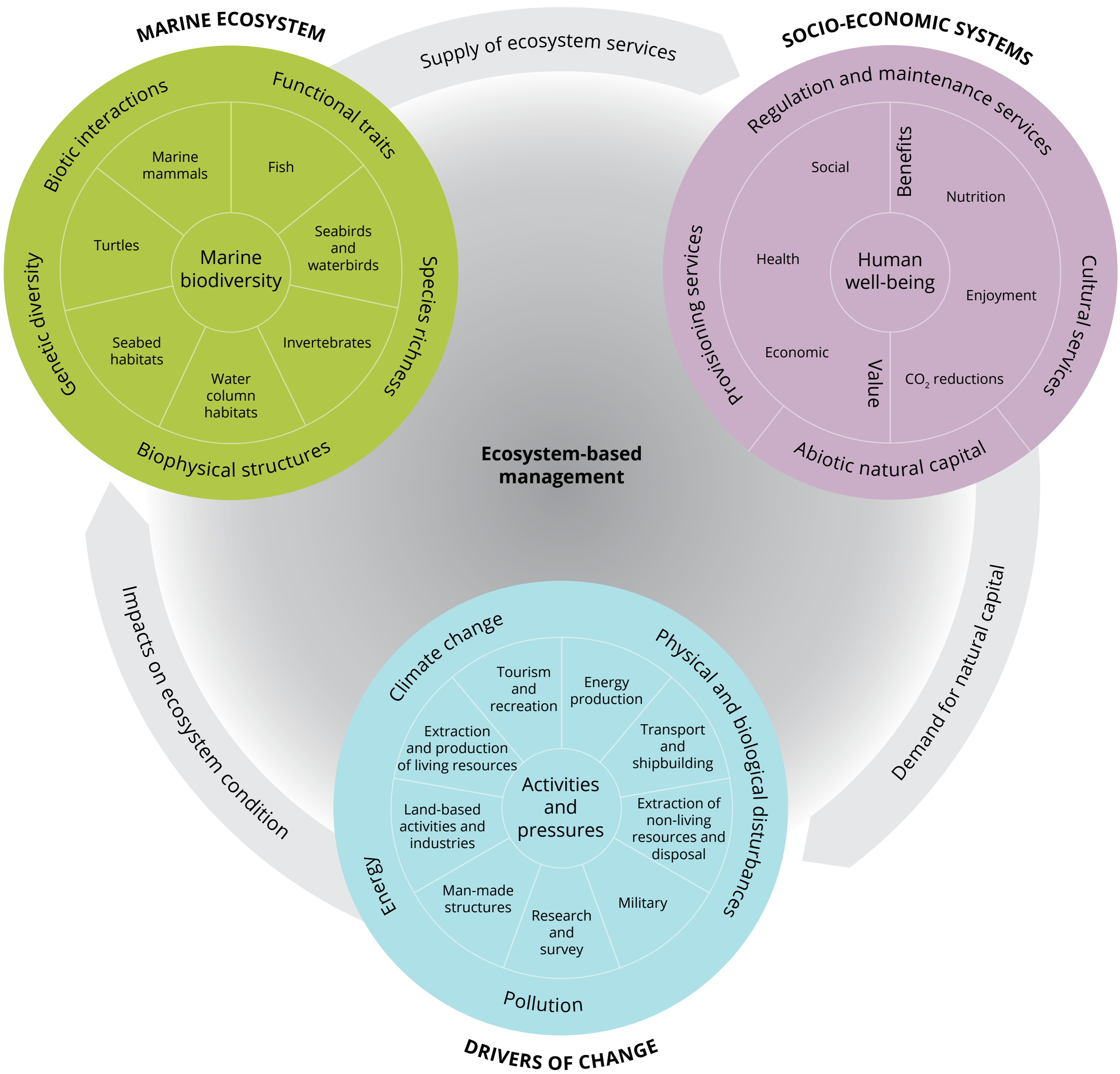
Part I sets the scene for the report. It describes relevant European policies and key elements such as ecosystem-based management of human activities at sea (Chapter 1). It does this by first looking at the nature of human engagement with the sea and providing a descriptive overview of Europe's seas. It then explains the integrated policy approach the EU is taking to ensure that a holistic view of the marine and maritime policy arena is adopted, rather than treating this policy area as a series of discrete policy issues. The Marine Strategy Framework Directive is one concrete example of an integrated policy instruments that incorporates the principles of 'ecosystem-based management'. It also explain how economic concepts such as capital and services can be applied to marine ecosystems (Chapter 2). It explains how economic concepts such as natural capital and services apply to marine ecosystems. It also argues that the services provided by the biotic constituent of the sea's natural capital (i.e. marine ecosystem capital) are critical to meet people's basic needs, and to support our well-being and livelihoods. The concepts and information in this chapter explain how the findings of the assessment of the current state of Europe's marine environment in Part II relate to these benefits. This chapter also serves as an introduction to the final analysis of our use of Europe's seas natural capital provided in Part III.

Part II focuses on ecosystem state and the human drivers of change i.e. pressures and activities. It describes the state and available trends of marine ecosystems and biodiversity (Chapter 3) in relation to the pressures and their impacts (Chapter 4), and the human activities (Chapter 5) influencing Europe's seas. It then builds on these findings to discuss how the EU is responding to the 'systemic' challenges emerging from the interactions between marine ecosystems and our socio-economic systems through its policy framework and knowledge infrastructure (Chapter 6).

Part III provides elements towards a new understanding of our interaction with the sea building on the findings in Part II on the condition of marine ecosystems and the 'drivers of change' acting upon them. It does so by looking into the possible impact of ecosystem change on the capacity of marine ecosystems to continue to supply the services and associated benefits we need in our daily lives (Chapter 7). Finally, the report concludes by summarising its main findings and highlighting some of the main challenges Europe faces in securing a transition towards long-term sustainable use of our seas and its natural capital (Chapter 8). Securing such transition will be key for achieving the EU's objective of 'living well within the limits of our planet' by 2050, as envisioned in the 7th Environment Action Programme.

As such the report structure follows closely the analytical framework put in place for the report (Figure I.1), while evolving various components of the ecosystem-based management approach to human activities in Europe's seas.

Figure I.1 Assessing the marine environment in an EU policy context — towards ecosystem-based management



Source: Adapted from Stanners et al., 2007; EC, 2008; Ecorys, 2012; Maes et al., 2013, EC, 2015.

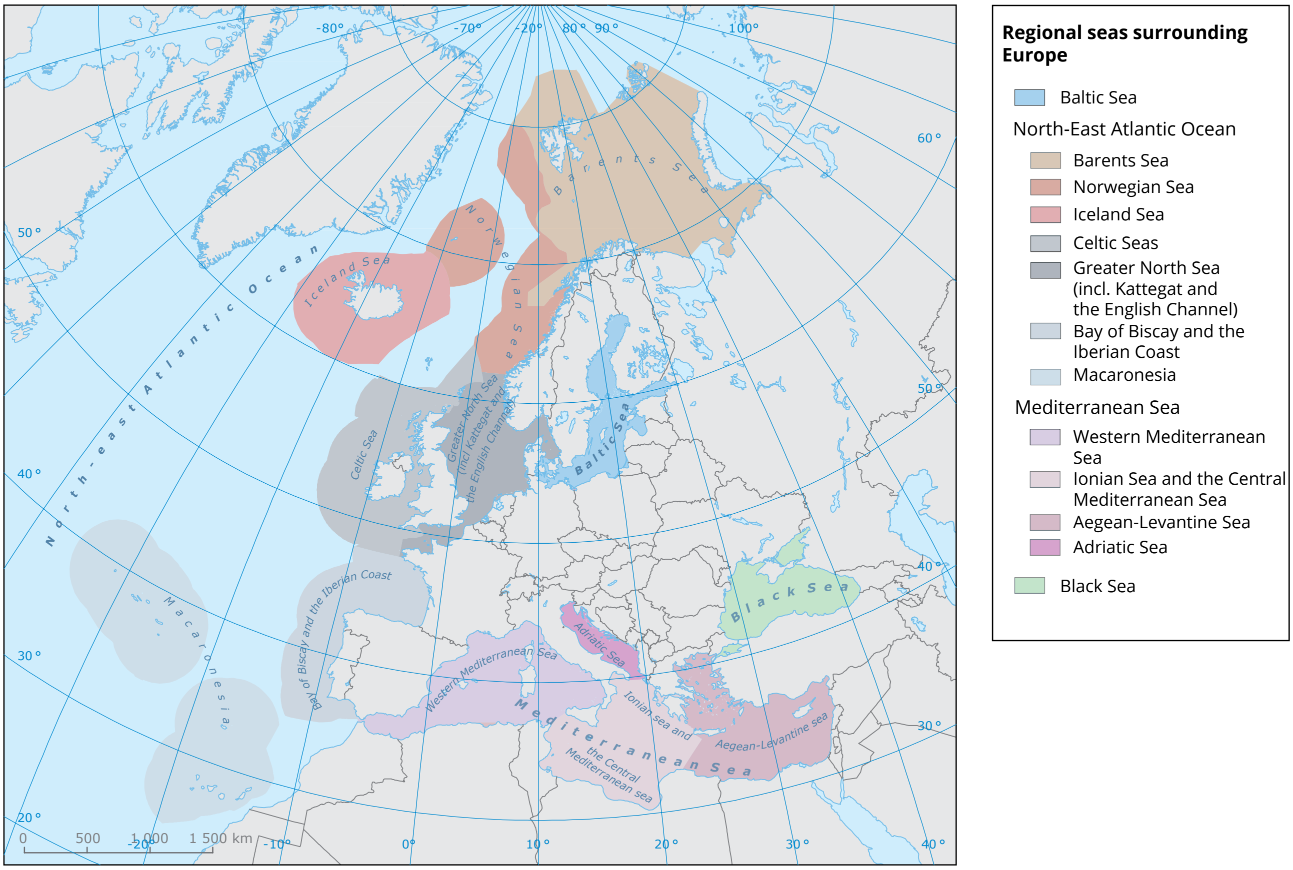
1 Towards ecosystem-based management in Europe's seas

1.1 Europe's seas and our interaction with them

Europe's seas include a wide range of marine and coastal ecosystems, ranging from the stable environment of the deep ocean to highly dynamic coastal waters (Table 1.1, Figure 1.1). Each sea is shared by a myriad of individuals, institutions, cultures, and activities. They are also the home to thousands of species of marine plants and animals.

Human society depends greatly on the sea. Fish are an important source of food. Compounds from microscopic algae are used in medicines and cosmetics. Coastal water vegetation such as seagrasses protect our shores from erosion and floods, and act as nurseries for commercially exploited and migratory marine animals. The sea also helps to decompose and detoxify substances such as wastewater and oil. The oceans regulate climate change by absorbing greenhouse gases, and have already absorbed about 30% of the carbon dioxide that humans put into the air (IPCC, 2013). Resources under the seabed are also a tremendous source of energy, providing the oil and gas needed to run our homes, vehicles, ships, and factories. The seabed is increasingly home to wind turbines, which provide further electricity. And the seabed is also used as a source of inert raw materials, such as the sand and gravel used to make our houses and roads. Finally,

Figure 1.1 Regional seas surrounding Europe



the sea also provides us with opportunities for recreation and leisure, such as swimming, and sailing, contributing to our well-being (Table 7.1, Table 7.2).

Humans have been operating within marine ecosystems for millennia, causing change through a variety of complex interactions at sea and on land. The consequences of past and current human activities are now so profound that they have had significant impacts on the structure and functioning of marine ecosystems around the globe (Jackson et al., 2001a; Rockström et al., 2009). Impacts on the sea's health can have negative consequences for the delivery of future ecosystem services upon which human communities depend (Crilly and Esteban, 2012; Maes et al., 2013; Costanza et al., 2014; Rogers, Sumaila, Hussein et al., 2014). The most serious of these adverse changes are those related to over-exploitation of natural resources, to biodiversity loss, and to climate change.

Despite this worrying historical legacy, exploitation of the seas continues to grow and is expected to grow further in the future. Indeed the EU's Blue Growth policy is based on the increased exploitation of the seas. However, this exploitation should become more rational, reducing humans' impact on the ecosystem. By planning ahead and by taking an ecosystem-based management approach (EBM, Box 1.2, Box 1.3) we may increase the productivity of our seas in a sustainable way. Achieving this balance will be a major challenge that can only be met by the countries sharing a regional sea.

Table 1.1 Regional seas surrounding Europe — selected geographic characteristics

Regional seas surrounding Europe	Neighbouring EEA/ collaborating countries	Regional sea surface area (km²)	EU Member States share of surface area of regional sea (km²) and (%)	% of EU Member States sea surface area reported under the MSFD	Area of catchment (km²)	Population in catchment
Baltic Sea	**SE, FI, EE, LT, LV PL, DE, DK**	**394 000**	**370 000 (93.9)**	**92**	**1 653 000**	**77 019 000**
North-east Atlantic Ocean	**UK, NO, DK, DE, NL, BE, SE, IE, FR, PT, ES, IS**	**7 835 000**	**4 076 000 (52.0)**	**58**	**2 721 000**	**260 192 000**
Barents Sea	NO	1 944 000	0 (0)	---	706 000	1 401 000
Norwegian Sea	NO	888 000	0 (0)	---	89 300	824 000
Iceland Sea	IS	756 000	0 (0)	---	103 000	283 000
Celtic Sea	UK, IE, FR	920 000	916 000 (99.6)	---	185 000	23 135 000
Greater North Sea	DK, SE, NO, DE, BE, NL, FR, UK	670 000	503 000 (75.1)	---	966 000	183 889 000
Bay of Biscay and the Iberian Coast	FR, PT, ES	804 000	804 000 (100)	---	661 000	48 500 000
Macaronesia	ES, PT	1 853 000	1 853 000 (100)	---	10 300	2 160 000
Mediterranean	**ES, FR, IT, SI, MT, HR, BA, ME, AL, EL, CY, TR, UK**	**2 517 000**	**1 210 000 (48.1)**	**86**	**1 121 000**	**133 334 000**
Western Mediterranean	FR, IT, ES, UK	846 000	660 000 (78.0)	---	429 000	53 852 000
Ionian Sea and Central Mediterranean Sea	IT, MT, EL	773 000	240 000 (31.0)	---	76 300	8 295 000
Adriatic Sea	SI, IT, ME, AL, HR; EL	140 000	120 000 (87.7)	---	242 000	37 327 000
Aegean-Levantine Sea	EL, CY, TR, UK	758 000	190 000 (25.1)	---	374 000	33 860 000
Black Sea	**BG, RO, TR**	**474 000**	**64 000 (13.5)**	**46**	**2 414 000**	**191 994 000**
Sea of Marmara	TR	11 700	0 (0)		39 290	No data
Total	**---**	**11 220 000**	**5 720 000 (51.0)**	**66**	**7 909 000**	662 538 000

Note: Country codes (based on Eurostat country codes at 1 June 2012: see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Country_codes). Bold indicates Marine Regions and non-bold indicates subregions as defined by the MSFD; italics indicate regional seas not included in the MSFD.

Member States are responsible for more than half of the area of regional seas surrounding the European continent and outermost regions, an area of more than 5.7 million km^2. This area is the main geographic focus of this report. The EU also includes 34 islands and overseas territories associated with Denmark, France, the Netherlands, Portugal, Spain, and the United Kingdom. The EEZ (Exclusive Economic Zone) around these territories and islands (and areas on the extended continental shelf) adds an additional 15 million km^2. These areas are not discussed further in this report.

In 2011, 206 million people, or 41% of the EU population, lived in Europe's coastal regions (Eurostat, 2011a). Interestingly, only 56% of the up-stream catchment areas of rivers that flow into Europe's seas is under EU jurisdiction. In total, these catchment areas are home to more than 660 million people, both in EU and non-EU countries. All these people potentially influence Europe's seas through discharges of nutrients, wastes, etc.

For many years, the EU has sought to address the environmental challenges influencing its seas, and it continues to address these challenges today. Part of its solution has been the development of an extensive policy framework.

1.2 The integrated policy approach

Up until now, environmental policies have mostly focused on improving the environmental efficiency of individual components of society and/or nature. For example, policies have targeted individual industrial sectors or specific key species, such as endangered birds or vulnerable habitats (i.e. not all species and not all habitats). By and large, such approaches have not managed to reverse the trend of negative environmental impacts (EEA, 2014b). This has led to a realisation among policymakers and public authorities that there is a very complex relationship between human activities and environmental problems. These complex relationships present a challenge for public policy.

Successful solutions to these challenges require a more holistic, integrated and systemic approach. This approach must look at problem-definition, analysis, and response, and must go beyond traditional policy approaches. These solutions have to encompass not only the individual parts of an ecosystem, but also recognise the linkages and connections between different parts of the ecosystem as well as the linkages to socio-technical systems (this is the so-called ecosystem-based management approach or EBM, Box 1.2, Box 1.3). The EU is increasingly crafting policy solutions that do this. It formulates its policies using an integrated, three-step timeframe as a direct response to these systemic challenges.

Step one includes short-term targets for individual sectoral policies for the period 2011–2018. Step two includes mid-term goals, which link policy ambitions to more comprehensive policies. An example of this would be the 7th EAP, which outlines mid-term goals for the environment and climate for the 2020–2030 period. The third-step is the long-term vision: the EU is working towards a 2050 vision of societal transition, informed by a better acknowledgement of planetary boundaries, a circular green economy, and the resilience of society and ecosystems.

EU marine policies

In the EU marine and maritime domain, the concrete policy measures associated with these three steps include a range of initiatives, such as the 7th EAP; the EU Biodiversity Strategy to 2020; the Integrated Maritime Policy (IMP); and the Common Fisheries Policy (CFP) (Table 1.2). All of these initiatives include elements on data-collection and information-sharing in order to provide a sound knowledge base for policy development and decision-making.

The 7th EAP is entitled 'Living well, within the limits of our planet'. It sets out a strategic overarching framework to achieve a 2050 vision for Europe and its environment. This vision includes a green, circular economy that safeguards the environment and the health of future generations. For marine ecosystems, the 7th EAP focuses on achieving sustainable fisheries and on reducing marine litter.

The main aim of the EU Biodiversity Strategy is to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020 (Box 1.1). A key element of the Strategy is the full implementation of EU nature legislation in order to better protect biodiversity and ecosystems, and to enable more use of green infrastructure. The Biodiversity Strategy calls for better management of fish stocks and tighter control of invasive species. It also provides a policy umbrella for the objectives of the Habitats Directive, Birds Directive, Water Framework Directive, and the Marine Strategy Framework Directive.

The Common Fisheries Policy lays down rules for managing fisheries and for conserving fish stocks. It aims to ensure that fishing and aquaculture are environmentally, economically, and socially sustainable. And it aims to ensure that these industries provide a source of healthy food for EU citizens. The Common Fisheries Policy also aims to foster a dynamic fishing

Box 1.1 Headline targets and visions for biodiversity in the EU Biodiversity Strategy to 2020

By 2020: Halting the loss of biodiversity and the degradation of ecosystem services in the EU, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss.

By 2050: European Union biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value, and for their essential contributions to human well-being and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided.

Source: EC, 2011a.

industry and to ensure a fair standard of living for fishing communities (EC, 2014c).

The Integrated Maritime Policy aims to provide a coherent approach to maritime affairs and to increase coordination between marine-related policy areas. It focuses on issues that do not fall under a single sector and on issues that require coordination across sectors. These cross-sectoral issues include marine knowledge, 'Blue Growth', and maritime spatial planning. The Marine Strategy Framework Directive adopted in 2008, is the environmental component of the Integrated Maritime Policy. It is the policy tool used for setting the limits for sustainable use of marine ecosystems and resources. As such, the implementation of the Integrated Maritime Policy will encourage the ecosystem-based approach to management (EBM) of our seas, helping to make human activities more sustainable.

Table 1.2 Timeline for selected policy objectives and targets for achieving healthy, clean and undisturbed, and productive Europe's seas

Objectives	Sources	Deadline for implementation												
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2030	2050
Healthy seas														
Halt the loss of biodiversity and the degradation of ecosystem services	EU Biodiversity Strategy to 2020													
Fully implement the Birds and Habitats Directives	EU Biodiversity Strategy to 2020													
Halt the loss of biodiversity	7th Environment Action Programme													
Establish an ecologically coherent network of protected areas under the title of Natura 2000	Directive 92/43/EEC	1998												
Achieve Good Ecological Status in coastal waters	Directive 2000/60/EC													
Include spatial protection measures contributing to a coherent and representative network of MPAs	Directive 2008/56/EC													
Achieve 'good environmental status' in marine waters	Directive 2008/56/EC													
Marine biodiversity is restored or maintained	Directive 2008/56/EC													

Table 1.2 Timeline for selected policy objectives and targets for achieving healthy, clean and undisturbed, and productive Europe's seas (cont.)

Objectives	Sources	Deadline for implementation												
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2030	2050
Clean and undisturbed seas														
Establish EU-wide quantitative reduction target for marine litter	7th Environment Action Programme													
Combat invasive alien species	EU Biodiversity Strategy to 2020													
43% reduction in areas or ecosystems exposed to eutrophication	Thematic Strategy on Air Pollution													
Reduce carbon emissions from shipping by 40% compared to 2005 levels	Roadmap to a single European Transport Area													
All bathing waters achieve a classification of at least 'sufficient' quality	Directive 2006/7/EC													
Achieve good chemical status in coastal and territorial waters	Directive 2000/60/EC													
Reduce maximum sulphur content of marine fuels from 3.5% to 0.5%	Directive 2012/33/EC													
All fish stocks exploited at Maximum Sustainable Yield (MSY) rates	Regulation (EU) No 1380/2013													
Productive seas														
Fishing is within Maximum Sustainable Yield	Roadmap to a resource efficient Europe													
Phase out environmentally-harmful subsidies	Roadmap to a resource efficient Europe													
Renewable energy should account for 20% of final energy consumed on both land and sea	Directive 2009/28/EC													
Member States shall develop maritime spatial plans, applying an ecosystem-based approach	Directive 2014/89/EU										→ 2021			
Marine knowledge														
Reducing uncertainty in knowledge of the seas, and provide sounder basis for marine management	Marine Knowledge 2020													
Common Information Sharing Environment (CISE) for the surveillance of the EU maritime domain	COM/2010/0584 final													
Analysis of marine waters for assessment of environmental status	Directive 2008/56/EC (6 years-cycle)													
Collect, manage and provide access to high-quality fisheries data	Data Collection Framework 2008													
Reporting of conservation status of habitats and species based on established surveillance	Directive 92/43/EEC (6 years-cycle)													
Share data sets and services between public authorities for purposes of public tasks (INSPIRE+PSI)	Directive 2007/2/EC Directive 2013/37/EU													

Note: Red: directives/regulations, blue: policy/strategy objectives.

1.3 The Marine Strategy Framework Directive

From a European policy perspective, the management of human activities in the seas requires an integrated, holistic approach in order to ensure the resilience of marine ecosystems and the long-term delivery of ecosystem services. This integrated approach can be seen in the Marine Strategy Framework Directive, which was adopted in 2008.

The Marine Strategy Framework Directive is the environmental component of the Integrated Maritime Policy (IMP). It also makes a significant contribution to achieving the goals of the EU Biodiversity Strategy for the marine environment. It aims to maintain biodiversity and provide diverse and dynamic oceans and seas that are healthy, clean, and productive. The Marine Strategy Framework Directive is a central component of the EU policy response to tackling the wide range of challenges caused by exploitation of resources in Europe's seas (EC, 2008).

The objective of the Marine Strategy Framework Directive is to achieve 'good environmental status' (GES) for all marine waters by 2020. Good environmental status is described only in general terms through 11 descriptors, including biodiversity; non-indigenous species; commercially exploited fish; food-webs; eutrophication; sea-floor integrity; hydrographical conditions; contaminants in the environment; contaminants in seafood; marine litter; and energy (EC, 2008).

In 2012, EU Member States reported for the first time on the state of the marine environment, and on how they planned to achieve good environmental status by 2020. This reporting included an analysis of the essential features and characteristics of their marine waters. It also included an initial assessment of the current environmental status and of the predominant pressures and impacts on their marine areas. The final component of the reporting was an economic and social analysis of the uses of the marine environment and the resulting costs of degradation (EC, 2014b). Member States are also identifying environmental indicators and associated targets that quantify good environmental status.

The key tool for the achievement of the Marine Strategy Framework Directive goals is the Programme of Measures, which each Member State must establish by 2016 at the latest following two preparatory steps. Firstly, the Programme of Measures requires the elements described above (initial assessments, good economic status and targets). Secondly, the Programme of Measures requires the preparation of monitoring programmes. All these elements form part of the marine strategies that each EU Member State have to implement for achieving GES for its waters. MSFD thus operates as an adaptive, step-by-step process in which each step builds upon the previous one (EC, 2014e).

With the support of the legislation adopted by the Council and the European Parliament in July 2014 to create a common framework for maritime spatial planning (EC, 2014), the Marine Strategy Framework Directive provides the EU Member States sharing a marine region with a strong tool to jointly identify and assess the limits for sustainable use of Europe's seas.

The overarching EU policy tools are thus already in place. However, key questions remain. How far has Europe progressed towards overcoming traditional sectoral management approaches and truly achieving ecosystem-based management? And how far has Europe progressed in achieving its goal of a healthy marine environment? The following chapters will provide an overview of the current state of the seas, the pressures acting upon the marine environment, and the trends in the maritime activities driving them. They also explain the concepts of natural capital and ecosystem services, and how these apply to the sea. In addition, the following chapters explain how to measure the degradation of the sea's natural capital using the ecosystem services approach, and they provide a first indication of the extent of this degradation at a European level. This information constitutes a reference point for measuring progress towards EU policy goals in the future.

1.4 Understanding ecosystem-based management

The Integrated Maritime Policy will strengthen ecosystem-based management of our seas. But what does the ecosystem-based approach to the management of human activities in the marine environment mean in practice? Ecosystem-based management (EBM) features in several EU legislation and policy documents, such as the Marine Strategy Framework Directive and the Common Fisheries Policy (Box 1.2). The definitions of ecosystem-based management in these documents are not identical. However, they at least provide a starting point to understand ecosystem-based management in a European marine and maritime context.

The common denominator in these definitions of ecosystem-based management indicates that the approach is about preserving the long-term potential or capacity for ecosystems to continue to deliver the services and benefits upon which human societies depend. As illustrated by the definition in the Common Fisheries Policy, individual sectors have to

Box 1.2 EU policy definitions of ecosystem-based management

The marine strategies shall apply an ecosystem-based approach, which the Marine Strategy Framework Directive broadly defines as *management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations*.

The Common Fisheries Policy says that the *ecosystem-based approach to fisheries management means an integrated approach to managing fisheries within ecologically meaningful boundaries, which seeks to manage the use of natural resources, taking account of fishing and other human activities, while preserving both the biological wealth and the biological processes necessary to safeguard the composition, structure and functioning of the habitats of the ecosystem affected, by taking into account the knowledge and uncertainties regarding biotic, abiotic and human components of ecosystems*.

Source: EC, 2008; EC, 2014.

consider how they affect the composition, structure and functioning of the habitats (including species) in ecosystems. In addition, and as illustrated by the definition in the Marine Strategy Framework Directive, all sectors and EU Member States sharing a marine region have to jointly consider and balance their collective interests and assess the cumulative pressure they are placing on that marine region.

Besides the definitions in EU legislative documents, definitions have also been provided by the scientific community (McLeod and Leslie, 2009). Looking across the different definitions formulated by the scientific community and policy documents, a set of common denominators emerges (McLeod and Leslie, 2009). In the paragraphs that follow, we look at some of these common denominators.

These definitions agree that **ecosystem-based management is a 'place-based' approach**. One component that human activities (and related pressures) and ecosystem features have in common is that they all exist or occur in a particular place. A number of human activities can occur at a single location, whether it is an offshore wind farm, a fishery, or a place of leisure activity. This location will also host a number of habitats and species. Interactions between human activities on the one hand, and habitats/species on the other, occur at a range of spatial scales from local sites (e.g. a reef) to large-scale marine ecosystem features (e.g. the Gulf Stream). While there is no single correct scale for ecosystem-based management, the scale chosen in a particular policy has to be ecologically relevant. The Directive for Maritime Spatial Planning could potentially play a crucial role in advancing the place-based component of ecosystem-based management in the Marine Strategy Framework Directive (EC, 2014).

Scientists also agree that **ecosystem-based management is about recognising connections** — not only within an ecosystem, but also between ecosystems and human societies. At a wider level, it is also about connections between countries, cultures, and economies, and how these connections influence the environment. Ecosystem-based management recognises that human well-being remains intimately linked to healthy ecosystems and the benefits these ecosystems can provide. For this reason, ecosystem-based management is about understanding that humans are not a force that stands apart from the environment. Rather, humans are an integrated part of not only the environment and its challenges, but also of the solutions.

Ecosystem-based management is about cumulative pressures and impacts. A key insight of ecosystem-based management is that human activities often affect the marine environment in complex ways. Certain combinations of activities can enhance environmental resilience, and have an effect that is greater than the sum of their parts. Other combinations of human activities can have negative environmental effects that are far worse than the sum of their parts. Ecosystem-based management is a way to better recognise and account for the cumulative impacts of multiple activities by recognising the different drivers of change, and the way these drivers interact across different spatial and temporal scales.

Lastly, ecosystem-based management is about recognising multiple objectives — it focuses on the range of benefits that humans receive from the marine ecosystems (rather than focusing on a single service), and how these benefits are affected by many different human activities. People will seek a variety of different services from the same place or habitat. For example, should a shallow sandbank be used for offshore renewable energy, aggregates for the construction industry, or maintained as a fish spawning area? Taking time to understand all the competing demands on a place (and the trade-offs involved in a decision) before proceeding with a policy will allow for more informed management decisions.

In order to better illustrate current EU management efforts in the context of ecosystem-based management, this report uses a definition adapted from McLeod and Leslie (2009) (Box 1.3). This more clear and simple definition is preferred for measuring progress towards ecosystem-based management, when compared to the EU legislative definitions.

Box 1.3 Ecosystem-based management

Ecosystem-based management is an integrated approach to management that considers the entire ecosystem including humans.

The goal is to maintain ecosystems in a healthy, clean, productive, and resilient condition, so that they can continue to provide humans with the services and benefits upon which we depend.

It is a 1) spatial approach that builds around 2) acknowledging connections, 3) cumulative impacts and 4) multiple objectives rather than traditional approaches that address single concerns e.g. species, sectors, activities or individual national interests (adapted from McLeod et al., 2009).

2 The sea's natural capital

Summary of main points in this chapter

- The sea's natural capital is critical to meet people's basic needs, and to support our well-being and livelihoods (and the economy more broadly). It is made up of two constituents: ecosystem capital and abiotic natural capital. Marine ecosystem capital comprises all the living elements of the sea (e.g. fish, algae, etc.) and their interactions. Marine abiotic natural capital comprises the non-living elements of the sea (e.g. sand and gravel).
- Ecosystem services are the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people. Marine ecosystem services include provisioning services (such as food from fish); regulation and maintenance services (such as the sea's ability to absorb greenhouse gases, thus regulating the climate); and cultural services (such as the availability of charismatic marine species to observe or to research). We get many benefits from these services such as nutrition, reductions in anthropogenic CO_2, and recreation.
- The generation of ecosystem services can be explained as a 'cascade' flowing from the structural elements of marine ecosystems (e.g. algae), to the processes (e.g. photosynthesis) and to the functions (e.g. primary production) within these ecosystems. All the components of this cascade rely on biodiversity to interact. Service generation depends on the 'health' of marine ecosystems because 'healthy' ecosystems possess the full range of interactions supporting service generation. However, the components of this cascade only become services if there are people who directly consume, use (actively or passively) or enjoy them, and thus benefit from them.
- Biodiversity is critical for ecosystem service generation. This is because biodiversity supports ecosystem functioning, and can also directly deliver several ecosystem services. The loss of biodiversity could therefore disrupt and even halt the delivery of marine ecosystem services.
- Due to the close connection between marine ecosystems and their biodiversity, we need to pay equal attention to both of them when defining marine ecosystem services and assessing their state/use. This is needed to ensure that our assessments can estimate whether the services can be provided sustainably.
- Socio-technical systems require continuous flows of natural capital (both biotic/ecosystem-based and abiotic) to operate. Marine ecosystem capital can be degraded or lost when the sea's natural capital overall is not used sustainably, and such degradation and loss has costs for society.
- Replacing marine ecosystem capital with other forms of capital is often impossible or carries significant risks. Hence, if we want to keep on getting the services and associated benefits from marine ecosystem capital, our best option is to maintain it.
- Applying the 'ecosystem services' concept in the context of ecosystem-based management is central to maintaining marine ecosystem capital. This would require that:
  - Ecosystem services be used as a 'common language' for decision-makers, managers, and stakeholders. This is because such a 'language' would allow them to better understand and relate to all the benefits from marine ecosystem capital, and to do so in a shared way.
  - All human activities using the sea's natural capital (and not only those single economic sectors using marine ecosystem services and abiotic flows, such as fisheries and marine energy production) are managed as an integrated whole and within the ecosystem's 'carrying capacity'.
  - The approach takes into account that a greater range of pressures are exerted on marine ecosystems and biodiversity indirectly by human activities using/sourcing marine abiotic natural capital, than by those activities using marine ecosystem assets and services.

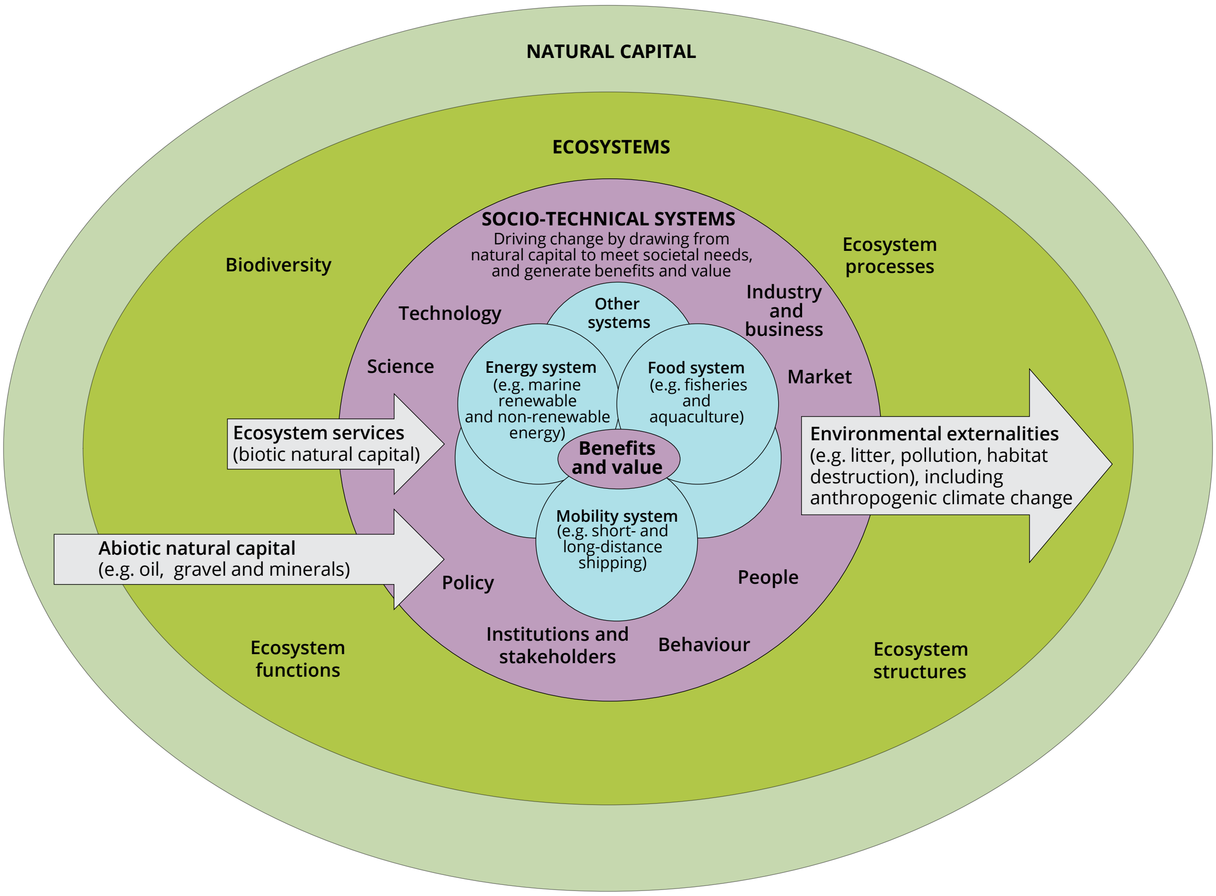
The introduction of the ecosystem-based approach to the management of human activities in the marine environment into the EU policy framework (Box 1.2) implies increased integration between marine ecology and economics. Treating marine ecology and economics as an integrated whole is essential for achieving sustainable use of the seas and human well-being.

This chapter explains how economic concepts such as capital and services apply to marine ecosystems. It also argues that the services provided by the biotic constitutent of the sea's natural capital (i.e. marine ecosystem capital) are critical to meet people's basic needs, and to support our well-being and livelihoods (and the economy more broadly). The concepts and technical information in this chapter should help explain how the findings of the assessment of the current state of Europe's marine environment in Chapters 3, 4 and 5 relate to these benefits. This chapter also serves as an introduction to the final analysis of our use of Europe's seas natural capital provided in Chapter 7.

2.1 The sea's natural capital and marine ecosystem services

The sea clearly plays a key role in determining a country's economic output and social well-being by providing resources and services, and by absorbing emissions and wastes (Figure I.1, Figure 2.1, Table 7.1, Table 7.2). This role is the sea's contribution to 'natural capital' (Box 2.1) (Pearce et al., 1989). The concept of 'natural capital' builds on the 18th-century idea of manufactured capital as one of the factors of production, where natural capital is thus considered a type of capital. Other types of capital include manufactured capital (e.g. machines and buildings); human capital (e.g. people, their skills and knowledge); and social capital (e.g. norms and institutions) (Pearce et al., 1989; Ekins, 1992; ten Brink et al., 2012).

Figure 2.1 The interactions between natural capital, its ecosystems and socio-technical systems



Note: Socio-technical systems act as 'drivers of change': they use natural capital and its ecosystems to meet societal needs, generate benefits, which have economic and other value, and promote well-being, but the externalities from such use can damage ecosystems.

Source: Adapted from EEA, 2014c; and EEA, 2015j.

Natural capital is arguably the most 'fundamental' of the forms of capital since it provides the basic conditions for human existence, i.e. water, air, food and resources, amongst other benefits. Maintaining it should therefore set the limits for our socio-technical systems, which require continuous flows of natural capital (both living/ecosystem-based and non-living) to operate (Figure I.1, Figure 2.1, Box 2.1) (EEA, 2015j).

The sea's natural capital includes biotic (living) and abiotic (non-living) elements, and comprises all the marine natural resources that society draws upon. It is made up of two constituents: ecosystem capital (also known as biotic natural capital) and abiotic natural capital (Box 2.1). Marine ecosystem capital comprises all marine biota (living organisms) and the biotic-abiotic interactions at the ecosystem level that are needed to keep the biota alive. For example, larval transport and food availability for marine filter-feeding organisms (e.g. mussels) depend on abiotic water movement. Marine abiotic natural capital comprises the non-living elements of the sea (e.g. seawater, sand and gravel).

Out of the two constituents of the sea's natural capital, marine ecosystem capital tends to go 'unseen' compared to marine abiotic natural capital, which is the basis of many economic activities and has a clear market price/value (Chapters 5 and 7). Thus, with obvious exceptions (such as using fish as a source of food), there is often little awareness of how marine ecosystem capital is generated, or of how it is delivered to people. Many times, the reason is that much of this ecosystem capital does not have a direct market price and hence it is not perceived as being important to support people's lives.

A generalised conceptual model for the generation of marine ecosystem services

The generation of ecosystem services in marine (and any other) ecosystems can be explained, in general terms, as a 'cascade' (see partial example in the diagram in Box 2.2, and also Figure I.1). The cascade's flow would start with the interactions between the ecosystem's 'structural' elements, which comprise both the living organisms (e.g. seagrass) and the non-living physical and chemical attributes of the ecosystem (e.g. light and nutrients). These interactions take place via basic ecosystem 'processes' (e.g. photosynthesis). The outputs from these interactions are the 'functions' of the ecosystem (e.g. primary production or the synthesis of organic compounds from dissolved inorganic compounds). The components of this cascade constitute the ecosystem's potential — in terms of quantity, quality and reliability — to deliver ecosystem services (e.g. climate regulation through marine carbon sequestration) (adapted from the United Kingdom National Ecosystem Assessment, 2011; Maes et al., 2013). Biodiversity plays a key role in the structural set up of ecosystems (e.g. the population abundance and/or biomass of the seagrass), which is essential to maintaining ecosystem processes and supporting ecosystem functions, and thus to the potential for service generation (Maes et al., 2013) (Box 2.2).

It follows, as a general rule, that the potential for service delivery is linked to the 'health' of marine ecosystems because 'healthy' ecosystems are fully functioning, i.e. they possess the full range of ecosystem interactions supporting service generation (Borja et al., 2013; Maes et al., 2013).

Box 2.1 Natural capital and its two constituents

Ecosystem capital (also known as biotic natural capital) involves ecosystems and their functioning, and is supported by biodiversity. Ecosystem capital thus includes the interactions between biota (living organisms such as fish, plankton and algae) and with their surrounding abiotic (non-living) environment. It consists of both ecosystem stocks (i.e. ecosystems viewed as assets) and ecosystem flows (i.e. ecosystems viewed as providers of services and benefits to society). When used by people, ecosystem flows turn into a wide range of valuable ecosystem services that are essential for human life and well-being such as seafood provision, absorption of CO_2, etc. (Table 7.1). In principle, ecosystem capital is renewable if it is used sustainably, but it will be degraded/depleted if misused. Moreover, ecosystem assets can also be lost through human use. For example, the conversion of a seagrass meadow into a harbour will destroy that habitat/ecosystem.

Abiotic natural capital is the second constituent of natural capital. It does not include living organisms, even though some elements of abiotic natural capital may have been alive in the past (such as oil, which is made up of long-dead organic matter). Just like ecosystem capital, abiotic natural capital also consists of assets and flows. Some abiotic assets can originate in the sub-soil (i.e. geological resources) and are non-renewable and depletable, such as minerals and fossil fuels. However, there are also abiotic assets that do not originate in the subsoil and are non-depletable, such as solar radiation. Abiotic flows come from abiotic assets and/or geo-physical cycles. They can be renewable/non-depletable (such as wind energy and marine tidal energy) or depletable depending on the flow (Table 7.2).

Source: Adapted from Maes et al., 2013; and Petersen et al., 2014.

Ecosystem services represent the actual flow of ecosystem capital that is realised because of a human active or passive demand. They are thus the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people (Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al., 2013) (Table 7.1). However, obtaining the benefits from the services requires human inputs such as labour, capital, or energy investments (Maes et al., 2013). Marine ecosystem services include provisioning services (such as food from fish); regulation and maintenance services (such as the sea's ability to absorb greenhouse gases, thus regulating the climate); and cultural services (such as the availability of charismatic marine species to observe or to research) (Figure I.1, Table 7.1). We get many benefits from these services such as nutrition, reductions in anthropogenic CO_2, and recreation.

Box 2.2 How marine ecosystems can generate marine ecosystem services: an example using the 'climate regulation by carbon sequestration' service

Primary production: how food is created in the oceans

Primary production involves the creation of food in marine ecosystems through the synthesis of organic compounds from dissolved inorganic compounds. It is an ecosystem function supporting the whole of the marine food web. Primary production begins with primary producers such as algae and seagrass (which are biotic 'structural' elements, see diagram below). Primary producers require energy to transform inorganic carbon from dissolved nutrients into organic carbon, which is then 'fixed' in their tissues. When this energy comes from the sun, the transforming ecosystem process is known as photosynthesis (where light and nutrients are abiotic 'structural' attributes of the system, see diagram below). The actual 'fixed' organic carbon in the living tissue of the photosynthetic organisms is the net primary production. However, the amount of primary production is the result of several other ecosystem processes in addition to photosynthesis, including nutrient uptake and respiration by the primary producers. All these ecosystem processes are influenced by the biodiversity of the photosynthetic organisms (mainly their species richness and abundance). The bulk of sun-based marine primary production is carried out by microscopic algae called phytoplankton. However, in coastal zones, seagrasses, macroalgae, and coral reefs contribute significantly to this ecosystem function.

Primary producers are then eaten by primary consumers, namely microscopic animals called zooplankton, such as copepods (which are also biotic 'structural' elements of ecosystems). The species composition, life strategies, and efficiency of these consumers are affected by temperature and other of their physico-chemical living conditions (which are also abiotic 'structural' attributes of the system). These conditions thus determine the amount of grazing, respiration, and excretion of the primary consumers (which are also ecosystem processes), which are also influenced by the biodiversity of these organisms. Such amounts, in turn, control the subsequent net secondary production (which is also an ecosystem function) available to other consumers at higher trophic levels such as fish, seabirds, mammals, and finally people.

How CO_2 is absorbed by the oceans

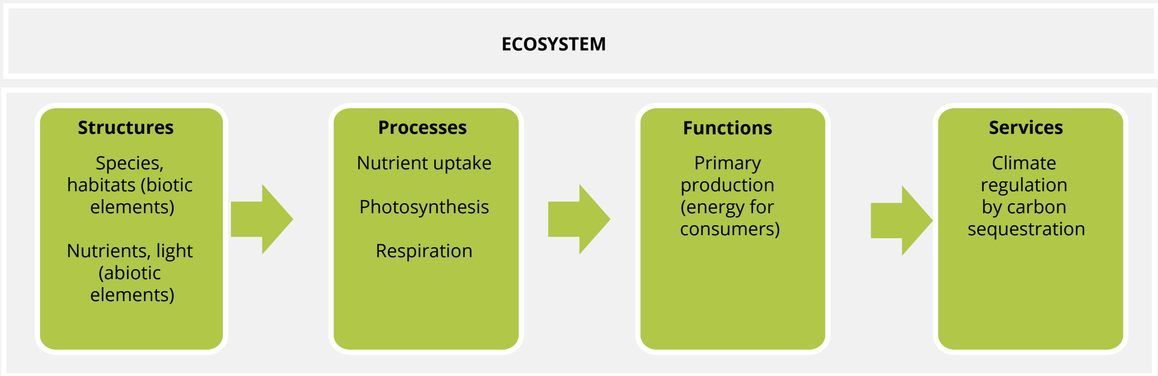
Not all of the excess CO_2 emitted by humans accumulates in the atmosphere, where it leads to anthropogenic climate change. The oceans can act as 'carbon sinks' and store some of this CO_2. This is partly a physical process where, as atmospheric CO_2 concentrations increase, more CO_2 dissolves into ocean water. However, marine organisms play a key role in climate regulation/control by acting as reserves or stores for CO_2 contributing to the 'marine carbon sequestration' service. Primary producers 'fixing' carbon in their living tissue as a result of primary production constitute the basic store (see diagram below linking the primary production function to the marine carbon sequestration service). Primary and all other consumers taking up this 'living' carbon act as further carbon stores. In addition, marine organisms facilitate the burial of carbon in seabed sediments when they die and sink to the bottom of the ocean. Overall (physical and biological) carbon sequestration by the oceans significantly slows the accumulation of atmospheric CO_2 and the resulting climate change. Thus, about 30% of all CO_2 released by humans is now stored in the oceans (IPCC, 2013). Without the marine CO_2 sinks mediated by marine organisms, the rate of anthropogenic global climate change would have been much higher than already observed.

Rates of total marine carbon sequestration depend on atmospheric CO_2 levels and ocean physico-chemical and biological factors (e.g. temperature, ocean circulation, ocean water mixing, the degree of CO_2 saturation of ovean water, and photosynthesis). At present, more CO_2 in the air leads to more CO_2 in the ocean water. However, this uptake of CO_2 by the oceans has negative effects, because it results in the acidification of ocean water (Section 4.9). The pH of ocean surface water has declined from 8.2 to below 8.1 over the industrial era (EEA, 2014d). Such a pH decrease corresponds to an increase in oceanic acidity of 26% [2] over that time-period (IPCC, 2013; EEA, 2014d). Laboratory and field studies show that acidity can

(2) Note the pH scale is logarithmic.

Box 2.2 How marine ecosystems can generate marine ecosystem services: an example using the 'climate regulation by carbon sequestration' service (cont.)

have adverse effects on many marine organisms, such as reduced ability to form and maintain shells and skeletons, as well as reduced survival, growth, abundance and larval development (IGBP et al., 2013). Therefore, marine acidification constitutes an added pressure on marine biota and marine ecosystems in general, which are already heavily suffering from other anthropogenic influences (EEA, 2014b; EEA, 2015h) (see also Chapters 3, 4 and 5). Further uptake of CO_2 by the ocean will increase ocean acidification (IPCC, 2013). Surface ocean pH is projected to decrease to values between 8.05 and 7.75 by the end of the 21st century depending on future CO_2 emission levels (IPCC, 2013; EEA, 2014d). The largest projected decline would represent more than a 100% increase in acidity compared to today's levels. This would very likely cause severe damage to marine ecosystems. At the same time, the ocean's capacity to absorb CO_2 from the atmosphere will be reduced by the further uptake of CO_2 because of the increasing CO_2 saturation of the water. In addition, the oceans capacity to absorb CO_2 itself is diminished by the progressive increase in the temperature of ocean water (colder water can absorb more CO_2 than warmer water) due to climate change. All of this will, in turn, decrease the oceans' role in regulating climate change (IGBP et al., 2013).



Source: Adapted from Wassmann and Olli, 2004; and Garpe, 2008.

Some considerations on the application of the general model for marine ecosystem service generation

Public policy, in particular at the EU level, is focusing more and more on the sustainability of our use of the sea's natural capital. There has been a particularly strong focus on assessing marine ecosystem capital because its self-renewal can be at risk from human activities using it directly, as well as from human activities using/sourcing marine abiotic natural capital since these can also damage ecosystems indirectly. Thus, if not managed sustainably, all these activities can degrade/deplete or destroy marine ecosystem capital. In addition, the focus on marine ecosystem capital is because, out of the two constituents of the sea's natural capital, this has the greatest link to human well-being through the services it can provide (Table 7.1). Assessing the state of marine ecosystem services can tell us about the self-renewal of marine ecosystem capital, and thus about whether our use of the sea's natural capital is sustainable (Chapter 7). Such an assessment would entail applying the generalised conceptual model outlined above on how these services are generated (see e.g. Box 2.2, Figure I.1).

An example of the potential application of this generalised model is the implementation of the Marine Strategy Framework Directive's Article 8.1.c. This article requires an 'economic and social analysis of the use of marine waters' and an analysis of the associated 'cost of degradation of the marine environment'. These analyses are about the use and degradation of marine ecosystem capital, and can be carried out using a marine ecosystem services approach (Chapter 7).

Nevertheless, before applying the generalised model for marine ecosystem service generation, it is important to understand that the general principles behind it come from the terrestrial domain, where the ecosystem services concept originated. There is more information available on terrestrial ecosystems than on marine ecosystems. This means that the general principles applicable to terrestrial ecosystem service generation may not always be directly applicable to marine ecosystem service generation. A consequence is that specific methodologies are needed when applying these general principles to the sea, which should be capable of taking into account the sea's complexity (i.e. its fluid and interconnected nature), the presence of mobile species, and issues relating to its large scale (Raffaeli, 2006; Atkins et al., 2013). These methodologies also need to be innovative in the way they try to overcome or account for clear gaps in the marine knowledge base. Such gaps include: the poor data available to characterise and map the different system elements; unclear causality (i.e. the interactions or linkages between system elements, in particular over time and space); how to account for the role of biodiversity in marine ecosystem service generation (Box 2.3); and how to measure the rate of ecosystem change resulting from human activities in the context of ecosystem resilience (Chapter 3).

There has been an increase in research on marine ecosystem services in recent years, in particular from the EU Framework Programme (FP6 and FP7). Research has included projects such as ODEMM, SESAME, KnowSeas, VECTORS, MESMA, and DEVOTES. The findings from these projects can help fill some of the gaps in the marine knowledge base outlined above; although this is not generally the case yet. Integration of these findings in 'EU reference' documentation on the topic of marine ecosystem service assessment would facilitate their use across the EU (Chapter 7).

One example of how research can help the assessment of marine ecosystem services and support the management of human activities using the sea's natural capital can be seen in the ODEMM ([3]) EU FP7 project. This project made important advances in improving knowledge on the chain of causality between ecosystem structures, processes, functions, services, and human activities and their pressures on the marine environment. Thus, it established the linkages between marine ecosystem components and the ecosystem services provided by those components on one hand, and the human activities (drivers) taking place in the EU's marine regions and the pressures caused by them on these components and services on the other hand (White et al., 2013b).

Following the ODEMM project, there has been a further refinement of the linkages it established, where the marine ecosystem components covered by the Marine Strategy Framework Directive have been linked to the marine ecosystem services delivered by Europe's seas (Culhane et al., unpublished). These types of linkages can be used as a baseline reference for EU-wide application of the marine ecosystem services concept (Chapter 7). This is under the understanding that they are subject to certain assumptions, limitations and uncertainties. For example, actual evidence of the linkages may only be available at a given location, which is a reason why an assessment of marine ecosystem services that can support taking the appropriate management action 'on the ground' has to be specific to that location (Hattam et al., 2015).

2.2 The role of biodiversity in marine ecosystem service generation

Gaps in our knowledge

We know that biodiversity is critical for the generation of marine ecosystem services but there are some knowledge gaps in our understanding of what the exact relationship between the two is. We do not always understand the sensitivity of marine ecosystem functioning (and associated potential for service delivery) to changes in biodiversity, such as those changes that result from the influence of the abiotic environment and human activities (Norris, 2012). In addition, we have gaps in our understanding of how biodiversity correlates to the different categories of marine ecosystem services (see services classification in Chapter 7). For example, evidence of the link between biodiversity and several of the so-called 'cultural' services is poor (see review in Cardinale et al., 2012) (Table 7.1). And, while we may find it difficult to correlate biodiversity with different ecosystem service categories, we find it even more difficult to quantify any correlations we can make (see review in Atkins et al., 2013).

What we know

Nevertheless, it is clear that biodiversity supports marine ecosystem potential for service delivery indirectly by supporting the functioning of marine ecosystems. Furthermore, biodiversity has also the potential to deliver marine ecosystem services directly (Box 2.3).

We know enough about biodiversity's role in the generation of marine ecosystem services to conclude that biodiversity loss is likely to affect service generation differently depending on what species are lost and what places they occupy in the marine food web (Raffaelli, 2006). We can also conclude that increased biodiversity loss will accelerate changes in ecosystem functioning and the potential for service delivery. This is because the link between biodiversity and marine ecosystem functioning is non-linear and saturating (ecosystem function is dependent upon biodiversity at low levels of species richness only) (see review in Cardinale et al., 2012). Finally, we can

([3]) Options for Delivering Ecosystem-Based Marine Management (http://www.liv.ac.uk/odemm).

Box 2.3 The role of biodiversity in marine ecosystem service generation

Biodiversity (see definition in CBD, 1993) can have different roles in supporting ecosystem functioning and ecosystem potential for service delivery (both indirect and direct) as follows:

Contribution to ecosystem functioning through:

- enhancing the efficiency of ecosystem processes, e.g. making the nutrient-uptake, photosynthesis, and respiration processes of primary producers more efficient, and thus facilitating the function of primary production (Box 2.2);
- functional traits diversity, which is the variation in the degree of the expression of the multiple functional traits of the species present in a community. Functional traits are those that define species in terms of their ecological roles, i.e. in terms of how they interact with the environment and with other species;
- species diversity, which provides structuring to habitats and ecosystems as needed for many other species to exist.

Direct potential for ecosystem service delivery through:

- genetic diversity, which is the diversity of the gene pool. This can deliver the 'genetic material' **provisioning service**, such as the marine plant and algal genes used in biotechnology (Table 7.1);
- species richness, which refers to the total number of species; and taxonomic diversity, which is the total number of species of certain groups, e.g. marine mammals. These can deliver **cultural services,** such as whale watching (Table 7.1);
- the diversity of specific biotic interactions (such as predation or foraging) in a food web or in species networks. This can deliver **regulation and maintenance services,** such as seed dispersal. An example of this service is seagrass-seed dispersal through the consumption of seagrass and excretion of its seeds by marine animals, including fish, turtles, and birds (Sumoski and Orth, 2012) (Table 7.1).

Source: Adapted from reviews in Cardinale et al., 2012; Maes et al., 2013; and Atkins et al., 2013.

conclude that biodiversity loss could even cause an abrupt change (i.e. a decline or stop) in ecosystem functioning and the potential for service delivery under certain conditions. This could be in cases where the ecosystem processes supporting ecosystem functioning and the potential for service delivery are driven by both species diversity and functional diversity (see definition in Box 2.3), and functional diversity is low (i.e. there are only a few or no other species involved in the relevant process when the critical species dies off) (see review in Cardinale et al., 2012).

An illustration of where marine biodiversity loss could cause an abrupt change in ecosystem functioning and the potential for service delivery would be the decline in the number of species at the top of the marine food web. This is because these species are responsible for key ecosystem interactions, namely direct predation and associated prey behaviour. Such species include tuna, sharks, whales, sea lions, sea otters, and possibly some species of birds (see review in Heithaus et al., 2008).

The decline in the number of these top predator species means that the role they play in the food web could be left unfulfilled, which could trigger food-web cascades. These cascades could temporarily or permanently shift the ecosystem into a different state (see review in Heithaus et al., 2008). Regime shifts are large, abrupt, long-lasting changes in ecosystems that often have considerable impacts on the economy and society because they affect the flow of ecosystem services and associated benefits to people (Biggs et al., 2009, Box 3.10). An example of these impacts/effects would be the collapse of commercial fish stocks resulting from the regime shift that happened in the Black Sea in the early 1990s. Returning to the original ecological state could be difficult, even when the driver that precipitated the regime shift is reduced or removed, because shifts change the internal dynamics and feedbacks of an ecosystem (Biggs et al., 2009).

The situation illustrated above is part of the 'diversity-stability' hypothesis, which suggests that biodiversity provides a general insurance policy that minimises the chance of large ecosystem changes (Worm et al., 2006; see review in Cardinale et al., 2012). However, the relationship between biodiversity and ecological stability is still very much the subject of research. In addition, research is showing that this relationship seems to be different for terrestrial and marine ecosystems, which is due to the complexities of marine ecosystem functioning that have been outlined throughout this chapter.

It also is important to realise that simply because a marine ecosystem stock is able to meet the human demand for a given marine ecosystem service (or two, or a very limited range), this does not necessarily imply that the marine ecosystem *as a whole* is 'healthy' (i.e. fully functioning). This insight has several implications. For example, one implication is that continued flows (catches) of one type of commercial fish today do not mean that commercial fishing has no effect on other fish species, nor that it does not have an effect on future flows of this fish species. It also does not mean that these continued flows do not have an effect on the potential for delivery of other ecosystem services (whether now or in the future). Exchanges between and within ecosystem stocks and associated ecosystem flows are taking place everywhere at all times, even if these exchanges may not be obvious.

There are several reasons for such exchanges. One reason is that there are different marine ecosystem components (e.g. habitat types, and biotic groups at the individual species and functional group level) and biodiversity dimensions (see e.g. Box 2.3) involved in the 'production' of a service. Marine ecosystem components would thus have different 'production' rates over time and space; different sensitivity/ vulnerability to different human and natural change factors; and different capacities to recover from disturbances. For example, in terms of sensitivity/ vulnerability to change, a commercial fish species such as cod needs an undisturbed benthic habitat to thrive; while this may not be so attractive to fish species that naturally thrive in slightly disturbed conditions such as plaice (Hiddink et al., 2008; Beare et al., 2013; van Denderen et al., 2013).

Final reflection

Because of the close connection between ecosystems and biodiversity, it is critical that we pay equal attention to both ecosystems and their biodiversity when defining ecosystem services and assessing their state/use. This is needed to ensure that our assessments can estimate whether the services can be provided sustainably (Palmer and Febria, 2012). In order to achieve this, ecosystem 'health' (defined here as the maximum ecosystem capacity for service delivery) should be assessed using multiple metrics, and these metrics should cover both the ecosystem's static and dynamic nature (Palmer et al., 2012). The former relates to the presence/existence of ecosystem 'structural' elements (such as the seagrass species present and their extent), and the latter relates to their performance within ecosystems (such as the seagrass productivity/ reproduction).

2.3 Using the sea's natural capital

Human activities and the sea's natural capital

Socio-technical systems depend on the sea's natural capital (Figure I.1, Figure 2.1) to meet people's basic needs, and to support our well-being and livelihoods (and the economy more broadly). In order to fulfil the demand from these systems, we need to access, transform and share the sea's natural capital. However, many of the human activities involved in such processes can also degrade this capital, reducing its availability, or even destroying it. Marine ecosystem capital is the part of the sea's natural capital with the potential to generate ecosystem services supporting our daily lives and, in particular, key aspects of our well-being such as health and happiness. These ecosystem services cannot be replaced by marine abiotic natural capital (see also below). Therefore, maintaining marine ecosystem capital, and the services it can provide, is key for our way of life.
In principle, a lot of marine ecosystem capital (e.g. commercial fish stocks) is renewable. However, it can be degraded or lost when the use of the sea's natural capital overall is mismanaged. And instances of habitat/ecosystem destruction linked to a change of use of marine space — such as building a marina — would be irreversible.

The self-renewal of marine ecosystem capital depends on whether human activities using it directly (e.g. fisheries) are managed sustainably, i.e. within the ecosystem's 'carrying capacity'. The carrying capacity is the threshold limit of system use that does not damage the system. In addition, the criterion of sustainability should apply to those activities that use/source marine abiotic capital (e.g. mineral and aggregate mining), as these activities can also damage marine ecosystems indirectly (see Chapters 3, 4 and 5, in particular Table 5.1). In fact, human activities using/ sourcing marine abiotic capital can generate a greater range of pressures, both in terms of numbers and type, on marine ecosystems and biodiversity than those activities using marine ecosystem assets and services (Table 5.1).

All these human activities are therefore 'drivers of change' on marine ecosystems and biodiversity (Figure I.1, Figure 2.1). They can threaten the integrity and resilience of marine ecosystems, and thus their capacity to continue delivering the services and benefits we need. It should be noted that EU and national policy is another driver of change in marine ecosystems and biodiversity. This is both because it can promote certain potentially damaging human activities and because it can respond to the threats raised by these activities.

It follows that if marine ecosystem capital has benefits for people, the degradation and loss of marine ecosystem capital has costs. These costs are known as the 'cost of degradation', which corresponds to a loss of welfare. The 'cost of degradation' can be assessed in different ways, e.g. through foregone benefits (such as loss of profits), increased production costs, or increased mitigation costs.

For example ([4]), seagrass can provide a wide range of marine ecosystem services including acting as a nursery for commercial and migratory fish and invertebrate species (Table 7.1). In the Mediterranean Sea, this service is mostly provided by the main endemic species *Posidonia oceanica.* This seagrass species has been estimated to contribute 4% to the total value of commercial fish landings and 6% to the total expenditure of recreational fisheries in the Mediterranean Sea, equating to a total of EUR 78 million and EUR 112 million a year respectively (Jackson et al., 2015). *Posidonia oceanica* is slow growing and highly vulnerable, which is why it is protected by the EU Habitats Directive and other EU, global and national regulations (Pergent et al., 2010). Following historical decline, it now covers about 2% of the area of the Mediterranean Sea and the population trend is decreasing according to the IUCN red list of threatened species (Pergent et al., 2010). Research predicts further decline of *Posidonia oceanica* due to increased sea surface temperature as a result of anthropogenic climate change (Jorda et al., 2012). The cost of further degradation of *Posidonia oceanica* seagrass would include the above-mentioned benefits provided by its nursery service, which will be lost to commercial and recreational fisheries. The 'cost of degradation' is further discussed later in this report (Chapter 7).

It must be stressed that replacing marine ecosystem capital with other forms of capital is often impossible or carries significant risks with regard to what the end result will actually be (EEA, 2015h; EEA, 2015j). It is therefore wiser to prevent marine ecosystem degradation and loss instead. The risks of attempting to replace marine ecosystem capital include not being able to properly reflect the multi-functionality of marine ecosystem components (e.g. seagrasses store carbon, and provide habitats and recreational opportunities, etc.), as these cannot be fully replicated by other forms of capital such as manufactured capital. Another risk when attempting to replace marine ecosystem capital with other capital is not being able to know where and when exactly to do so. This is because of the complexity and interconnectedness of marine ecosystems over space and time. Marine ecosystem processes and functions are non-linear and discontinuous, which makes it difficult to predict the impacts upon them. This leads to some uncertainty in determining the true condition of a marine ecosystem at a given time, which means that we cannot be fully certain of whether the ecosystem will be resilient or change when faced with disruption. The uncertainty is especially great when it comes to estimating the ecosystem's carrying capacity and whether change might result in it reaching a 'tipping point' ([5]) leading to an ecological regime shift.

Finally, it is also worth stressing that marine ecosystem change is incredibly difficult — if not impossible — to reverse (Möllmann, 2011; Graham et al., 2013). This further reinforces the need to maintain marine ecosystem capital.

Maintaining marine ecosystem capital

Maintaining marine ecosystem capital by avoiding its degradation and loss could be achieved by applying the 'ecosystem services' concept in the context of ecosystem-based management (Chapter 1). There are three main requirements to make this happen.

The first requirement is to ensure that the concept of ecosystem services becomes a 'common language' for decision-makers, managers, and stakeholders because this is a 'language' that can allow them to better understand and relate to all the benefits that come from marine ecosystem capital in the same way.

The second requirement is the establishment of an integrated management regime for all possible human activities using the sea's natural capital, rather than only managing those single, economic sectors that draw directly from the specific services and abiotic flows the sea provides (as tends to be the case now) (Chapter 1). Further, this integrated regime should take into account that human activities using/sourcing marine abiotic capital can generate a greater range of pressures, both in terms of numbers and type, on marine ecosystems and biodiversity than those activities using marine ecosystem assets and services (Chapter 5).

([4]) See also the example from the New Economics Foundation in Chapter 7.
([5]) See what 'tipping points' are at http://biodiversity.europa.eu/topics/tipping-points.

The third requirement is to ensure that the ecosystem's 'carrying capacity' be set as the limit for the development of all possible human activities.

Such a holistic approach should therefore include all human activities on the abiotic marine environment (i.e. the water column and the seabed in the sense of marine space), such as transport and the deployment of marine renewable energy infrastructure. It should also include those activities relating to the exploitation of abiotic outputs (e.g. sand, oil, gas, and gravel). Thus, all the activities using or facilitating access to abiotic natural capital can degrade the general condition of ecosystems because they generate emissions, such as air and water pollution, and waste. They can also cause damage to marine species and abrasion of marine habitats (Table 5.1).

The holistic approach should also include activities using marine ecosystem services, such as fishing and bio-prospecting of marine biota for the production of chemicals and medicines. Thus, overuse of marine ecosystem services can reduce and even deplete the ecosystem stock, i.e. its capacity for further generation of the specific services being used, and of other services. Lastly, the holistic approach should also extend to activities facilitating access to marine ecosystem services, such as the construction and maintenance of coastal tourism infrastructure facilities, which can generate a mix of the pressures listed above relating to the use of marine abiotic natural capital (Table 5.1).

Human activities that can protect and enhance marine ecosystems and their biodiversity should also be considered in such a holistic context. These activities include spatial protection measures (such as marine protected areas; Box 6.1), and marine nature restoration. An example of the latter is the successful LIFE Blue Reef project for the restoration of the boulder reef at Læsø Trindel in the Kattegat (Denmark) (Box 2.4). However, it is important to differentiate between habitat restoration activities developed specifically to benefit ecosystems/biodiversity, and other human activities that may end up providing artificial marine habitats. Such activities, for example the deployment of offshore platforms for oil exploitation, are not necessarily driven by the same primary aim. Moreover, some of these other human activities can actually cause specific marine pressures leading to marine ecosystem degradation and loss as outlined above and shown in Chapters 3, 4 and 5.

Maritime spatial planning, and thus the new EU Maritime Spatial Planning Directive, will be a key tool to support this holistic approach.

Nevertheless, the task of maintaining marine ecosystem capital is hard for two main reasons. Firstly, because it is difficult to assess its condition in a precise manner at a given time as explained above. Secondly, because the full value of marine ecosystem capital is rarely reflected in economic choices. This can lead to purely market-based management of human activities using the sea's natural capital, and to privileging the maintenance of some marine ecosystem services, namely the 'visible' ones with immediate economic value (Chapter 7). These 'visible' services include all the services under the 'provisioning' category (e.g. seafood from commercial fish stocks), and those services from the 'cultural' services category that relate to physical and intellectual interactions with marine biota and ecosystems/seascapes (e.g. whale watching) (Table 7.1).

When 'visible' services are privileged by management, other services that are not easily monetised tend to be ignored (Chapter 7). These 'unseen' services include most services from the 'regulation and maintenance' category (e.g. global climate regulation by marine carbon sequestration, Box 2.2), and those services from the cultural services category relating to spiritual, emblematic and other cultural interactions with marine biota and ecosystems/seascapes (e.g. existence and bequest) (Table 7.1).

Box 2.4 An example of marine ecosystem restoration: The LIFE Blue Reef project

The LIFE Blue Reef project for the restoration of the boulder reef at Læsø Trindel in the Kattegat (Denmark) received significant support from the EU LIFE Programme, and won the 2015 European Natura 2000 Award for best conservation project. It ran from 2006 to 2013 and aimed to restore the reef and bring back the high biodiversity characteristic of this type of habitat (reefs are included in Annex I of the Habitats Directive). The reef was degraded because its boulders had been removed over the previous 50 years, mainly to be used in the construction of harbours and coastal defences. Restoration involved bringing rocks from a quarry in Norway to the reef in 2008. By 2012, biodiversity had generally improved compared to pre-restoration conditions. The quality of the macro algal forest was considerably better, larger benthic fauna like sea anemones were present, there were more fish (e.g. cod and saithe), and there were also more numerous visits from harbour porpoises. More species of fauna and flora are currently settling there and even more are expected to do so in the future.

Source: Adapted from Reker. J. pers comm. and the Danish Nature Agency (http://naturstyrelsen.dk/naturbeskyttelse/naturprojekter/blue-reef).

Such unwittingly biased management at the expense of overall ecosystem health, or of the 'unseen' services, also carries the risks listed earlier in this section. Reversing this potential bias would require identifying, quantifying and managing the trade-offs between maintaining or restoring marine ecosystem capital and the exploitation of the sea's natural capital overall in relation to the drivers of marine ecosystem change resulting from human needs. It will also require identifying, quantifying and managing the trade-offs between services in relation to those same drivers of change. It will therefore require finding out how increasing the generation of one service may decrease the generation of other services, and/or the overall integrity and resilience of the relevant ecosystems (Foley et al., 2005; Kareiva et al., 2007; review in Norris, et. al, 2012; Maes et al., 2013; Rogers et al., 2014).

EU policy support for maintaining marine ecosystem capital

Partly as a response to the shortcomings outlined above with regard to managing our use of the sea's natural capital, the EU has built on its nature protection legislation (e.g. the Habitats Directive), and introduced legislation supporting ecosystem-based management (e.g. the Water Framework Directive and the Marine Strategy Framework Directive). These newer environmental directives include references to enhancing ecosystems, ecosystem functions, and ecosystem services.

The EU has also recently shifted towards a more systemic policy perspective, explicitly addressing natural capital and ecosystem capital, and their assessment as shown in the 7th Environment Action Programme and the Biodiversity Strategy to 2020. Requirements for this assessment can include bio-physical quantification and monetary valuation, as is called for in Target 2/Action 5 of the Biodiversity Strategy.

Information from the implementation of EU environmental legislation can be used to assess the 'health' or condition of marine ecosystems. Thus, this information can be used to derive both structural and functional metrics to assess marine ecosystems, which, when combined, allow the most suitable assessment of ecosystem condition (Palmer and Febria, 2012). Other EU legislation and policy (and/or global or regional policy) can also be helpful in this respect. For example, the Common Fisheries Policy requires inter alia the assessment of the state of commercial fish stocks to ensure sustainable extraction. Therefore, EU environmental legislation and EU policy have the power to work as a strong tool to assess the capacity of marine ecosystems to deliver services, and to evaluate the sustainability of the services provided to people. However, this power has not been completely fulfilled yet (Chapter 7).

3 Are our seas healthy?

Key messages on marine biodiversity

- Marine biodiversity remains insufficiently assessed at the EU level. It is showing patterns of degradation across all regional seas indicative of a poor state of many species and habitats. Thus Europe's seas cannot currently be considered to be in a healthy state.
- For species and habitats assessed from 2007 to 2012 under the Habitats Directive, results show that 9% of marine habitats and 7% of marine species assessments were considered to be in 'favourable conservation status', whilst 66% of marine habitat assessments and 27% of marine species assessments were considered to be in 'unfavourable conservation status'.
- The observed loss of biodiversity affects ecosystem functioning and may cause irreversible loss of ecosystem resilience. Loss of ecosystem resilience puts in jeopardy ecosystem health and may disrupt or halt the supply of key marine ecosystem services.
- Significant efforts are needed to enhance coordination of marine biodiversity information across all regional seas to improve our information base.

3.1 Introduction

Europe contains a wide range of ecosystems, ranging from the stable, deep oceans to the highly dynamic coastal seas. By considering the state of marine biodiversity, we can better understand the services and benefits human societies receive from these marine ecosystems.

Biodiversity is the variability among all living organisms: this includes diversity within species, between species, and of ecosystems (CBD, 1993). It is the essential structure of ecosystems, and ranges from the smallest bacteria in the sediment of the seafloor to the largest whale in the ocean. More than 36 000 species (excluding bacteria) have been identified for Europe's seas, although up to 48 000 may exist (Costello and Wilson, 2011). The ranges and distribution patterns of species and habitats vary across regional seas, with the Mediterranean Sea hosting the highest natural biodiversity.

Loss of biodiversity leads to loss of resilience

Over the last couple of decades, we have improved our scientific understanding of how biodiversity — and loss of biodiversity — affects ecosystem structure and functioning (Box 2.3). This knowledge is also highly relevant for Europe's seas and our use of them.

The state of biodiversity is affected by anthropogenic drivers of change. These drivers of change can result in both chronic (i.e. persistent and long lasting) and acute (i.e. short and severe) impacts. Although acute impacts cause the greatest threat, chronic impacts are more insidious, because they slowly but pervasively break ecological interactions.

The cumulative impacts of historical and current anthropogenic drivers of change in the ocean are profound. These impacts are causing measurable changes to the functioning of marine habitats and species population structures throughout the globe (Jackson et al., 2001a; Jackson, 2008; Micheli, Halpern, et al., 2013).

These changes can be seen in the decrease in abundance of individual species; a loss in their distribution range; and/or a loss of their habitats. This pattern of change has been experienced by the few marine species that, to our knowledge, have become extinct in Europe's seas. Among these species are the Baltic sturgeon *Acipenser oxyrinchus*, the Great auk, and the Canarian black oystercatcher (Table 3.1). Before such patterns of change result in the full 'extinction' of a species, they first result in a pre-extinction phase known as an 'ecological extinction' (Box 3.1). Ecological extinctions are now observed for many European marine species such as the Angel shark, and the European eel (Table 3.1).

Box 3.1 Ecological and species extinctions

Ecological extinction is the reduction of a species to such low abundance that, although it is still present in the community, it no longer interacts significantly with other species (Estes et al., 1989).

Species extinction is when there is no reasonable doubt that the last individual has died (Davies et al., 2004; IUCN, 2012).

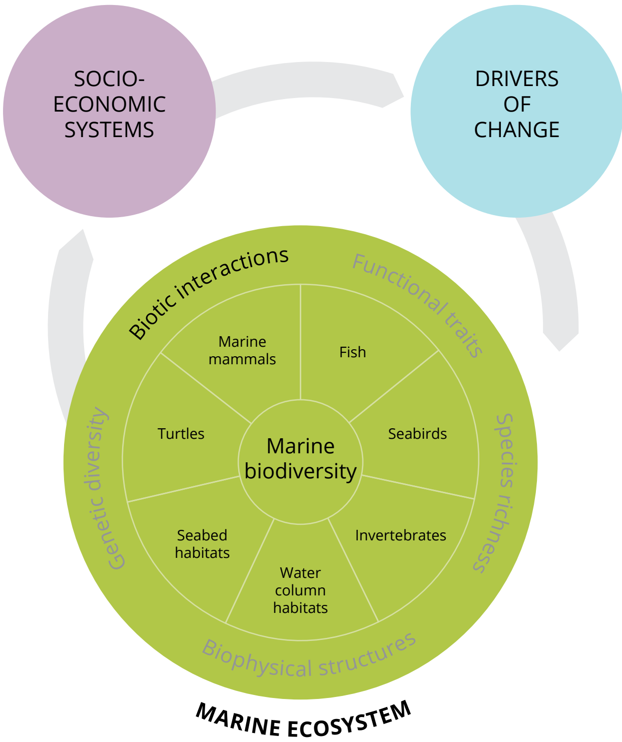
In general, there is evidence from European regional seas of a reduction in the abundance of some individual species, as well as a reduction in the extent of undisturbed habitats at local and regional scales (Table 3.1). This reduction, and the associated loss of ecosystem structure and functioning, can undermine ecosystem resilience (Box 3.2). This in turn influences the ecosystem's capacity to provide services and benefits for human societies, which affects human health and well-being (Coll et al., 2010; Cardinale et al., 2012). However, as long as a species has not reached species extinction there is hope that it can recover through targeted policy and management efforts.

Assessing European marine biodiversity

In a European context, it remains difficult to assess the extent of the loss of biodiversity to the structure and functioning of marine ecosystems. The difficulties can be seen in the lack of coherence of the reported information at the 'ecosystem level' under the Initial Assessment reporting of the Marine Strategy Framework Directive (MSFD) (ETC/ICM, 2014).

In order to understand the effects of anthropogenic drivers of change upon marine ecosystems, it is essential to identify the constituent ecosystem components that allow for a description of the health of the marine environment. Such components can include biodiversity features analysed at different levels of detail (e.g. functional groups, species populations, habitats, and specific biological assemblages). But the components also include ecosystem processes and patterns (e.g. structure and functioning of food-webs and/or seafloor integrity) (McLeod and Leslie, 2009; Figure 3.1).

Figure 3.1 Assessing the state of marine ecosystems, habitats, and species



Note: See also Figure I.1.

Box 3.2 Ecological resilience

Ecological 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: an ecosystem's capacity to resist change; the amount of change an ecosystem can undergo while still retaining the same controls on structure and function; and an ecosystem's ability to re-organise following disturbance.

Resilience thus relates to characteristics that underpin the capacity of ecosystems to provide ecosystem services and benefits.

Source: EEA, 2012b.

This chapter focuses on describing changes in these components. The components discussed in this chapter include the state of the marine seafloor habitats; the state of water column habitats; the state of species; and the state of marine food webs in Europe's regional seas. There are more than 36 000 species and 1 000 habitats in Europe's seas (Costello et al., 2011; Davies et al., 2004). The status for the vast majority of these species and habitats are not assessed. The following eight groups were selected for this chapter as they are frequently reported on and assessed under EU Directives: seabed habitats (Section 3.2); water column habitats (Section 3.3); marine invertebrates (Section 3.4); fish (Section 3.5); turtles (Section 3.6); seabirds (Section 3.7); marine mammals (Section 3.8); and food webs (Section 3.9). Plants are included in the two habitats groups. These eight groups directly relate to three of the descriptors of 'good environmental status' in the MSFD. They include descriptor 1: biodiversity; descriptor 4: food webs; and descriptor 6: seafloor integrity.

By showing the available evidence (even though this evidence is fragmented across the European regional seas), it is possible to demonstrate that significant changes are already occurring in Europe's marine ecosystems. This chapter discusses whether these changes mean that the marine food webs and marine biodiversity of Europe's seas can be considered to be in a healthy state (Section 3.10).

3.2 Seabed habitats

Messages on seabed habitats

- There is a great diversity of seabed habitats across the different regional seas of Europe, with over 1 000 different seabed habitat types identified.
- From 2007 to 2012, reporting by Member States under the Habitats Directive showed that 66% of the biogeographic assessments for nine marine habitats showed 'unfavourable conservation status', compared to 9% showing 'favourable conservation status'. The remaining assessments were reported as 'unknown' or 'not assessed'.
- In 2012, 76% of the MSFD Initial Assessments for seabed habitats concluded with 'unknown' status, reflecting the difficulty in monitoring and assessing marine habitats.

Rich and diverse seabed habitats

Europe's seas are home to a rich and diverse range of seabed habitats, with over 1 000 different seabed habitats described (Davies et al., 2004). These habitats vary from the coral reefs found in the cold, dark depths of the North-east Atlantic Ocean to the seagrass meadows found in the clear, warm waters of the Mediterranean Sea.

The nature of seabed communities depends on a number of environmental factors, including light, energy, and the type of seabed substrate. The complexity of the land-sea interface also gives rise to mosaics of seabed habitats, from the bladder wrack habitats of the Baltic Sea to the freshwater-influenced systems of the Danube Delta. Marine species themselves can also modify the seabed by creating biogenic habitats (Box 3.3). Further away from the coasts, expansive areas of sediment-based seabed habitats can be found, from huge sandbanks such as Dogger Bank, to the fine mud plains of the Irish and North Seas. In very deep waters (more than 1 800 m in depth), it is possible to find underwater canyons, seamounts, and abyssal seabed habitats.

Seabed habitats are involved in a range of key ecological processes, which support the delivery of provisioning, regulating, and cultural ecosystem services. For example, seabed habitats produce plant and animal biomass through primary (e.g. photosynthesis) and secondary processes (e.g. grazing and predation); enable food-web dynamics; enable species diversification and the creation of habitats and nursery/spawning grounds; and provide for erosion control and nutrient cycling. Seagrass habitats such as *Posidonia oceanica* meadows found in the Mediterranean Sea (Boudouresque et al., 2009; Duarte et al., 2009) or *Zostera marina* found in the Baltic Sea and the Wadden Sea provide all these services.

Seabed habitats in unfavourable status

It is often difficult to find coherent information on the state of seabed habitats at the scale of regional seas. As part of the MSFD Initial Assessment, EU Member States provided 702 individual seabed habitat assessments. However, 76% of these assessments concluded that the status of these seabed habitats was 'unknown', whilst 5% of the assessments concluded that the seabed habitat was in 'good environmental status' (ETC/ICM, 2014). This reflects the difficulty in monitoring and assessing seabed habitats, both because of the difficulty in collecting data over such vast areas, and also because of the lack of robust and accepted assessment methods.

The MSFD has not resulted in a lot of information on seabed habitats, but the Habitats Directive has been more successful in this regard. The Habitats Directive specifically mentions nine marine habitats ([6]). From 2007 to 2012, assessments show that only 9% of these marine habitats were considered to be in 'favourable' conservation status, and 66% of these marine habitats assessments were considered to be in 'unfavourable' conservation status (Figure 3.2). In the 2001–2006 assessment period, 9% of the marine habitat assessments were considered to be in 'favourable' conservation status, and 40% of the marine habitat assessments in unfavourable' conservation status. It is not possible to draw robust conclusions from a direct comparison between the two periods at this level of detail, because changes in the percentage of favourable and unfavourable assessments do not always infer true changes, but instead demonstrate better knowledge (i.e. there were fewer unknown assessments in 2007–2012).

([6]) The nine marine habitats are: sandbanks that are slightly covered by sea water all the time; Posidonia beds (*Posidonia oceanica*); Estuaries; mudflats and sandflats not covered by seawater at low tide; marge shallow inlets and bays; reefs; submarine structures made by leaking gases; Boreal Baltic narrow inlets; submerged or partially submerged sea caves.

Box 3.3 Biogenic reefs and their state

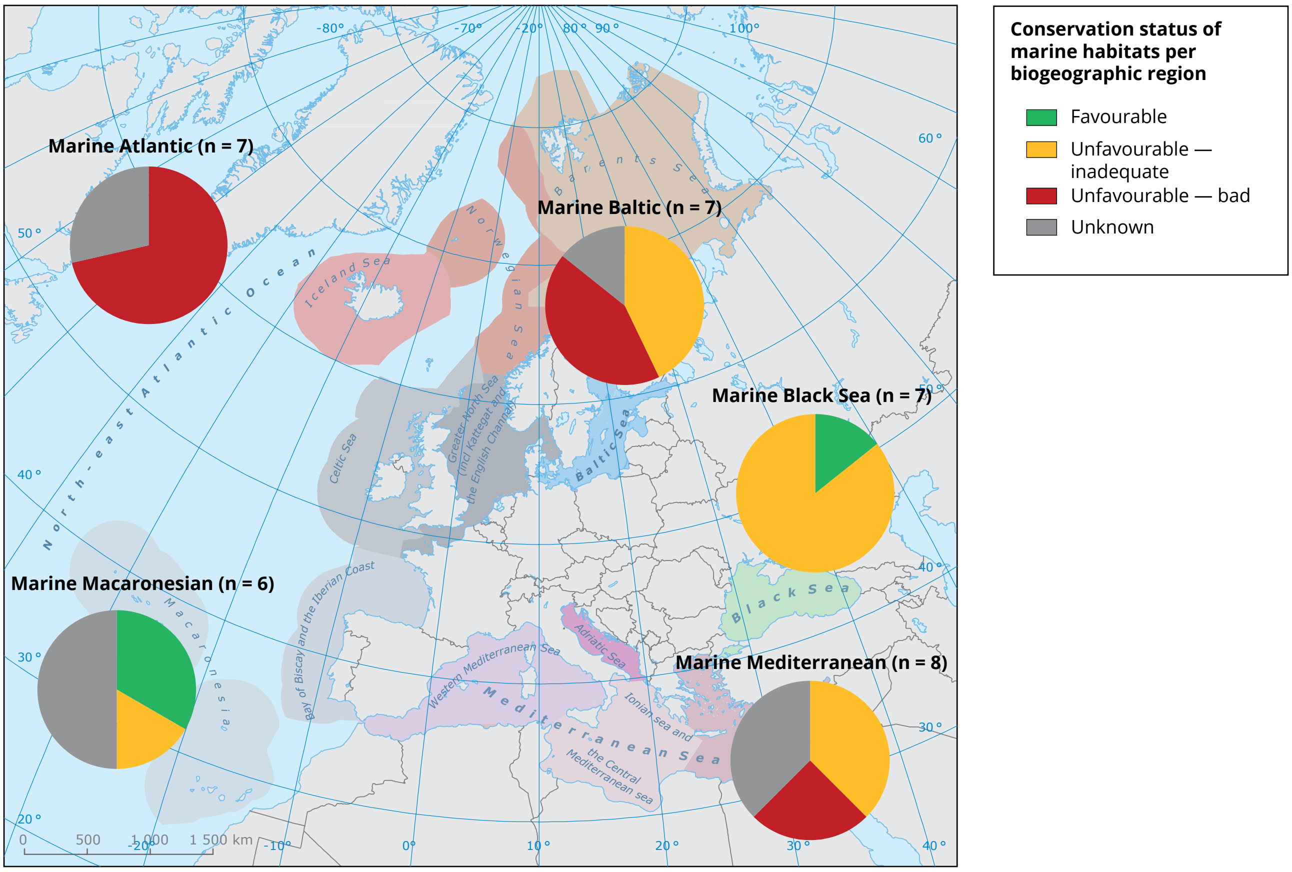
Biogenic reefs are generally created by colony-forming animals, although in the Mediterranean the coralligenous assemblages are biogenic reefs created mainly by red algae through sheer numbers and density. Only a few species, such as mussels, oysters, worms, and corals, are able to create these reef structures. However, the reefs themselves are often teeming with other life. Biogenic reefs provide a range of services, including nutrition through food provision; regulation of waste, toxins and other nuisances; and cultural services, such as scuba diving. For example, horse mussel (*Modiolus modiolus*) reefs are considered to support one of the most diverse sub-tidal habitat communities in north-west Europe, and are thought to be the largest contributor to secondary benthic production (biomass generation of consumer organisms).

These structurally-complex biogenic reefs are highly sensitive to pressures generated by human activities — especially those pressures that cause damage or removal of the reef-building species. For example, analysis of information collected by direct observation and interviews with fishermen suggest that 30–50% of the cold-water coral reefs found in Norwegian waters have been damaged to an observable extent by trawling. In the English channel and southern North Sea, naturally occurring beds of native oysters (*Ostrea edulis*) have declined significantly during the 20th century. Biogenic reefs can take many years to recover, and some may never recover. For example, ross worm (*Sabellaria spinulosa*) reefs have failed to recover in the Wadden Sea following their dramatic decline over recent decades.

Sources: Fosså et al., 2002; OSPAR, 2013; Ballesteros, 2006.

These patterns suggest that although we are unable to assess the status of many of the seabed habitats at a regional sea scale, there are a number of seabed habitats that are not in 'good environmental status' (and may be moving further away from 'good environmental status').

Figure 3.2 Conservation status of marine habitats per biogeographic region as reported under the Habitats Directive



Notes: Marine habitats include reefs; sandbanks; Posidonia beds; shallow inlets and bays; estuaries; mudflats and sandflats; Boreal Baltic narrow inlets; submarine structures; and sea caves. Number in brackets are number of assessments.

Source: EEA, 2015a.

3.3 Water column habitats

Messages on water column habitats

- The water column habitats of Europe's seas are dynamic, and the Black Sea and the Baltic Sea are the world's largest and second largest brackish water (water that is more salty than fresh water, but less salty than ocean water) basins.
- Information on the health of water column habitats at a regional scale is very limited, but there are signs that many water column habitats are not in 'good environmental status'.

Dynamic water column habitats

The marine pelagic ecosystem (that part of the sea ranging from the water surface down to almost the seabed) is the largest ecosystem on Earth, because it encompasses 99% of the total biosphere volume (Wurtz, 2010). Water-column habitats exhibit more variation than seabed habitats. Salinity, temperature, and light are all important environmental factors in characterising water-column habitats. For example, low or reduced salinity waters are found closer to land where there are strong freshwater influences from river outflows.

Much of the dynamics seen in water-column habitats are driven by ocean fronts, which are similar to the cold-air fronts and warm-air fronts we see in our daily weather forecasts. Ocean fronts can change quickly, or remain in place for a long time. They separate regions of warm and cool water, as well as salty and fresh water. Ocean fronts themselves are areas of turbulent and well-mixed waters, in which biological productivity can be high. Significant ocean fronts occur in the North-east Atlantic Ocean during the summer and autumn.

Photo: Phytoplankton bloom off the southern coast of England, North-east Atlantic Ocean.

Phytoplankton can form massive blooms, which can be detected by satellite remote sensing. The white clouds are in fact billions of phytoplankton floating in the water-column.

Source: © USGS Landsat image courtesy NEODAAS Plymouth

Water-column habitats provide the base of the food web, with half the primary production coming from photosynthesis performed by microbes and phytoplankton communities found in water column habitats (UKMMAS, 2010b). Changes to these microbial and phytoplankton communities can potentially affect the survival and success of fish, turtles, seabirds, and marine mammals. Moreover, through various feedback processes, water-column habitats can both influence — and be influenced by — climate change (see Box 3.4 and Chapter 3: Climate change).

In addition, water-column habitats provide a range of key ecological processes, which support the delivery of provisioning ecosystem services; regulating ecosystem services; and cultural ecosystem services. For example, water-column habitats support the fixation of carbon; nutrient cycling; primary and secondary production; detoxification of pollutants; and the maintenance of biodiversity.

Assessing the status of marine water-column habitats

The condition of water-column habitats varies by regional seas, as was shown by the EU Member State reporting under the MSFD Initial Assessment. In the Baltic Sea, 71% of the water column habitat assessments were not in 'good environmental status'. Conversely, in the Mediterranean Sea, 46% of the water-column habitat assessments were in 'good environmental status' (ETC/ICM, 2014). The equivalent information for the Black Sea and the North-east Atlantic Ocean was either 'not reported', or was reported and considered to be 'unknown'. However, a focused case study in the North-east Atlantic Ocean showed significant changes in the community composition of water-column habitats over the past 50 years (Box 3.4). When this focused case study is considered alongside the Initial Assessment from the MSFD, a mixed picture emerges of the status of water column habitats across Europe's seas. Although some regional seas might have elements of 'good environmental status' for water-column habitats, this is not consistent across all of the regional seas.

Box 3.4 Copepods of the North-East Atlantic Ocean and their ecological role

Copepods play a key role in the structure and function of water column habitats in the mid- and high-latitude ecosystems of the North-east Atlantic Ocean. *Calanus finmarchicus* is an herbivorous copepod, which plays a crucial role in transferring primary production to higher trophic levels in the food web. It is one of the most commonly found species of zooplankton in the colder waters of the North-east Atlantic Ocean.

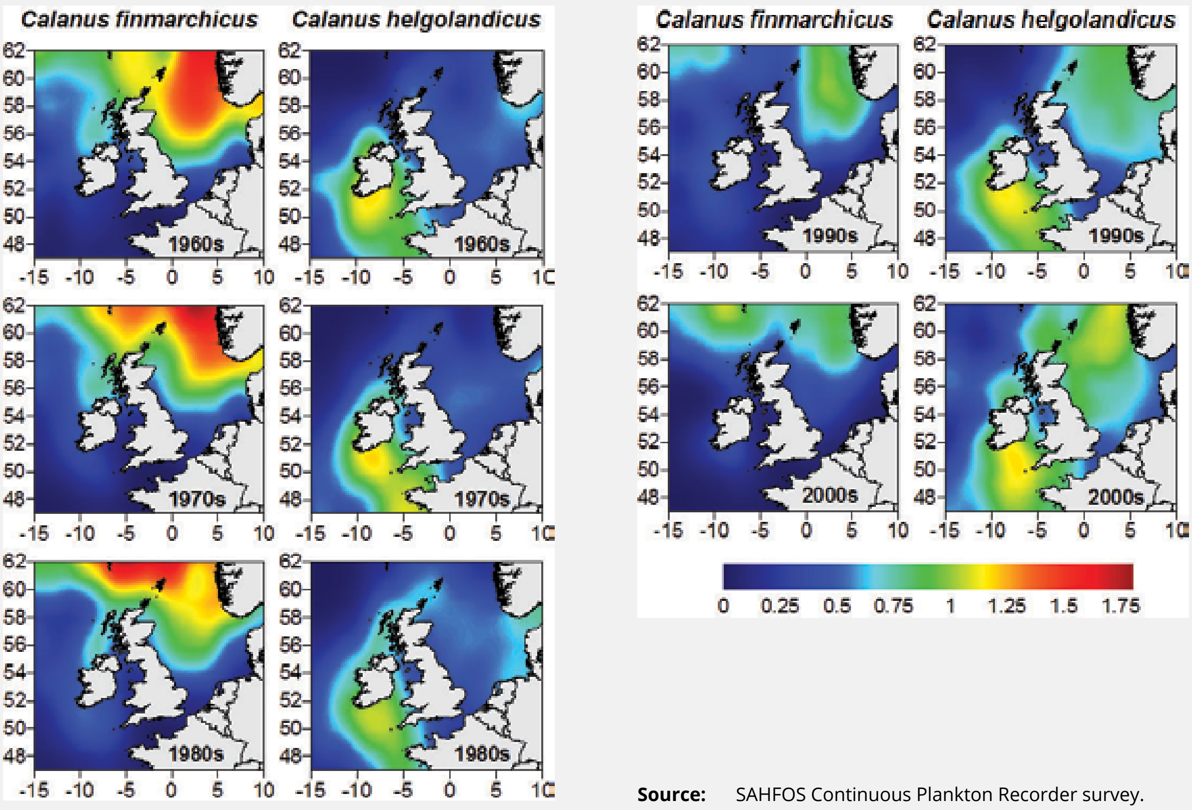
Over the last 50 years, the abundance of *C. finmarchicus* has decreased in the North-east Atlantic Ocean. In contrast, the warmer water copepod, *C. helgolandicus*, has become more abundant in many regions (Figure 3.3; Beaugrand, 2003). These changes are a reflection of rising sea temperatures in the North East Atlantic.

C. finmarchicus has a higher energy content than *C. helgolandicus*, and is considered to be a key element for the larval survival of some commercial fish species such as the Atlantic cod (*Gadus morhua*), herring (*Clupea harengus*), and mackerel (*Scomber scombrus*). The shift in copepod community composition has influenced the growth, recruitment, and survival of other trophic levels such as seabirds (Wanless et al., 2005) and fish (Beaugrand et al., 2008).

Modelling studies show that there could be further poleward movement of *C. finmarchicus* by about one degree of latitude per decade. This suggests that in the North Sea, the species could disappear by the end of the 21st century (Helaouët and Beaugrand, 2009). Such changes are likely to cause major adjustment in pelagic ecosystems in terms of abundance, trophodynamics, predator-prey relationships, and bio-geochemical cycles. These changes could also open up opportunities for the introduction of new non-indigenous species.

Sources: UKMMAS, 2010b.

Figure 3.3 Changes in the mean decadal abundance reflecting poleward movement of *Calanus finmarchicus* and *Calanus helgolandicus* in the North-east Atlantic Ocean



Source: SAHFOS Continuous Plankton Recorder survey.

3.4 Marine invertebrates

Messages on marine invertebrates

- Marine invertebrates account for over half of the marine species documented in European waters (excluding bacteria and viruses).
- Coherent information on the health of marine invertebrates at a regional scale is very limited, but there are signs that marine invertebrate communities are not in 'good environmental status'.

Marine invertebrates: small, numerous, and important

Marine invertebrates (animals without a spine) account for over half of the marine species documented in European waters (Narayanaswamy et al., 2013). They represent a hugely diverse group of animals, including for example: jellyfish, sea anemones, corals, lobsters, crabs, shrimp, barnacles, sea stars, brittle stars, sea urchins, shellfish, sponges, squid, and octopus.

Marine invertebrates are of significant ecological importance, and are found in high abundances throughout European estuaries, coastal bays, and further offshore. They are also responsible for delivering a wide range of provisioning, regulation, maintenance, and cultural services (Galparsoro et al., 2014). For example, they help to mix muddy sediments, which enhances both the aerobic decomposition of organic matter and the nitrification-de-nitrification process. They therefore play a vital role in nutrient recycling. Other species, such as mussels, are 'filter-feeders', removing small food particles from the water column. Collectively, marine invertebrates filter huge volumes of water, consuming much of the zooplankton, phytoplankton, and anthropogenic pollutants (e.g. microplastics) that the water contains. In doing so, marine invertebrates can shape the chemical and biotic composition of a water-column habitat.

Similarly, some species of marine invertebrates play a key role in structuring seabed habitats. Aggregations of marine invertebrates can build reef communities — from the cold-water coral reefs of the North-east Atlantic Ocean and Mediterranean Sea, to the oyster reefs of the Black Sea, and the mussel beds of the Baltic Sea. Marine invertebrates are also an essential food source for higher trophic levels of the food web. This includes many fish, seabirds, marine mammals, and turtles. Marine invertebrates are also an important nutritional source for humans.

Photo: Facies of coralligenous reefs of the Mediterranean Sea characterised by different engineering algal and invertebrate species.

Marine invertebrate species richness is particularly high in the Mediterranean Sea, with over 2 100 species of mollusc and over 600 sponge species. Nearly half of these sponge species are found only in the Mediterranean Sea (Coll et al., 2010).

Source: © OCEANA/Juan Cuetos

Do we know enough to assess the state of benthic invertebrates?

In 2012, EU Member States collectively provided 30 assessments of marine invertebrates under the MSFD Initial Assessment (ETC/ICM, 2014). All 30 assessments were categorised as being 'unknown' with respect to environmental status.

Although the MSFD has not yet resulted in much information on the state of marine invertebrates, the reporting under the Habitats Directive has been more helpful in this regard. Under the Habitats Directive, further information is available for seven marine invertebrate species ([7]) in the Mediterranean Sea and Atlantic regions. The 2007–2012 biogeographical assessments, derived from Member State reporting under the Habitats Directive, show that six of the seven species assessed in the Mediterranean Sea

([7]) The seven species are: the Long-spined urchin (*Centrostephanus longispinus*); red coral (*Corallium rubrum*); a trochid mollusc (*Gibbula nivosa*); the European date mussel (*Lithophaga lithophaga*); the Ribbed Mediterranean limpet (*Patella ferruginea*); the pen shell (*Pinna nobilis*); and the Mediterranean slipper lobster (*Scyllarides latus*).

are considered to be in 'unfavourable conservation status', whilst one of the four species assessed in the Atlantic is considered to be in 'unfavourable conservation status'.

More than 18 000 marine invertebrate species exist in Europe's seas, so it remains difficult to draw a general conclusion on the state of marine invertebrates based only on this limited information.

However, regional examples on the state of marine invertebrates do exist. These show that a wide range of pressures influence the abundance and extent of benthic (the area of the sea close to the seabed) invertebrates. These pressures include the effects from eutrophication, hazardous substances, and direct and indirect physical disturbance (e.g. from marine litter or bottom trawling).

For example, looking at the effects from a single stressor (such as eutrophication and organic enrichment), these will first create increased biomass and higher abundances of marine invertebrates in food-limited communities. However, marine invertebrates that are sensitive to this stressor, and large-sized species specialised to a food-limited system do not tolerate such changes, and they will be out-competed by smaller and more tolerant species. This leads to loss of biomass and diversity.

At even higher levels of organic enrichment, there will be hypoxia and anoxia. These levels of organic enrichment also result in a release of toxic hydrogen sulphide, which will eventually kill most benthic invertebrates. This will have further impacts on the entire ecosystem (HELCOM, 2009b; Box 3.5).

In the Mediterranean Sea, marine invertebrates are also under multiple pressures. This includes competition from invasive species like *Caulerpa racemosa* and *Caulerpa taxifolia*, which overgrows corals like *Cladora caespitosa* (Kružić et al., 2008). Similarly, invertebrates are depleted by lost fishing gear. This has been observed in every canyon of the Ligurian Sea (Western Mediterranean Sea), where lost nets, long fishing lines, lead weights, and ropes were found damaging highly sensitive species such as the alcyonacean *Callogorgia verticillata* or the cold-water coral *Lophelia pertusa* (Bo et al., 2014; Fabri et al., 2014).

In some parts of the North Sea, the benthic communities are impacted by heavy-beam trawling. For example, in the German part of the North Sea, some areas (an average area of measurement is 3 x 3 nautical miles) are fished annually for up to 400 hours by beam trawls (ICES, 2014). The recovery time for species and habitats affected in this way has been estimated at between 7.5 and 15 years after one single pass of a beam trawl (OSPAR, 2010c).

Thus, while no coherent information is available across Europe's seas, there is strong regional evidence that communities of benthic invertebrates remain under severe pressure in certain parts of the Europe's seas.

Box 3.5 Benthic invertebrates are under multiple pressures in coastal ecosystems

The Kattegat is a shallow and large transition area (approximately 30 000 km^2) between the North Sea and the Baltic Sea. It is an area influenced by pressures such as fisheries and eutrophication.

Between 1994 and 2004, a loss of 50 species (from 230 to 180 species) occurred at monitoring localities in the Kattegat (Ærtebjerg et al., 2005). This pattern of change is still observed in 2011 as the decline continued. Large fluctuations are observed for biomass and a number of individual species with no clear trends. In 2011, the populations of certain species groups, such as arthropods (e.g. crustaceans) and polychaetes (e.g. worms) were approximately one third of their population size in 1994 (Hansen, 2012).

During 2002, a hypoxia event covering 3 400 km^2 was observed in the Kattegat. It is estimated that the event killed 371 000 tonnes of benthic invertebrates, mainly in offshore sandy habitats and muddy habitats (Hansen et al., 2004). Such on-going and continuous losses are severely disrupting the food web and overall productivity of benthic invertebrates.

Oxygen depletion in the Baltic Sea is ten times worse than a century ago, with hypoxic areas now covering some 60 000 km^2 (Carstensen et al., 2014) or 15% of the Baltic Sea. This development is in keeping with the global trend, whereby the area of dead zones due to hypoxia has doubled every decade since 1960s (Diaz and Rosenberg, 2008). It has been shown that it can take decades before benthic fauna returns to a dead seabed after oxygen conditions have improved (Aarhus University, 2014).

Source: EEA, 2013b.

3.5 Marine fish

Messages on marine fish

- Over 650 marine fish species are thought to inhabit European seas, ranging in size from the 11 m Basking Shark *Cetorhinus maximus* to open water species that rarely reach 1 cm in length.
- Most of the assessed commercial fish stocks (58%) are not in 'good environmental status' (GES), while 40% of EU catches remain unassessed.
- Long-term historical declines of commercial fish landings, coupled with changes to marine food-webs induced by fishing, show signs of unhealthy fish populations.

Fish, eel, lampreys, sharks, and rays

Fish are the most numerous and diverse group of vertebrates, with approximately 22 000 known species worldwide — of which 60% primarily occur in the marine environment (UKMMAS, 2010b). Marine fish represent an important link in marine food-webs, both as predators and as prey for marine mammals and seabirds. They are of course also important in sustaining commercial fishing. Marine fish are found throughout Europe's seas, and their distribution and relative abundance is affected by many factors. Approximately 330 fish species are thought to inhabit the 'shelf seas' (relatively shallow seas) surrounding the British Isles. These species range in size from the 11 m Basking Shark (*Cetorhinus maximus*), to the Atlantic bluefin tuna (*Thunnus thynnus*), to gobies and open-water species that rarely reach 1 cm in length. In the Mediterranean Sea, up to 664 species of fish have been recorded (Quignard and Tomasini, 2000).

Fish species can be categorised based on the habitat they occupy and exploit. For example, demersal fish live and feed on or near the bottom of seas, and they can be found in a variety of areas, from inshore coastal waters (e.g. flounder) to further offshore (e.g. cod, hake, plaice). In contrast, pelagic fish mostly inhabit the water column (i.e. well above the seabed), ranging from the relatively shallow waters above the continental shelf, (e.g. herring), to the shelf edge (e.g. mackerel), and further offshore to the deep waters beyond the continental shelf (e.g. tuna).

Both demersal fish and pelagic fish are caught for commercial purposes — primarily as a source of food for the human population.

The life-history characteristics of fish species can make them vulnerable to human activities. For example, many deep-sea fish are longer-lived, slower-growing, and spawn fewer young. These traits make them extremely vulnerable to fishing activities, leading to high and unsustainable mortality rates, even if they are not the target species but end up as by-catch. This high mortality

Photo: Basking Shark (*Cetorhinus maximus*) feeding at the surface on plankton.

Source: © Alexander Mustard

rate is particularly the case for elasmobranchs such as sharks and rays, where sharp declines in historical landings can be observed (Box 3.6). Other species that migrate between freshwater and marine environments are exposed to the impact of a wide variety of human activities beyond fishing, such as dams blocking upstream migration; power plants causing additional mortality; pollution; and destruction of inland habitats. Many of these migrating species have suffered serious declines in abundance and distribution in recent decades. For example, the European sturgeon *Acipenser sturio* has undergone more than a 90% population decline in the past 75 years (Gesner et al., 2010). Most Baltic salmon populations were considered depleted in the early nineties, only producing between 5% and 20% of their potential (Ranke, 2002). And the European eel stock has decreased by 95% to 99%, compared to its levels in the 1960s (ICES, 2012b).

How much do we know about the state of fish populations?

Assessments by EU Member States under the MSFD Initial Assessment provide a mixed picture regarding the state of fish in European regional seas (the assessment included a mixture of commercial and non-commercial species) (ETC/ICM, 2014). Of the 363 population size assessments provided by Member States, 21% were considered to be in good status, and 26% were considered not to be in good status. The remaining assessments were reported as 'unknown' (40%) in status or 'other' ([8]). The majority of assessments that concluded fish population sizes were not in good status were from the North-east Atlantic Ocean and the Mediterranean Sea.

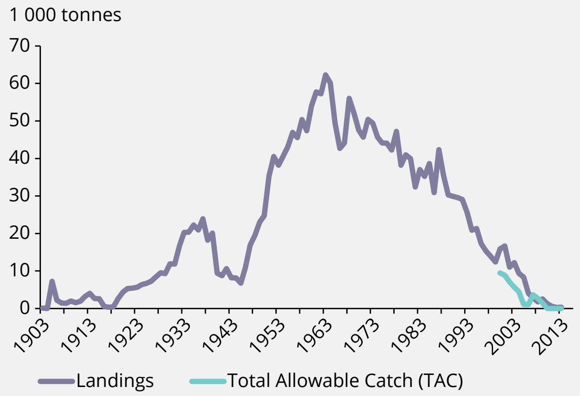
Stock assessments provide the best source of information on the status of commercial species, and allow for a more complete and coherent assessment at the European and regional level. Two aspects are considered when making a stock assessment. The first aspect is the level of exploitation, or fishing mortality (F), in relation to what is considered sustainable. This relationship of exploitation to sustainability is expressed as F_{MSY}. The second aspect is the reproductive capacity of the stock, also known as spawning stock biomass (SSB). This reproductive capacity needs to remain above a precautionary level (i.e. SSB_{MSY} or a proxy) to prevent an impaired recruitment in the next year. Only when the stock is exploited sustainably *and* the reproductive capacity is not impaired can the stock be considered to be in 'good environmental status' (GES). Two additional aspects to GES that are crucial to understand the health of fish stocks are the age and size structure of the populations. However, no threshold level for GES is currently available.

Currently, most of the assessed commercial stocks in European waters (58%) are not in GES, with 19% of the stocks exploited sustainably, 11% with their reproductive capacity intact, and only 12% considered in GES (i.e. fulfilling both F_{MSY} and SSB_{MSY} criteria for GES)

Box 3.6 Sharks, rays, and skates: a steady decline in the North Sea?

Sharks, rays, and skates are long-lived fish found in all European waters, making up approximately 5% of all fish species. Typically, these species are slow-growing; have a late age-at-maturity; produce only few young per year; and are easy to catch due to their shape and size. These traits make them extremely vulnerable to mortality from fishing activities, even if they are not the target species. In the North-east Atlantic Ocean alone, ten species in the category 'sharks, rays, and skates' are considered to be critically endangered, or vulnerable (IUCN 2013), and for all of these species the population trend is declining. International landings of spurdog and rays have been declining since the 1950s and 1960s (Figure 3.4 and 3.5). The distribution of sharks, rays, and skates in the North-east Atlantic Ocean has also changed dramatically (Walker and Hislop, 1998). The common skate is now only caught sporadically, and occurs almost entirely in the northern North sea. It is assessed by ICES as depleted in the Irish and North Sea (ICES, 2014a).

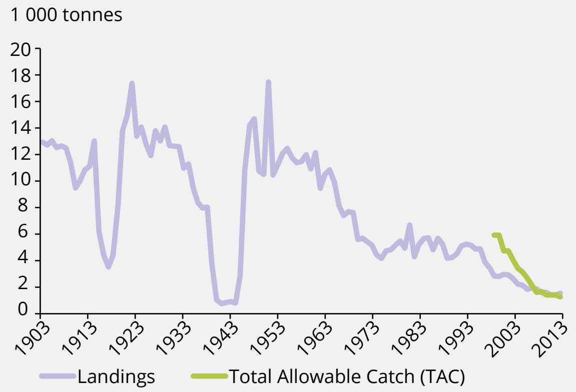
Figure 3.4 Estimated total international landings of spurdog in the North-East Atlantic Ocean and agreed Total Allowable Catch (TAC)



Note: North-East Atlantic Ocean refers to ICES areas: Baltic, I, II a, II b, III, IV, V, VI, VII unspecified, VIIA, VIIB,C, VIID, E, VIIF, VIIG-K, VIII, IX, X, XII, XIV.

Source: ICES, 2014a.

Figure 3.5 Estimated total international landings of skates and rays in the Greater North Sea and agreed Total Allowable Catch (TAC)

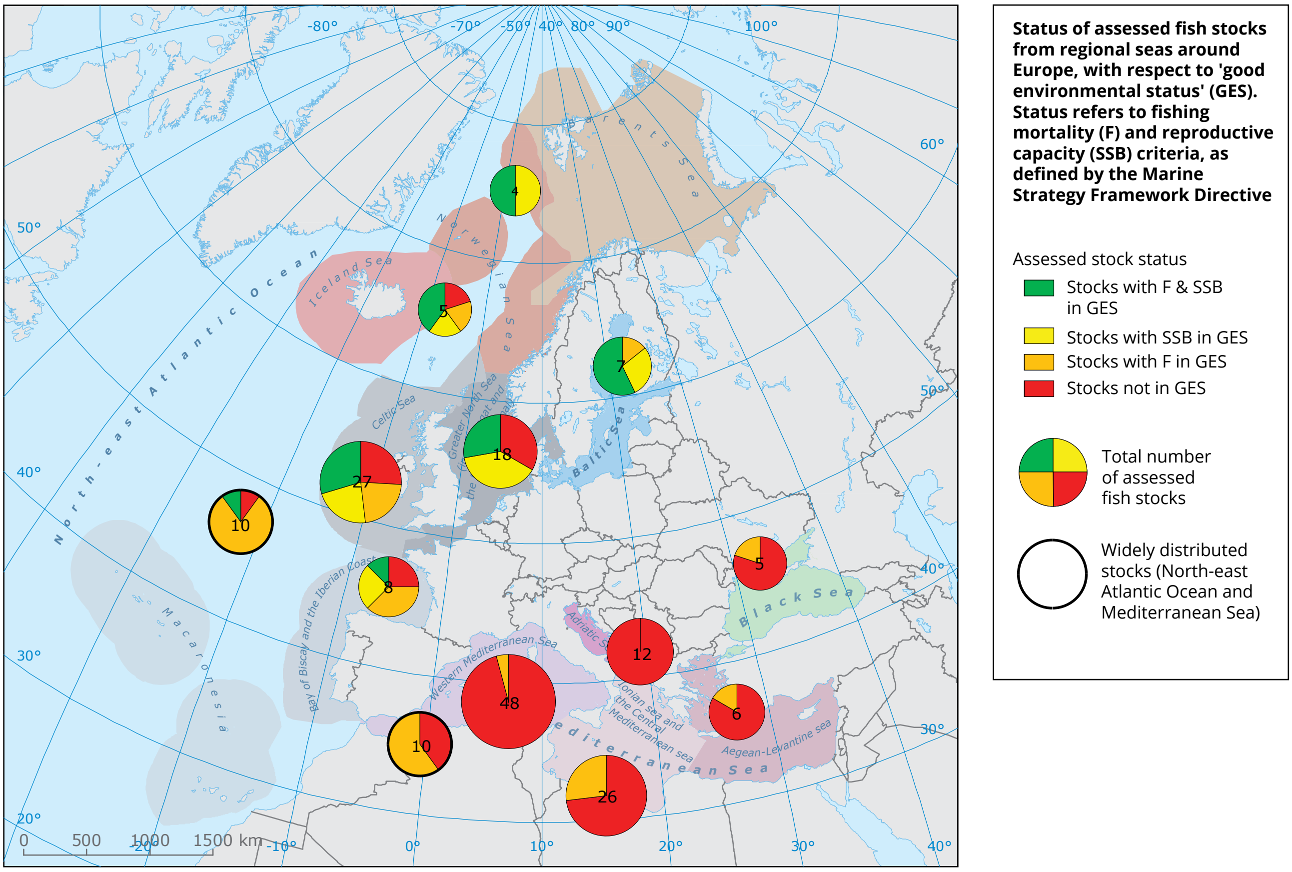


Note: Greater North Sea represents ICES Area III and IV.

Source: Based on ICES, 2014a.

([8]) Status classified using an alternative terminology including (but not always) a positive or negative state, which makes it impossible to establish a direct correlation to being at GES or not.

Figure 3.6 Proportion of assessed fish stocks in 'good environmental status'



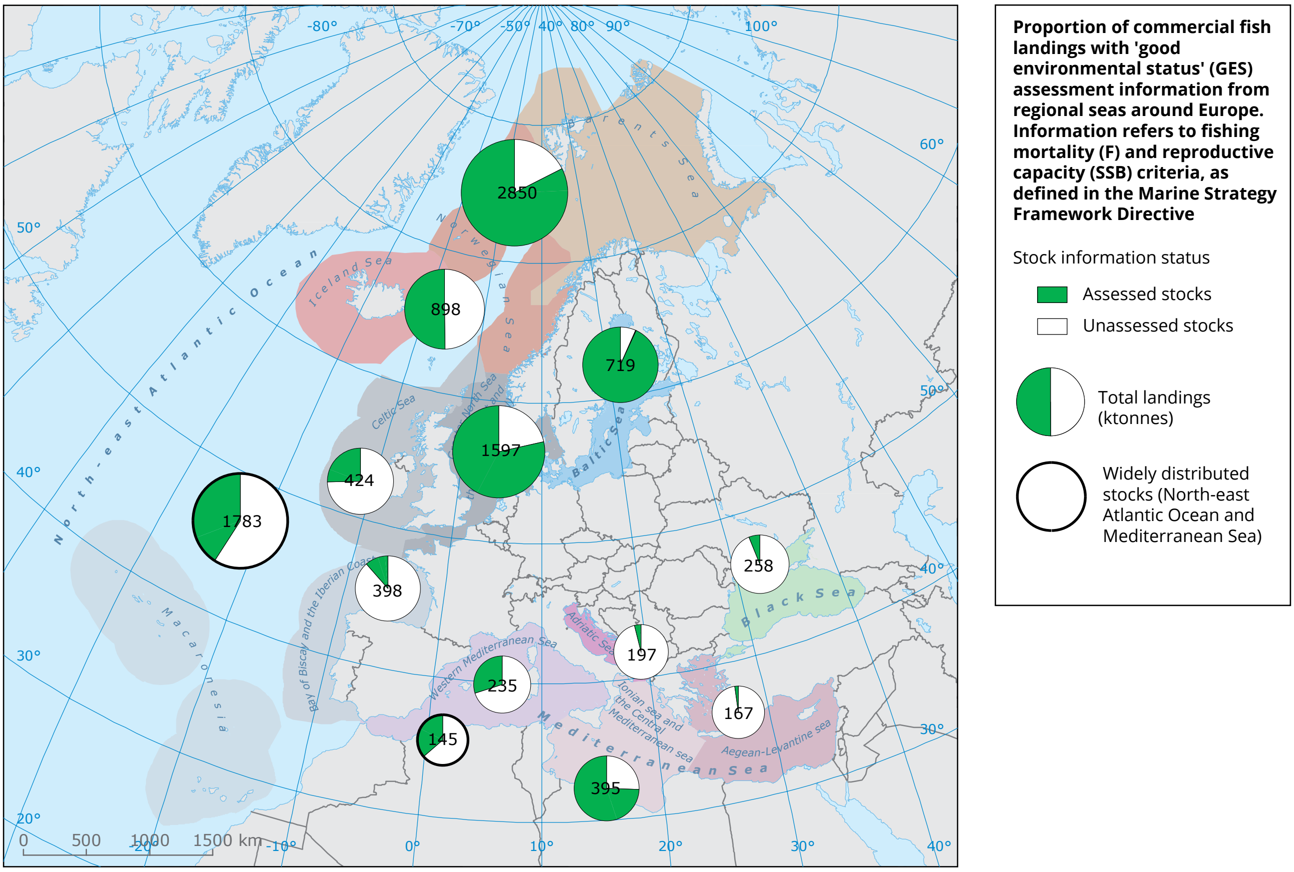
Source: EEA, 2015b.

(CSI 032). These percentages vary considerably between regional seas (Figure 3.6). In North-east Atlantic Ocean and Baltic Sea, 22% of the regionally assessed stocks are not in GES, 24% are exploited sustainably, 25% have their reproductive capacity intact, and 29% are in GES. The situation is worse in the Mediterranean and Black Sea, with 84% of the regionally assessed stocks not in GES and 16% exploited sustainably. Estimates for status of reproductive capacity are not available for these stocks. Hence, no stocks can be considered in GES in these regional seas.

It should be noted that the assessed stocks, i.e. those stocks for which GES information can be calculated, correspond to 60% of the EU commercial catch. The vast majority of this catch (93%) is from stocks in the North-east Atlantic Ocean and Baltic Sea. There therefore remains an important fraction of the EU catch from unassessed stocks (Figure 3.7). This situation is worse in the Mediterranean and Black Seas, where 68% of the total regional catch is not assessed, compared to 35% in the North-east Atlantic Ocean and Baltic Sea. Thus, even our knowledge about commercial fish species as a subset of overall fish species remains partial.

The increasing pressure on commercial species, especially since the 19th century, has caused important changes to their population size (Roberts, 2007). This can be seen from historical trends in fish landings. Although they are an imperfect indicator for assessing the health of fish stocks (Pauly et al., 2013), total landings in Europe's seas reached a peak in the mid-1970s, but have been mostly declining ever since (Pastoors and Poulsen, 2008; Gascuel et al., 2014). In addition to changes in abundance, the fishing strategies adopted to cope with the decline of target species have also transformed the food-web (Gascuel et al., 2014). As large predator species declined, a wider part of the ecosystem was targeted, and landings became more diversified. As a result, the landings began to feature a greater share of smaller, prey species. A recent global assessment of fish biomass also shows a similar pattern, where the biomass of large predatory species was estimated to have declined by

Figure 3.7 Proportion of commercial fish landings with 'good environmental status' assessment information i.e. assessed



Source: EEA, 2015b.

two-thirds between 1880 and 2007, with 54% of this decline occurring in the last 40 years (Christensen et al., 2014). An increase in biomass smaller prey fish can be observed over the last 100 years, indicating that a change in the food-web structure of marine ecosystems has also occurred at a global scale.

Based on the information available (including the MSFD reporting by Member States), both assessed commercial fish stocks and available studies on historical landings of fish species in Europe's seas show signs of unhealthy fish populations.

3.6 Turtles

Messages on turtles

- Five species of turtles can be found in Europe's seas. European turtles are restricted to the North-east Atlantic Ocean and the Mediterranean Sea.
- Biogeographical assessments under the Habitats Directive show that turtles in Europe's regional seas are not in 'favourable conservation status' for the period 2007–2012.

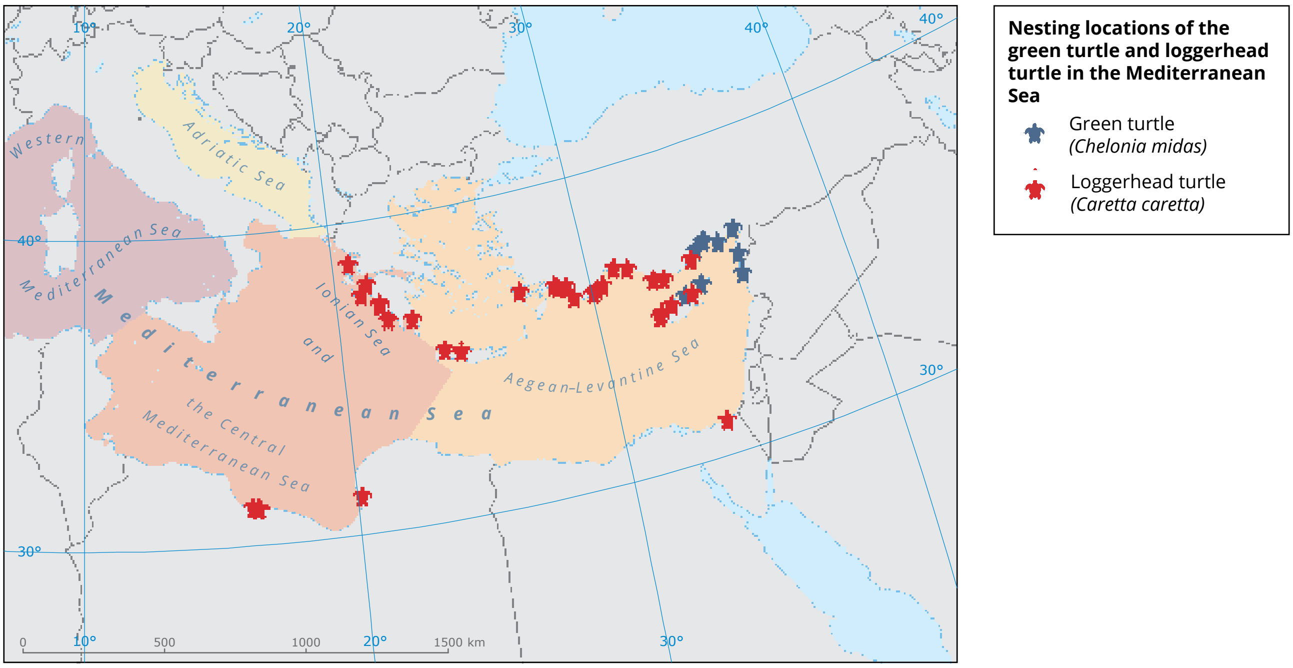
Turtles: the ancients of the sea

Marine turtles have survived on Earth for more than 200 million years, and today seven species of marine turtles inhabit the world's oceans (Spotila, 2004). In Europe, turtles can be primarily found in the Mediterranean Sea, where the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*) nesting populations are considered as indigenous. Another three species of turtle are visitors to the Mediterranean Sea and the North-east Atlantic Ocean. The leatherback turtle, the largest species of turtle, is the most regularly sighted visitor (Casale and Margaritoulis, 2010).

Turtles can provide good indicators of marine environmental health, as their population numbers are closely associated with the health of their environment. Turtles play an important role in ocean ecosystems. For example, loggerhead turtles provide habitat maintenance through their foraging behaviour. This foraging behaviour affects the compaction, aeration, and nutrient distribution of the seabed sediment. It also affects the species diversity and dynamics of the benthic ecosystem (Lazar et al., 2011; Bjorndal and Jackson, 2002).

Turtles may also help to balance food webs if present in adequate numbers. For example, leatherback turtles have been known to consume up to 200 kg of jellyfish per day (Duron-Dufrenne, 1987). Declines in leatherback turtle populations along with declines in other key predators, such as some commercially valuable fish species, could have repercussions for the control of jellyfish populations (Purcell et al., 2007). Turtles also have a strong connection to the coastal environment. In the Mediterranean Sea, the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*) return to land to nest on beaches characterised by low human population density (Figure 3.8). Mediterranean-origin green turtles and Mediterranean-origin loggerhead turtles exhibit a distinct genetic difference from

Figure 3.8 Major nesting ground of green turtles and loggerhead turtles in the Mediterranean Sea



Source: Casale et al., 2010.

Atlantic-origin green turtles and Atlantic-origin loggerhead turtles. This is despite the fact that Atlantic-origin green turtles, and especially Atlantic-origin loggerhead turtles, frequent feeding grounds in the Mediterranean Sea.

The worrying state of turtle populations

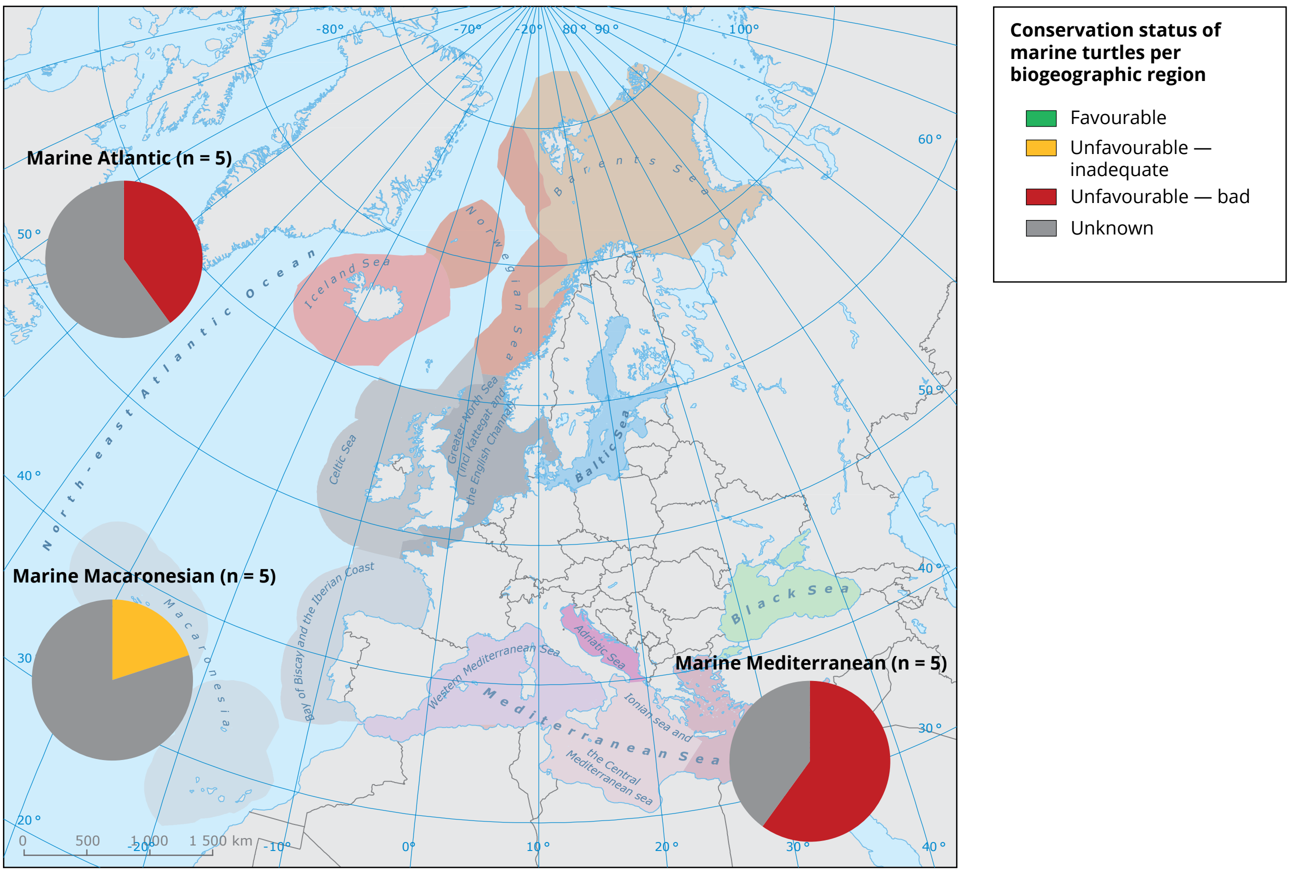
Today there are thought to be fewer loggerhead and green turtles throughout the Mediterranean Sea than in the past (Coll et al., 2010). Severe exploitation of marine turtles occurred in the first half of the 20th century by fisheries that specifically targeted turtles in the eastern Mediterranean Sea (Sella, 1981). Today, international trade in turtles is no longer a conservation issue in the Mediterranean Sea due to trade restrictions on all marine turtles.

Reliable population estimates for turtles are hard to come by. However, reporting by EU Member States under the Habitats Directive for the period 2007–2012 gives a strong indication that turtles are not in 'favourable conservation status' across European regional seas.

The loggerhead turtle (*Caretta caretta*) is assessed as being in 'unfavourable conservation status' in two regions: the Mediterranean Sea and the North-east Atlantic Ocean including Macaronesia (Figure 3.9). The green turtle (*Chelonia mydas*) is assessed as being in 'unfavourable conservation status' in two regions: the Mediterranean Sea and the North-east Atlantic Ocean, although its status in Macaronesia is reported as 'unknown'. The leatherback turtle (*Dermochelys coriacea*) is assessed as being in 'unfavourable conservation status' in the Mediterranean Sea, but as having 'unknown' status in the North-east Atlantic Ocean including Macaronesia.

Additional information from fisheries by-catch statistics and from modelling studies suggest that a large number of turtles are caught as by-catch from fisheries targeting other species. Recent estimates suggest that in the Mediterranean Sea there are over 132 000 turtle captures per year, with pelagic long lines estimated to capture 57 000 turtles per year (Casale, 2011). These captures result in an estimated 44 000 turtle deaths per year (Casale, 2011).

Figure 3.9 Conservation status of marine turtles per biogeographic region



Note: Marine turtles include *Dermochelys coriacea*, *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, and *Lepidochelys kempii*. The number of assessments is shown in the brackets.

Moreover, anecdotal information suggests that the number and distribution of turtle nests have been decreasing around the coasts of the Mediterranean Sea in the past few decades — and more recently (Casale et al., 2010) (Box 3.7).

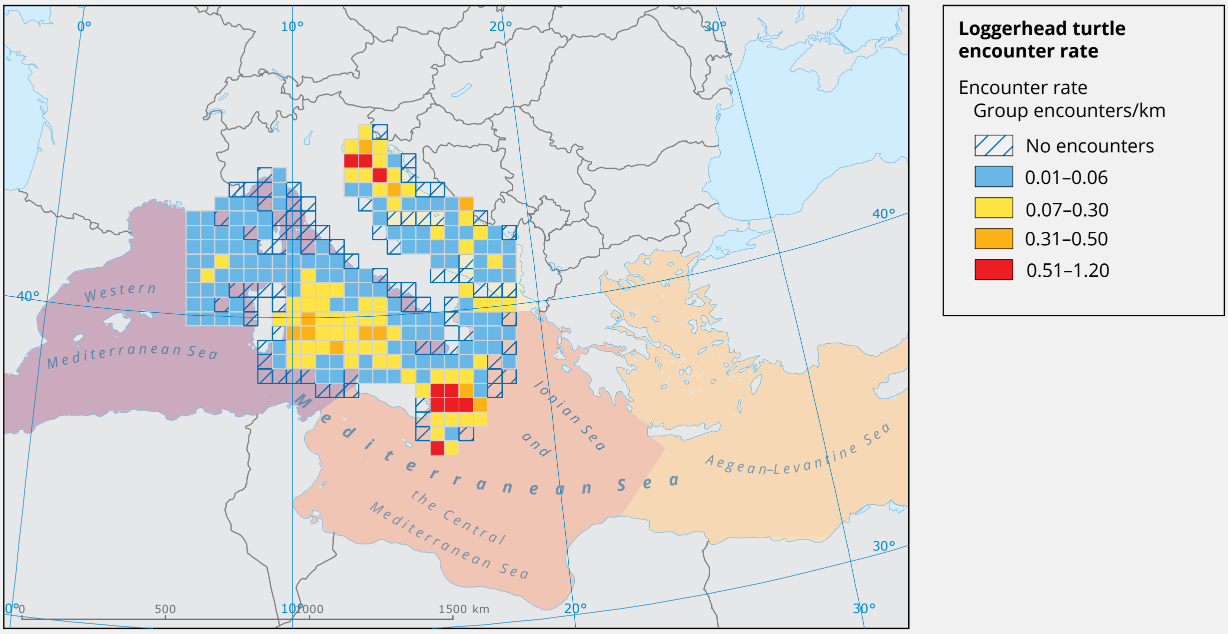
Box 3.7 Loggerhead turtle, *Caretta caretta*, in the Mediterranean Sea

The loggerhead turtle, *Caretta caretta*, can be found throughout the Mediterranean Sea. Studies have shown that there is a degree of genetic isolation between loggerhead turtles originating from Mediterranean nesting grounds and those originating from Atlantic ones, despite the fact that they forage in the same basin (Carreras et al., 2007). Moreover, due to the high degree of female philopatry to nesting grounds (the tendency of females to return to the same nesting grounds year after year), a Mediterranean genetic population substructure exists, which reflects the geographic distribution of the Mediterranean nesting sites (Carreras et al., 2007; Casale et al., 2010). Maintenance of good environmental status for the loggerhead turtle population therefore requires the safeguarding of nesting sites and principal foraging sites. Nesting sites can now only be found in the eastern Mediterranean, including the beaches of Greece, Turkey, Cyprus, and Libya (Casale et al., 2010). In the past, nesting sites could also be found in other regions of the eastern and central Mediterranean, but today only minor nesting aggregations or occasional isolated clutches are known to occur in countries such as Syria, Lebanon, Egypt, Tunisia, and Italy. Recent estimates based on nesting counts suggest that the average number of nests is over 7 200/year across the basin (Casale et al., 2010).

Turtles require a long time to reach sexual maturity, have high mortality in their early life, and exhibit the highest survival probability in the adult phase (Heppell et al., 2003). For these reasons, the measurement of trends in population status should also include estimates of abundance at sea, particularly in feeding and development grounds. Population estimates conducted through aerial surveys in a portion of Spanish Mediterranean waters suggested the annual presence of tens of thousands of loggerhead turtles (Casale et al., 2010).

Aerial surveys between 2009 and 2010, in Italian waters and adjacent neighboring countries, indicated a minimum population size (not corrected for availability and perception bias) of more than 60 000 loggerhead turtles in the Western Mediterranean. The same surveys indicated minimum population sizes of 39 000 in the Ionian and Central Mediterranean area and 25 000 in the Adriatic sea (ISPRA, 2013; Fortuna and Filidei Jr, 2011; Lauriano et al., 2011). This aerial survey data also confirmed the presence of aggregation and feeding grounds in the northern Adriatic Sea and southern Ionian Sea (Figure 3.10), which were postulated to exist based on by-catch information. Repeats of large-scale surveys such as these can allow detection of population trends over time, and identify critical areas for by-catch mitigation measures.

Figure 3.10 Sea turtle distribution range and relative density, as inferred through the encounter rate observed through aerial surveys carried out between 2009 and 2010



Source: ISPRA, 2013.

3.7 Seabirds and waterbirds

Messages for seabirds and waterbirds

- There are over 180 species of marine birds found throughout Europe's seas, and many of these undertake yearly migrations between feeding and breeding grounds.
- Information on the health of marine birds at a regional scale is available for some regions. By combining this information with case studies, we can tentatively conclude that approximately one third of marine bird populations are declining, one third are stable, and one third are growing.

Waterbirds and seabirds

There are over 180 species of waterbirds and seabirds that are known to regularly occur in Europe's regional seas.

Waterbirds live on or around water, and can inhabit both freshwater and marine environments. Large aggregations of waterbirds, such as waders, herons, egrets, ducks, geese, swans, divers, and grebes, can occur where food is abundant. For example, waterbirds often aggregate in estuaries where they feed on marine invertebrates in soft inter-tidal sediments; graze on saltmarshes and exposed eelgrass beds; and catch fish and marine invertebrates in shallow sub-tidal areas.

Seabirds are fully adapted to life within the marine environment, with many spending the majority of their lives at sea. They feed both at the ocean's surface and below it. They consume mainly fish, squid, and plankton, picking detritus from the surface, or foraging on exposed inter-tidal areas. Many seabirds, such as gannets, terns, and auks, nest in colonies, which can vary in size from a few dozen birds to thousands of birds. For example, the Scottish islands of St Kilda hold nearly 60 000 pairs of nesting northern gannets (Murray, 2011).

Both waterbirds and seabirds migrate — generally on a seasonal basis — for feeding and breeding purposes. The migration distances vary from species to species. Some species migrate within a regional sea, some between regional seas, and some between continents. For example, every year the Arctic Tern *Sterna paradisaea* migrates from its northern breeding grounds to the seas around Antarctica and back again — a round trip of about 70 900 km (Egevang et al., 2010). These migrations mean that the abundance and distribution of marine birds in Europe's regional seas changes with the seasons.

Waterbirds and seabirds provide a number of ecosystem services (Sekercioglu, 2006; Whelan et al., 2008; Wenny et al., 2011). For example, bird watching can be considered to be a cultural ecosystem service (Carver, 2009). Waterbirds and seabirds also provide regulating ecosystem services such as nutrient cycling. This occurs through the transport of nutrients (e.g. fish) from the seas to nesting colonies (ending up as faeces) in European coastal zones and islands. It also occurs through nesting behaviour, which can alter soil properties (Wenny et al., 2011).

A mixed picture

Between 1994 and 2004, population trends of birds inhabiting marine and coastal habitats in Europe were considered to be increasing (BirdLife International, 2004). However, a more mixed picture has emerged following a recent global assessment of waterbirds. This assessment found that in the Europe Ramsar region (which includes Greenland and Russia), 32% of waterbird populations were considered to be declining, 28% to be increasing, and 37% to be stable (Wetlands International 2012).

More information is emerging at the regional sea scale that shows a worrying trend in the status of seabirds. For example, it has been shown that a number of breeding seabird populations in the Greater North Sea and the Celtic Sea have remained below target levels since 2005 (ICES, 2013; Box 3.8).

Photo: Little auks (*Alle alle*).

Source: © Tim Smith

Box 3.8 Breeding seabird population trends in the North-east Atlantic Ocean

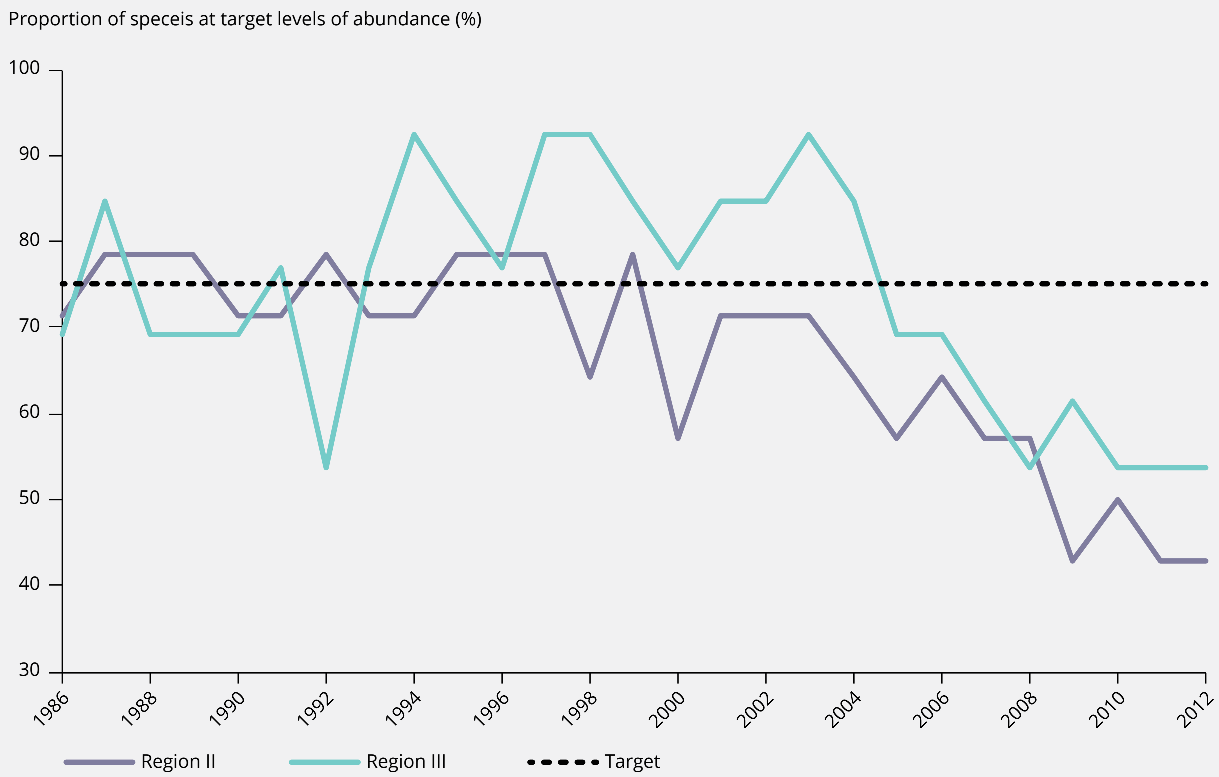
The OSPAR Ecological Quality Objective (EcoQO) indicator on seabird population trends describes changes in breeding seabird populations in the Greater North Sea (OSPAR Region II) and the Celtic Sea (OSPAR Region III). The associated EcoQO target is for 75% of the species monitored in an OSPAR region or sub-division to be within their species-specific target levels (Figure 3.11).

An assessment of this EcoQO indicator in 2013 showed that several species of seabirds have gone through substantial declines in recent years. This EcoQO target for seabird population trends was not achieved in the Greater North Sea between 2000 and 2012, or in the Celtic Sea between 2005 and 2012.

The causes of these seabird population declines are likely to be due to impacts from climate change and fishing activities on the seabird food supply. These impacts can be exacerbated by increased predation whilst on land (i.e. other animals attacking seabirds) and competition for food from other seabirds. Further work is needed to fully understand the causes of these declines, and identify appropriate management action.

Appropriate management actions can have significant positive impacts on seabird population numbers. For example, roseate tern numbers have increased from 18% of the reference level to 57% of the reference level following management actions. Management has included the removal of predators (such as gulls, and brown rats); prevention of human disturbance; maintenance of suitable nesting habitats for the birds at existing colonies; and creation of new potential breeding sites.

Figure 3.11 The percentage of species in OSPAR Region II (Greater North Sea) and Region III (Celtic Sea) that were within target levels of abundance during 1986–2012



Note: The EcoQO was not achieved in years when the percentage dropped below 75%.

Source: ICES, 2013; OSPAR Commission, 2009.

3.8 Marine mammals

Messages on marine mammals

- Almost 40% of the world's known marine mammal species can be found in Europe's regional seas.
- Information on the state of marine mammals at a regional scale is difficult to obtain. Nevertheless, it is clear that for some species, in some regions, marine mammal populations are in unfavourable conservation status.

Marine mammals in Europe

Marine mammals are found in all of Europe's regional seas, although the diversity of species varies between regions.

Thirty-six species of whales, dolphins, and porpoises — collectively known as cetaceans — can be seen in European waters, representing 42% of the cetacean species known around the world (Hoyt, 2003). The harbour porpoise is the only cetacean known to occur in all four of Europe's regional seas. Many cetaceans are considered resident (or regularly occurring) in Europe's regional seas (e.g. the common dolphin, the sperm whale, and the fin whale). Other cetaceans are considered to be visiting or occasionally-occurring species (e.g. the blue whale and the humpback whale).

Cetaceans can be categorised into baleen whales (Mysticeti) and toothed cetaceans (Odontoceti). Baleen whales feed on plankton and small fish; whilst toothed cetaceans feed on larger prey including fish and squid. All cetaceans are very mobile and can range over large distances. Some species, such as the humpback whale, are highly migratory, moving between northern feeding areas and warmer breeding grounds. Other species, such as short-beaked common dolphins, show more localised seasonal movements, often between inshore and offshore areas (UKMMAS, 2010b).

In addition to cetaceans, eight species of seals can be seen in Europe's regional seas, but several of these species are restricted in their distribution to the Arctic Sea (e.g. the walrus, the harp seal, the bearded seal and the hooded seal). Although seals spend most of their time at sea, they come out of the sea onto coasts and beaches to mate; give birth; raise young; molt; escape from predators; and rest. Seals primarily feed on fish and marine invertebrates.

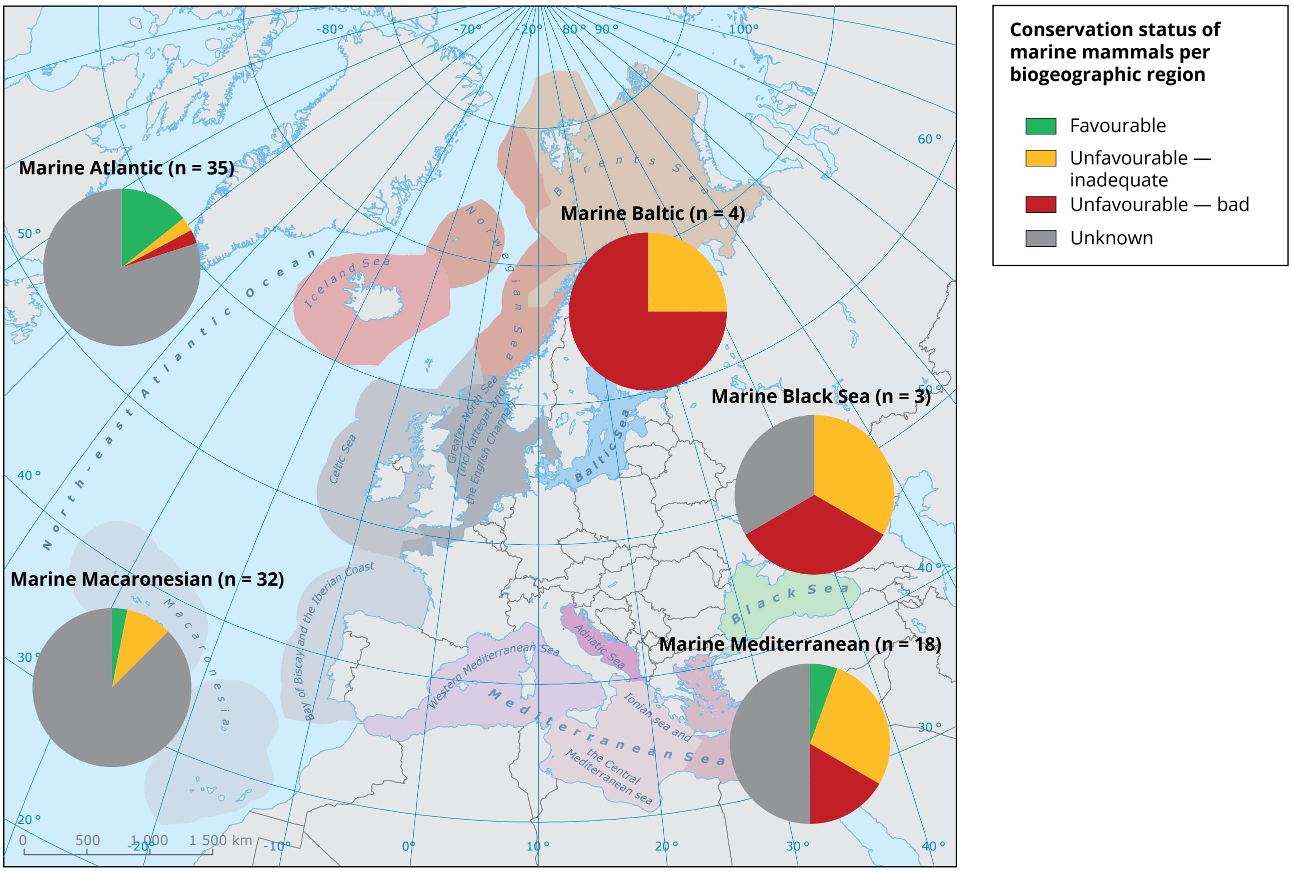
Following a moratorium on commercial whaling in 1986, whale-watching has become the most economically viable and sustainable use of marine mammals (Parsons and Rawles, 2003). The economic value of this cultural service to the European economy should not be underestimated. For example, in 2008 the estimated value of whale watching in Europe was USD 93 million ~ EUR 85.7 million (O'Connor et al., 2009). There is also evidence that marine mammals play an important role in the delivery of recycled nitrogen and other nutrients to surface waters (Roman and McCarthy, 2010).

Marine mammals: the most threatened category of marine life?

The wide-ranging and highly mobile nature of marine mammals can make any assessment of their conservation status very difficult, but there is evidence that many species are threatened or not in good status (Figure 3.12; Box 3.9). In 2007, an assessment found that 22% of European marine mammals are considered to be threatened (Temple and Terry, 2007). In the 1700s, the grey whale, *Eschrichtius robustus*, became regionally extinct in the North Atlantic as a result of hunting (Temple et al., 2007). Today, the Mediterranean monk seal is considered to be one of the most endangered mammal species in the world, with an estimated total population size of 350–450 animals (Aguilar and Lowry, 2013).

In 2012, for the MSFD Initial Assessment, EU Member States collectively undertook 56 assessments on the status of marine mammals, but nearly 80% of these assessments concluded that the status of those species assessed was 'unknown' (ETC/ICM, 2014). A similar pattern is observed in EU Member State reporting under the Habitats Directive, where 71% of the biogeographic assessments done for marine mammals concluded with an unknown conservation status (Figure 3.12); (EEA, 2015a). However, the conservation status for some species *is* known, and several species have been assessed as being in unfavourable conservation status in all biogeographic regions. For example, the common seal is considered to be in 'unfavourable conservation status' in the Atlantic Ocean and Baltic sea; whilst the Mediterranean monk seal is in 'unfavourable conservation status' for the Mediterranean and Macaronesian marine areas (EEA, 2015a).

Figure 3.12 Conservation status of marine mammals per biogeographic region



Note: The number of assessments is shown in the brackets.

Box 3.9 Fin whales in the Mediterranean Sea

The fin whale (*Balaenoptera physalus*) is the only regular Mysticete present all year round in the Mediterranean Basin. The species is found mostly in the pelagic waters of both the western and central Mediterranean Sea. Fin whales congregate during the summer months in the highly productive Corso-Ligurian Basin, their major feeding ground in the Mediterranean Sea. In the winter months, key feeding areas are located around Lampedusa Island, in the Sicily Strait, and around southern Spain.

No population estimates exist for the whole Mediterranean region, since available abundance data are not comparable due to different area sizes, study periods, and methods. Nevertheless, a decrease in numbers was observed over the last decade within Pelagos (a large protected area that encompasses waters around Sardinia, Corsica, southeastern France and the northwest coast of Italy) (Panigada et al., 2011). This decline may be explained by temporal and spatial fluctuations in the density and distribution of the animals within their full geographic range due to changes in the locations of their prey (Lauriano et al., 2010). Estimates from larger geographical areas include an estimate from the western Mediterranean in 1991, 3 583 individual fin whales (Forcada et al., 1996), and an estimate from the Central Tyrrhenian and Corsican Seas in 2010, 426 individual fin whales (Lauriano et al., 2010).

The reduced abundances recorded in recent aerial surveys, especially in the main feeding ground in the Pelagos region, raised concern and need to be considered carefully. This is especially the case considering that the Mediterranean subpopulation is estimated at less than 10 000 mature individuals. As a result, the fin whale Mediterranean subpopulation was given 'vulnerable' status by the IUCN in 2009. Environmental and acoustic pollution; general disturbance from ship traffic; and habitat degradation are known as threats to the fin whale population. However, mortality from vessel collision is considered the most harmful pressure on fin whales in the Mediterranean Sea.

There is an urgent need for a well-designed, long-term, abundance-monitoring programme that covers the full fin whale range in the Mediterranean Sea.

3.9 Marine food webs

Messages on marine food webs

- Food webs are one of the main regulators of ecosystem dynamics. They play a role in the way ecosystems respond to natural and human-induced changes.
- Slight changes in food webs can lead to dramatic changes in an ecosystem. These dramatic changes are called 'ecological regime shifts'. Ecological regime shifts in marine ecosystems have been observed in a number of Europe's regional seas.

Complexity of marine food webs

Every plant and animal species, no matter how big or small, depends to some extent on another plant or animal species for its survival. This dependency can in part be shown through predator-prey relationships, which can be visualised as food chains. Food chains are pathways that transfer energy and matter between feeding levels. Individual food chains operate within much larger (and infinitely more complex) networks called food webs.

The species composition of food webs varies according to habitat and region, but the principle of energy transfer from sunlight and plants through successive feeding levels is the same in most food webs (with a few exceptions). For example, in the marine environment, large fish may feed on smaller fish or invertebrates, which feed on zooplankton, which in turn feed on phytoplankton (Figure 3.13).

Each feeding level in a food web is called a 'trophic level', and there may be more than one species at the same trophic level (e.g. several predators feeding on the same prey). These predator-prey interactions are considered one of the main regulators of ecosystem dynamics (Allesina and Pascual, 2008), and they affect the way ecosystems respond to natural and human perturbations, such as fishing and habitat degradation (Heymans et al., 2014).

A change in one trophic level (e.g. the removal of large quantities of small fish) can have repercussions throughout the food web. If the changes are many, or individually significant, they can lead to long-lasting re-organisations of the food web. This re-organisation is often referred to as an ecological regime shift (Box 3.10).

Ecological regime shifts usually result from a combination of gradual changes in underlying drivers, combined with an external shock. Gradual changes in underlying drivers usually have little or no apparent impact up to a certain point, and then unexpectedly lead to a regime shift when that threshold is crossed (Biggs et al., 2009).

Although the underlying drivers that trigger ecological regime shifts vary, recent studies show that a loss of resilience (Box 3.2) can pave the way for a switch to an alternative stable state (Scheffer et al., 2001). However, ecological regime shifts are notoriously difficult to predict. Most come as surprises, with the conditions and mechanisms leading to them only becoming clear once the shift has occurred (Scheffer et al., 2001; Biggs et al., 2009).

Regime shifts in Europe's regional seas

The importance of food webs to the functioning of ecosystems is recognised in the Marine Strategy Framework Directive, where food webs are considered to be one of the 11 descriptors of 'good environmental status'. Despite this importance of food webs, no Member State has yet reported on them.

The interactions between species in a food web are complex and constantly changing, making it difficult to identify one condition that represents 'good environmental status'. However, changes in the

Box 3.10 Ecological regime shifts

Ecological regime shifts are large, sudden changes in ecosystems that last for substantial periods of time.

They entail changes in the internal dynamics and feedbacks of an ecosystem that often prevent it from returning to a previous regime, even when the driver that precipitated the shift is reduced or removed The ecosystem therefore remains in an alternative stable state.

Source: Biggs et al., 2009; Scheffer et al., 2001.

relative abundance of species in an ecosystem will affect interactions in several parts of a food web, and may have an adverse effect on food-web status (Rogers et al., 2010). As all marine food webs have already been adversely affected by humans, a judgement will need to be reached by Member States on what criteria will be used to assess the health of food webs and how these criteria will be assessed (Rogers et al., 2010).

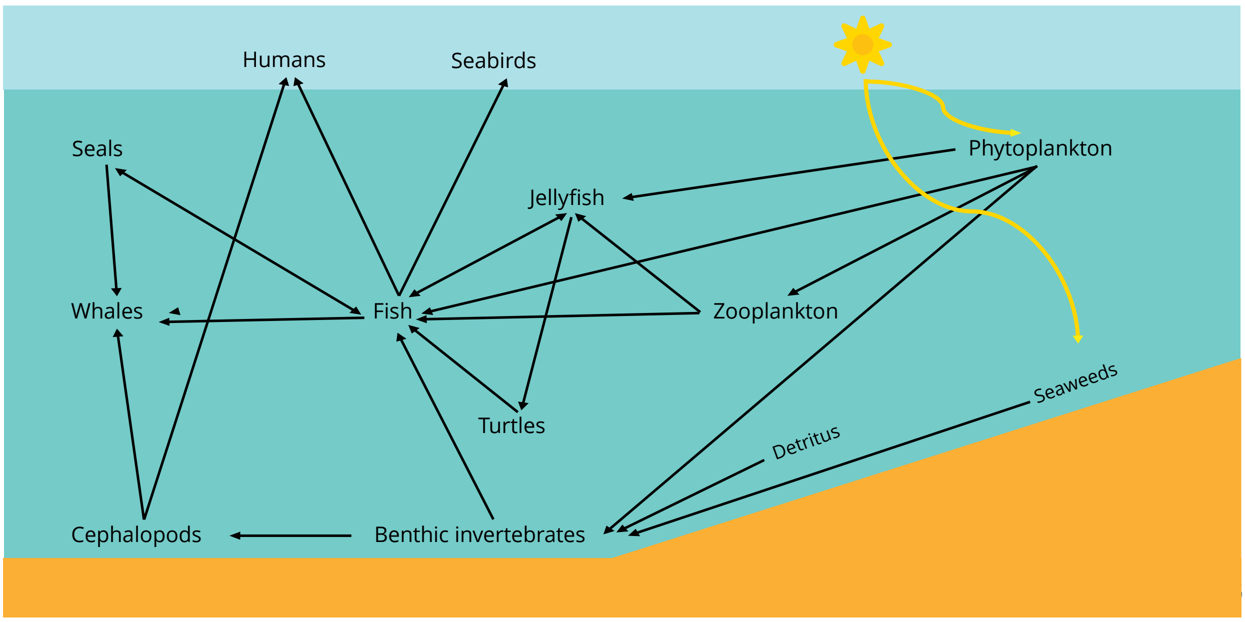
Ecological regime shifts in marine ecosystems have been observed in all four of Europe's regional seas. A century ago, the Black Sea marine ecosystem was characterised by variable fish fauna with clear water. However, overfishing, increased nutrient input, and a changing climate have triggered shifts in the ecosystem in the past 60 years. The first shift saw the loss of top predators and a high abundance of planktivorous fish. A second shift, triggered by an outburst of the invasive *Mnemiopsis leidyi* jellyfish, saw the collapse of planktivorous fish and an ecosystem that is now dominated by gelatinous plankton. The Black Sea is today an ecosystem characterised by frequent blooms of algae and jellyfish, seabed hypoxia (lack of oxygen), and localised production of hydrogen sulphide (Mollmann et al., 2011). In 1999, another invasive alien comb jellyfish species, *Beroe ovata*, arrived in the Black Sea. It is now estimated that predation of the *Mnemiopsis leidyi* jellyfish by the *Beroe ovata* may have started a recovery process in the Black Sea ecosystem (Shiganova et al., 2001).

The Baltic Sea has also suffered an ecological regime shift. In the 19th century, the Baltic Sea was an oligotrophic, low-nutrient, clear-water system. Over the 20th century, there was an increase in nutrient loading into the Baltic Sea from coastal communities and agriculture. This resulted in extensive hypoxic conditions at the seabed. These hypoxic conditions, along with overfishing and other hydro-climatic changes, are believed to have led to the collapse of cod stocks in the Baltic Sea (Jonzén et al., 2002). Herring stocks have also decreased for the same reasons, whilst sprat stocks have increased due to lower predation from cod. The Baltic Sea is now an ecosystem dominated by planktivorous fish and phytoplankton blooms (Mollmann et al., 2011). Major efforts to reduce nutrient loading are underway due to initiatives such as the Baltic Sea Action Plan (HELCOM, 2007).

Significant changes in North Sea plankton and fish communities have also been noticed over the past 50 years. Changes in the composition of the zooplankton community have been observed (Box 3.4), whilst other scholars reported changes in demersal fin fisheries (Kenny et al., 2009). This has led some scholars to characterise the changes as an ecological regime shift (Reid and Edwards, 2001). The drivers for these changes in the food webs of the North Sea are thought to be gradual warming and high fishing pressure (Mollmann et al., 2011).

These 'regional' regime shifts might have been initiated by climate-caused regime shifts in the late 1980s, which affected all the seas surrounding Europe (Conversi et al., 2010). These climate-caused regime shifts of the late 1980s may have made the seas less resilient to other anthropogenic pressures influencing each regional sea, contributing to the patterns of change that were subsequently observed.

Figure 3.13 Simplified marine food web



3.10 Are Europe's seas healthy?

It is difficult to say conclusively whether Europe's seas are healthy. Recapping that 'healthy' include aspects of halting the loss of biodiversity as well as ensuring that the long-term capacity of marine ecosystems to respond to human-induced changes in not compromised. Thus 'healthy' is about maintaining or restoring overall ecosystem resilience now and for the future rather than a looking back in history for an unexploited state. Looking from a European perspective at the knowledgebase on marine ecosystems and their biodiversity components, it is fragmented, and often lacks coherence.

In summary, 80% of the species and habitats assessments under the Marine Strategy Framework Directive are categorised as 'unknown', and only 4% have achieved the 2020 target of 'good' status. For the species and habitats that are known, 2% are considered in 'bad' status, and 14% are reported as being in 'other' status (Figure 3.14).

A more complete picture is available for the marine habitats and species protected by the Habitats Directive. In both reporting periods, i.e. 2001–2006 and 2007–2012, 9% of the marine habitat assessments were considered to be in 'favourable conservation status'. For the 2007–2012 period, 66% of the assessed marine habitats were considered to be in 'unfavourable conservation status' and 25% were categorised as 'unknown'. Marine species fared similarly, with 7% of the 2007–2012 assessments being in 'favourable conservation status'. A further 66% were categorised as 'unknown' and 27% were categorised as in 'unfavourable conservation status' in the 2007–2012 period.

Similarly, most of the assessed commercial stocks (58%) in Europe's seas are not in 'good environmental status', whilst the status of 40% of commercial fish stocks is not assessed due to lack of data.

The high amount of 'unknowns' in EU Member State reporting and in commercial fish stock statistics makes it difficult to conclusively answer whether Europe's seas are in a healthy state.

However, by comparing information available from European, regional, and national sources, a common pattern of change can be seen. For most, if not all, regional seas, ecological extinctions are being observed across species belonging to different functional groups. These ecological extinctions span species such as Monk seals in the Black Sea; bluefin tuna in the eastern North Sea; sharks in the Mediterranean Sea and North-east Atlantic Ocean; habitat-forming species like oysters in the North Sea; and sea grasses in the Baltic and Mediterranean seas (Table 3.1).

One could argue that the pattern of change presented above focuses unduly on a list of the worst possible scenarios available for European marine species and habitats. However, the regional sea conventions are observing similar trends across the regional seas. For the Baltic Sea, the regional sea convention HELCOM has 'red listed' 145 out 1 753 species (HELCOM, 2013). For the North-East Atlantic Ocean, the OSPAR Commission has listed 42 species and 16 habitats as 'threatened and/or declining' and in need of protection (OSPAR Commission, 2008).

In the Mediterranean Sea, 67% of resident marine mammal species are now listed as threatened (IUCN, 2012b). 42% of Mediterranean sharks, rays, and skates are considered threatened (Cavanagh and Gibson, 2007), and more than 8% of native marine fish species are considered threatened (Abdul Malak et al., 2011). Since the opening of the Suez Canal, more than 500 non-indigenous species have appeared in the Mediterranean Sea. So far, this has not led to extinctions of native species, although many are experiencing declines in abundance or even local extirpation. These trends have led some scientists to conclude that the establishment of non-indigenous species are 'part of a catastrophic anthropogenic ecosystem shift in the Mediterranean Sea' (Galil, 2007).

In the Black Sea, several marine mammals and seabirds are endangered or threatened in terms of their population size and distribution, with the potential to become extinct in the next 10–20 years (Krivenko et al., 2011).

Furthermore, the demonstrated pattern of change for European marine species and habitats appears to be following the same patterns as those observed across global oceans (Jackson, 2008). Based upon all of these observations, it would appear that loss of biodiversity is continuing to happen throughout European regional seas.

There is an emerging scientific understanding that losing individual species will influence ecosystem productivity and lead towards negative feedback into the ecosystem (Box 2.3). For this reason, it is apparent that the structure and functioning of European marine ecosystems are under significant — and potentially accelerating — threat. This cumulative pressure can lower ecosystem resilience, with potentially fatal consequences (Box 3.2; Box 4.11).

Ultimately, this puts in jeopardy the services and benefits that European societies are able to derive from our seas. And ecosystem services are already failing to function as normal. For example, HELCOM has estimated that out of 24 marine ecosystem services identified in the Baltic

Sea, only 10 were operating properly, with 7 being under severe threat (HELCOM, 2010).

Based on the evidence considered in this report it is very unlikely that the marine ecosystems of Europe's seas can currently be considered to be in a healthy state. Patterns of degradation are observed across of all the ecosystem components considered, and across all of the information sources considered. It can therefore be concluded on a precautionary basis that many marine ecosystems and their constituent parts are not in a healthy state in Europe's seas.

However, the marine ecosystems of Europe have considerable resilience, and it is clear that healthy marine ecosystems can be achieved with the right interventions. For example, so far only a few European marine species are known to be extinct.

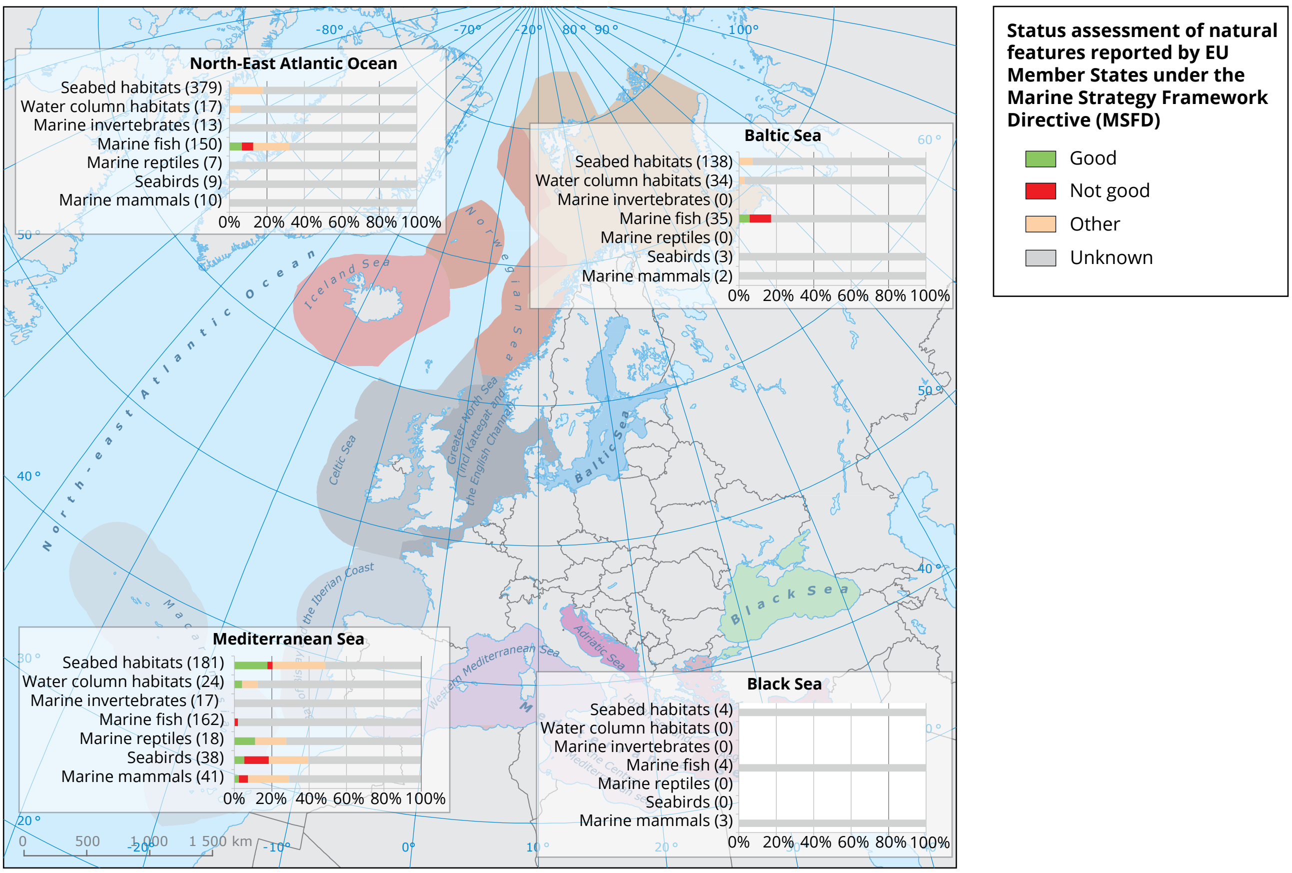
Perhaps as important, some positive trends of recovery are being observed. In the North-east Atlantic Ocean (here including the Baltic Sea), overfishing of assessed stocks has fallen from 94% in 2007 to 41% in 2014.

Individual species such as the bluefin tuna are also showing signs of recovery in some areas. Moreover, in some areas in the Baltic Sea and North Sea, it would appear that the ecosystem is starting to recover from the impacts of eutrophication. This can be seen in local improvements in seagrass depth distribution, or in the recovery of the ringed seal due to targeted management efforts (Table 3.1). Similarly, signs are appearing that Black Sea ecosystems might be on the road to recovery from the impact of the invasive *Mnemiopsis leidyi* jellyfish (Shiganova et al., 2001).

This indicates that European marine ecosystems still maintain some resilience, and maybe even the capacity to recover if the sum of pressures acting upon them is reduced. However, it is also clear that recovery can be a slow process spanning decades (as is the case for invertebrates).

This raises questions. What are the individual pressures on the state of biodiversity? What are the drivers of these pressures? These questions will be addressed in the following chapters.

Figure 3.14 Status assessment of natural features reported by EU Member States under the MSFD



Note: The figures in parenthesis are the number of assessments. The associated confidence rating of the information is rarely high. Please notice that the number of assessments per group may include multiple assessments of the same feature by different Member States. For example, in the Baltic Sea only two assessments of marine mammals were undertaken. If there were only one mammal species, one would expect eight assessments (one per Member State). There are several species of mammals in the Baltic Sea.

Table 3.1 Patterns of change for selected habitats, functional groups and populations in marine ecosystems

Biodiversity group	Region	Patterns of change	Most important pressures (1)
Seabed habitats			
Coastal habitats	European regional seas	Many European countries have estimated losses of coastal wetlands and seagrass beds of > 50% the historical area (2).	Physical damage; physical loss; and biological disturbance (i.e. non-indigenous species)
Posidonia beds	Mediterranean Sea	The rate of decline of *Posidonia oceanica* seagrass meadows in the Mediterranean Sea is currently 5% per year (3).	
Cymodocea meadows	North-east Atlantic Ocean	Estimated declines between 15% and 80% of its former natural distribution at the Gulf of Cadiz, Spain and in Portugal (4).	
Zostera marina	Baltic Sea	In the 1990s, the coverage of *Zostera marina* in Limfjorden was between 20% and 25% of the coverage in 1900 (5). This decline has continued in the period 1989–2009 but, from 2009 to 2011, the 'maximum depth limit' (its outmost reaching distance from shore) appears to have improved by 28% (6).	
Natura 2000 habitats	European regional seas	From 2007 to 2012, 9% of the marine habitat assessments were considered to be in favourable conservation status, and 66% in unfavourable conservation status.	
Water column habitats			
Calanus finmarchicus	North-east Atlantic Ocean	Modelling studies show movement of *C. finmarchicus* towards the North pole of at least 16 km per decade (due to climate change) (7).	Physical loss; biological disturbance; nutrient enrichment; organic matter enrichment; and climate change
Mnemiopsis leidyi	Black Sea	Pollution and overfishing facilitated the invasion of the alien combjelly *Mnemiopsis leidyi* and its significant impact on the Black sea and Sea of Azov ecosystems in the late 1980s, which led to fisheries collapse. But its predation by another alien combjelly species, *Beroe ovata*, which arrived in 1999, has meant that the Black Sea ecosystem shows signs of recovery (8,9).	
Marine invertebrates			
Invertebrate communities	Eastern North Sea	The average number of species per sample on 22 offshore stations in the Kattegat fell from 14 to 9.5 (32%) in the period 1994 to 2011. The number of individuals per m^2 changed from app. 2 500 to app. 1 100 in the same period (6).	Physical loss; biological disturbance; and interference with hydrological processes
Flat oyster	North Sea	Significant declines observed in 20th century. UK landings fell from 40 million in 1920 to 3 million in the 1960s. The northern 'cold water' population is now extinct[4].	
Ocean quahog	North-east Atlantic Ocean	Significant declines in both distribution and abundance have been observed in the North Sea over the past century (4).	
Marine fish			
Sharks	Mediterranean Sea	Hammerhead, Blue, Mackerel and Thresher shark populations declined between 96% and 99.99% relative to their former abundance (10).	Physical loss; and biological disturbance (i.e. selective extraction of species)
Angel shark	North-east Atlantic Ocean, Mediterranean Sea.	The Angel shark has been declared extinct in the North Sea and apparently also from large areas of the northern Mediterranean. It is now uncommon throughout most of the remainder of its range, with the possible exception of some areas of the Southern Mediterranean and the Canary Islands (11).	
European sturgeon	European regional seas	Once widely distributed in European waters, the European sturgeon is now restricted to the Garonne River in France (12).	
European eel	North-east Atlantic Ocean	A decline in Glass eels arriving at the European coast has been observed during the last 25 years, and only 1–5% of the former numbers of recruits arrive today (4).	
Marine reptiles			
Green turtle	Mediterranean Sea	In Turkey, declines of green turtle greater than 80% have been shown in the annual size of the nesting female subpopulation (13).	Biological and other physical disturbance
Marine birds			
Great auk	North-east Atlantic Ocean	The Great auk occurred across the North Atlantic but was driven to extinction by hunting in the 1850s (14).	Physical loss; biological disturbance; and contamination by hazardous substances
Black-legged kittiwake	North-east Atlantic Ocean (UK)	The UK index of Kittiwake abundance has declined rapidly since the early 1990s, to such an extent that by 2012 it was just 38% of the 1986 figure representing the lowest value in 27 years of monitoring (15).	
Canarian black oystercatcher	North-east Atlantic Ocean (Canary Islands)	Canarian black oystercatcher was endemic to the Canary Islands and was reported to have become extinct by the 1940s. Its decline was probably a result of overharvesting of intertidal invertebrates and disturbance by people, although predation by rats and cats has also been implicated (16).	

Table 3.1 Patterns of change for selected habitats, functional groups and populations in marine ecosystems (cont.)

Biodiversity group	Region	Patterns of change	Most important pressures ([1])
Marine mammals			
Grey whale	North-east Atlantic Ocean	The grey whale used to live in the North Atlantic, but was extinct by the early 1700s ([17]).	Biological disturbance, other physical disturbance and contamination by hazardous substances
Mediterranean monk seal	Mediterranean Sea and Black Sea	The Mediterranean Monk seal has an estimated total population size of 350–450 animals. It is considered to be extinct from the Black Sea and is no longer found across much of its previous range in the Mediterranean Sea and North Atlantic ([18]).	
Ringed seal	Baltic Sea	In the early 20th century, the Ringed seal population of the Baltic Sea was estimated at 180 000. Today, there are only 7 000–10 000 animals left ([19]).	
Ecosystems and regime shifts			
Food webs	Baltic Sea and Black Sea	Major regime shifts in fish communities and their associated food webs have occurred in the Baltic Sea and the Black Sea over the last century due mainly to climate change and overfishing ([20]). Regime shifts in European regional seas are likely linked as part of a change in the seas of the Northern hemisphere ([21]).	Not reported under MSFD

Sources: ([1]) As reported by Member States under the MSFD Initial Assessment. ETC ICM 2013 (unpublished). ETC/ICM MSFD Initial Assessment Summary report

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([6]) Hansen, J.W. (red.), 2012, Marine områder 2011, DCE — Nationalt Center for Miljø og Energi, Aarhus Universitet, Roskilde. (http://www.dmu.dk/Pub/SR34.pdf.) accessed 16 June 2014.

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([12]) Gesner, J., Williot, P., Rochard, E., Freyhof, J. & Kottelat, M., 2010, '*Acipenser sturio*', in: *IUCN Red List of Threatened Species*. (www.iucnredlist.org) accessed 8 June 2014.

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([14]) BirdLife International, 2012, '*Pinguinus impennis*', in: *IUCN Red List of Threatened Species*. (www.iucnredlist.org) accessed 8 June 2014.

([15]) JNCC, 2013, *Seabird Population Trends and Causes of Change: 1986–2012 Report*, Joint Nature Conservation Committee, Peterborough. (http://www.jncc.defra.gov.uk/page-3201) accessed 8 June 2014.

([16]) BirdLife International, 2012, '*Haematopus meadewaldoi*', in: *IUCN Red List of Threatened Species*. (www.iucnredlist.org) accessed 8 June 2014.

([17]) Temple, H.J. and Terry, A. (Compilers), 2007, *The Status and Distribution of European Mammals*, Office for Official Publications of the European Communities, Luxembourg.

([18]) Aguilar, A. and Lowry, L. 2013, '*Monachus monachus*', in: *IUCN Red List of Threatened Species*. (www.iucnredlist.org) accessed 8 June 2014.

([19]) HELCOM, 2013, HELCOM Red List of Baltic Sea species in danger of becoming extinct, Baltic Sea Environmental Proceedings No. 140, Helsinki Commission, Helsinki.

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4 Clean and undisturbed seas?

Key messages on clean and undisturbed seas

- Multiple pressures stemming from a range of human activities both on land and at sea are impacting Europe's seas. These pressures include: physical disturbances to the seafloor, in particular by the widespread nature of bottom-trawling; biological disturbances caused by fisheries, and the introduction on non-indigenous species mostly through shipping and the Suez Canal; pollution by nutrients, contaminants and marine litter mostly arriving from land; and energy input such as underwater noise as maritime activities expand.
- Climate change brings additional disturbance to the ecosystem and its effects are already visible in Europe's seas.
- Signs of improvement are showing for certain pressures, such as from fishing and nutrient loading. However, the combined effect of pressures is increasingly complex and of growing concern as it alters ecosystem functioning and erodes its resilience. Thus, at present, Europe's seas cannot be considered 'clean and undisturbed'.
- An adequate policy and management response will require improved systemic understanding of the linkages between the ecosystem and the human pressures and activities driving change.
- Innovative tools to assess cumulative pressures and impacts of human activities are appearing. These tools hold promise for supporting ecosystem-based management of human activities affecting Europe's seas.

4.1 Introduction

The previous chapter focused on the health of Europe's seas. By looking at the patterns of change in biodiversity and ecosystems, it showed that Europe's marine ecosystems are not in a healthy state. In this chapter, we assess whether Europe's seas can be considered to be 'clean and undisturbed', an objective for Europe's seas under the Marine Strategy Framework Directive.

In order to make this assessment, in this chapter we consider a variety of different pressures and how they affect marine ecosystems. The chapter looks at eight different pressures: physical disturbances to the seafloor caused by physical loss and physical damage (Section 4.2); biological disturbances caused by fishing (Section 4.3) and by the introduction of non-indigenous species (Section 4.4); pollution pressures from nutrients (Section 4.5), contaminants (Section 4.6) and marine litter (Section 4.7); and the input of energy, mainly in the form of underwater noise (Section 4.8) ([10]). Finally, we look at climate change, which influences the chemistry and physics of the oceans, and thus makes ecosystems more sensitive to the direct pressures coming from human activities (Section 4.9). The first seven of these pressures are direct pressures on the seas, whereas climate change is an indirect pressure.

The chapter concludes that Europe's seas cannot be considered to be clean and undisturbed (Section 4.10). In this respect, Europe is not meeting its objectives under the Marine Strategy Framework Directive (MSFD).

This chapter builds, where relevant and possible, on the information reported under the MSFD. It also calls on a wide range of information from other sources. Where relevant, this chapter includes discussions on how Europe and its Member States have responded to each of the pressures facing Europe's seas.

([10]) These pressures have been explicitly recognised in the Marine Strategy Framework Directive (MSFD), where several of the 'good environmental status' descriptors relate to pressures. These include D2, Non-Indigenous Species; D3: Commercial fish stocks; D5: Eutrophication; D6: Seafloor integrity; D8: Contaminants; D10: Marine Litter; D11: Noise and other energy inputs. The list of pressures is laid out in the MSFD Annex III.

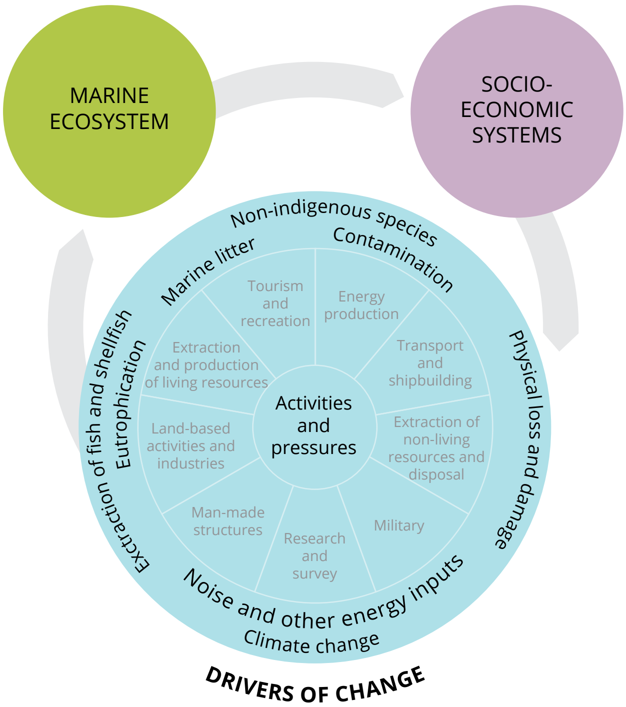
Human pressures have unpredictable results on the seas

This chapter looks at how human pressures affect marine ecosystems to understand if our seas can be considered clean and undisturbed (Figure 4.1). There are several ways in which human activities and the pressures stemming from them may disturb marine ecosystems. These pressures can be direct (when the activity affects specific biodiversity features), or indirect (when the biodiversity feature suffers as a secondary effect, because the activity affects the environment that sustains marine life). The impact that human activities have on the ecosystem will depend on the nature and intensity of the resulting pressures, as well as on the affected biodiversity features (Box 4.1).

It is important to emphasise that human pressures can have very unpredictable and wide-reaching effects on ecosystems. A single type of human driven pressure (such as large-scale extraction of shellfish, burning of fossil fuels, or the introduction of non-indigenous species) can trigger a number of responses in the ecosystem. Such responses can cascade through the ecosystem, and combine with other pressures to bring about further changes. These changes interact with the natural patterns of variability that exist in ecosystems, and this often results in further, unpredictable, non-linear responses. These non-linear responses can ultimately push the ecosystem towards an altered and undesirable state (e.g. Steffen et al., 2004; Jackson, 2008; HELCOM, 2010; OSPAR, 2010d).

As the complexity of the interactions between pressures and their impacts increases, so must our capacity to understand the resulting changes in ecosystems. Without this improved systemic understanding, we will be unable to formulate adequate policy responses.

Figure 4.1 Main pressures impacting the seas



Box 4.1 Human pressures and impacts on ecosystems

'Pressures' can be defined as the mechanism through which a human activity has an effect on any part of the ecosystem. Pressures can be physical (e.g. abrasion), chemical (e.g. introduction of synthetic components), or biological (e.g. introduction of non-indigenous species). The same pressure can be caused by a number of different activities.

'Impacts' can be defined as the adverse consequence(s) of pressures on any part of the ecosystem, where the change is beyond that expected under natural variation given prevailing conditions. Because human activities and pressures can differ in terms of their spatial extent, temporal occurrence, and the sensitivity of the affected ecosystem component(s), the overall magnitude of their impact also differs.

Source: Knights et al., 2011.

4.2 Physical loss and damage affect seafloor integrity

Messages on physical loss and damage to the seafloor integrity

- A range of human activities are causing physical loss of — and damage to — the seafloor. These pressures are affecting seafloor integrity.
- Because fishing occurs over such a wide spatial area, it is the main activity that causes seafloor damage. The impact of human activities affecting the deep seafloor is of increasing concern.
- Currently, most (74%) of the EU's fishing fleet effort results from mobile gears. The majority of mobile fishing gears (61%) disturb the seafloor. Since 2004, there has been a shift towards gears with less impact on the seafloor in the North-east Atlantic Ocean and Baltic Sea. This change may indicate a decrease in seafloor damage caused by fishing in these regions but more knowledge is needed to translate this trend into actual impact on the ecosystem.

Main pressures causing disturbance to the seafloor integrity

Europe's seafloor is currently under pressure from a range of human activities that cause physical loss and damage. This damage affects seafloor habitats and benthic communities, undermining seafloor integrity and ecosystem health (Box 4.2). To make matters worse, human activities are reaching further from the shore and to ever-deeper seafloors, where particularly vulnerable and largely under-researched ecosystems exist (Benn et al., 2010; Ramirez-Llodra et al., 2011; Mengerink et al., 2014).

'Physical loss' refers to the long-term alteration of seafloor areas and the loss of biogenic habitats (such as coral reefs, the tubeworm *Sabellaria* reefs, or shellfish communities). It is caused mainly by 'sealing' (i.e. attaching permanent man-made structures on the seabed) and 'smothering' (i.e. covering the natural seabed habitat with material such as gravel that might later disperse). Physical loss also includes the conversion of marine and coastal habitats to terrestrial areas through land-claim in coastal areas.

'Physical damage' is caused mainly by three pressures: abrasion, siltation, and the extraction of non-living material. Abrasion occurs when there is an erosive physical interaction between human activities and the seafloor (e.g. from trawling or the laying of electricity cables). Siltation is the change in the concentration and/or distribution of suspended sediments in the water column. It is caused by pressures such as dredging, trawling, and runoff from fertilisers. Extraction of non-living material includes the extraction of sand and gravel (mostly used for aggregates by the construction industry). It also includes the removal of surface substrates for the exploration of the seabed and its subsoil.

Extent of physical loss and damage in Europe's seas

Human activities that cause physical loss and damage to the seafloor occur at different temporal and spatial scales. Assessing the extent of these pressures is therefore challenging, particularly at the EU level. The reporting under the MSFD for physical loss and damage is incomplete and has important inconsistencies. However, it does show that most Member States recognised the relevance of both physical loss and damage in their waters, although they were uncertain on the extent of the pressures for most regional seas.

In areas that have been assessed, the proportion of the total area of marine waters reported as being subject to physical loss was typically less than 5%. Most

Box 4.2 Seafloor integrity

'Seafloor' refers to both the physical parameters (including habitats) and the chemical parameters of the seabed. It also includes the living benthic community of species existing in or on the seafloor.

'Integrity' is a measure of the spatial connectedness of the seafloor (i.e. that its habitats are not unnaturally fragmented), and of how undisturbed its naturally performing ecosystem processes are.

Source: Adapted from Rice et al., 2010.

reporting for this pressure referred to the North-east Atlantic Ocean and Baltic Sea. Estimates of the extent of physical damage were mostly not reported and varied greatly between Member States and regions, but this pressure was reported as being most high in areas of the North-east Atlantic Ocean and Baltic Sea (EC, 2014e; ETC/ICM, 2014).

Further evidence exists that shows human activities are disturbing seabed habitats throughout Europe's seas. For example, it has been estimated for UK waters (England and Wales) that more than half of the seabed area (134 400 km^2) is affected by indirect and direct physical disturbance (Foden et al., 2011). This disturbance is caused mainly by fisheries, with less than 0.1% of the disturbed area affected by multiple human activities. In the German North Sea waters, some areas (each area measures 3 x 3 nautical miles) have experienced up to 400 hours of beam trawling annually (Pedersen et al., 2009).

Important research is now being conducted on the spatial extent of pressures caused by fishing, the main activity causing physical damage to the seafloor. This research has resulted in fishing-pressure maps, which reveal the seabed areas that are most heavily fished and the gear used to fish them. Although there are still important caveats for using these maps, they show that in the North-east Atlantic Ocean and Baltic Sea many areas have seabed contact with fishing gear at least once per year, and some localised areas of seabed are fished more than eight times per year (ICES, 2014b).

Main origins of seafloor disturbance

In the MSFD reporting by Member States, the main activities reported as causing physical loss at the EU level were linked to man-made structures (of which land claim, coastal defence and flood protection; port operations; and submarine cable and pipeline operations are mentioned the most) and solid waste disposal. The reporting on physical damage clearly highlighted fishing as being the most important activity at the EU level. Dredging and port operations are the two main other activities that follow (EC, 2014e; ETC/ICM, 2014).

Increases in demand for living and non-living resources are expected in the future (EEA, 2014a). Given the diminishing or exhausted reserves on land and in shallow water, pressure on the seafloor is expected to increase from a wider range of activities (Glover and Smith, 2003; Benn et al., 2010). Vulnerable areas of the deep-sea are at particular risk of this expansion of human activities (Mengerink et al., 2014). Those activities that will impact large areas, like seabed mining, are of particular concern, especially when considering the possibility of cumulative and synergistic impacts from other pressures in the deep-sea environment (Box 4.3).

Box 4.3 The search for minerals moves into the deep sea

Raw materials are essential for the functioning and competiveness of the EU's economy. Seafloor mineral resources may become critical for our society to meet its future needs as demand for mineral reserves increases.

Seabed mining is considered one of the key elements to support the development of the maritime economy, as laid out in Europe's 'Blue Growth' strategy. The EU is currently formulating its position on how to develop seabed mining, but it could lead to an increase in mining operations in shallow waters and the start of such activities in the deep sea. Deep-sea mining is of particular concern as it will impact highly vulnerable deep-sea ecosystems. These are already being damaged by several other human pressures, such as deep-sea trawling or marine litter (Ramirez-Llodra et al., 2011). Furthermore, there is limited scientific knowledge about the impacts of seabed mining operations on deep-sea ecosystems but the consequences may be significant (Mengerink et al., 2014). A technical study of a single mining operation in the Pacific Ocean projects near total mortality of animal species in the area directly mined (in the case of this study, 300–700 km^2 of seafloor per year), as well as re-deposition of sediments suspended by mining activities disturbing seafloor communities over an area perhaps two to five times greater (Smith et al., 2008).

Furthermore, most of the areas likely to be chosen for future seabed mining lie beyond EU jurisdiction. In these areas, also known as high-seas international legislation to adequately regulate the industry and protect the marine environment following an ecosystem approach is still lagging behind. In spite of this governance gap, the global race to mine the seabed is now heating up. As of 2014, 17 contractors had registered exploration claims (granted for 15 years) with the International Seabed Authority (ISA) in seabed areas beyond national jurisdiction in the deep seas of the Pacific, Atlantic and Indian oceans, compared with only 6 in 2010 ([*]). Several of these contractors have sponsorship by EU Member States.

Note: ([*]) According to information on International Seabed Authority website accessed on June 2014 http://www.isa.org.jm/en/scientific/exploration/contractors.

How is physical disturbance affecting seafloor integrity?

The initial impacts of human activities that disturb the seafloor are usually local (i.e. in the area where the disturbance originally occurred) and spread out across a wide area. The impacts can also be temporary or permanent, depending on the nature of the human activity disturbing the seafloor. Thus, the extent of damage to seafloor integrity depends on the level of exposure to the pressures causing it (namely its cumulative effect) and on the sensitivity of the disturbed habitats and benthic communities. This makes it difficult to assess the impacts of these pressures in a quantitative or precise way. This difficulty is reflected in the MSFD reporting, where the EU Member State assessments of impact on the different seabed habitat types were often reported only qualitatively, if at all (EC, 2014).

Direct impacts of physical loss and damage include mortality and damage to benthic communities. Direct impacts also include the destruction and fragmentation of natural habitats (White et al., 2013). Habitat destruction has been associated with drastic declines in overall abundance and diversity of marine organisms. For example, in the Wadden Sea (the area of the North Sea stretching from southwest Denmark to the northeast of the Netherlands), the destruction of biogenic habitats has caused the regional extinction of at least 26 species during the past 2000 years (Lotze, 2005). Nevertheless, habitats vary in their sensitivity to disturbance from different pressures, as shown by investigations on seabed recovery rates. For example, the recovery time for seabed habitats in areas of the Greater North Sea (with low natural disturbance) was between 7.5–15 years following only one pass of a beam trawl (OSPAR, 2010d). In parts of UK waters (England and Wales), seabed community recovery was estimated to range from 1 month to approximately 15 years, depending on the gear applied and the sensitivity of the habitat (Foden et al., 2011).

Physical loss and damage can also adversely affect the wider ecosystem. Impacts on the benthic communities can alter food-web dynamics, whereas impacts on structural features of the seafloor (such as habitats) can induce changes in ecosystem processes and functions (Duplisea et al., 2001; Tillin et al., 2006; Rice et al., 2010). These changes can alter large-scale ecosystems. Historical evidence shows that most of the North Sea ecosystem today is severely transformed compared to its state before the era of industrial fishing, which started in the 19th century. Roberts (2007) has showed that the North Sea was once a biologically diverse and productive ecosystem, covered by a living crust formed by large oyster seabeds and other complex biological communities. Today, the North Sea's seafloor is mostly made of sand, mud, and gravel. This transformation has largely been attributed to bottom-trawling activity that began as early as the 14th century.

Seafloor damage from fishing

Fishing — and bottom-trawling in particular — is known to be the human activity most responsible for physical damage to the seafloor (Halpern et al., 2008a). This is also recognised by European Member-States in the MSFD reporting. Although fishing activity is widespread in the marine environment, its damage to the seafloor depends on several factors, namely the type of gear and the frequency of disturbance and the sensitivity of the benthic habitats and species (Box 4.4). Only a few studies have attempted to assess the large-scale effects of chronic trawling impacts on the seafloor and its associated benthic fauna. One study (Tillin et al., 2006) estimated that current bottom-trawl activities in the North Sea resulted in a 56% reduction in biomass and a 21% reduction in production of benthic invertebrates in the southern North Sea. The study showed that long-term trawling caused important shifts in the functional structure of benthic communities and an overall reduction in ecosystem productivity.

In the absence of more detailed information, it is possible to form a provisional indication of pressure and impact by analysing 'fishing effort'. Fishing effort is a measure of the amount of fishing activity, i.e. the time of a fishing vessel or fleet spent at sea fishing. Data show that in the past 10 years, since 2004/2005 depending on the regional sea, there has been a general reduction in fishing effort in most of the North-east Atlantic Ocean and Baltic seas, especially by larger trawlers and beam trawlers (EC, 2013b). A further analysis in (EEA, 2015c) shows that there are considerable differences between sea regions in the amount of fishing effort and deployed gear types, and thus in the impact of fishing on the seafloor (EEA, 2015c).

The same analysis shows that although most of the fishing effort is currently still deployed by bottom-disturbing gear, there appears to have been a gradual shift between 2004 and 2011 toward gears that have less impact on the seafloor. In spite of this recent shift, in 2011 most (74%) of the EU fishing effort used mobile gears, of which the majority (61%) disturbed the seafloor. Bottom trawl and demersal seine are the most common gear types (43%) (Figure 4.3).

Fishing has also expanded to the deep seafloor in recent decades. Technological innovations and the increase in size and power of fishing vessels and their gear have allowed bottom-trawl fisheries to

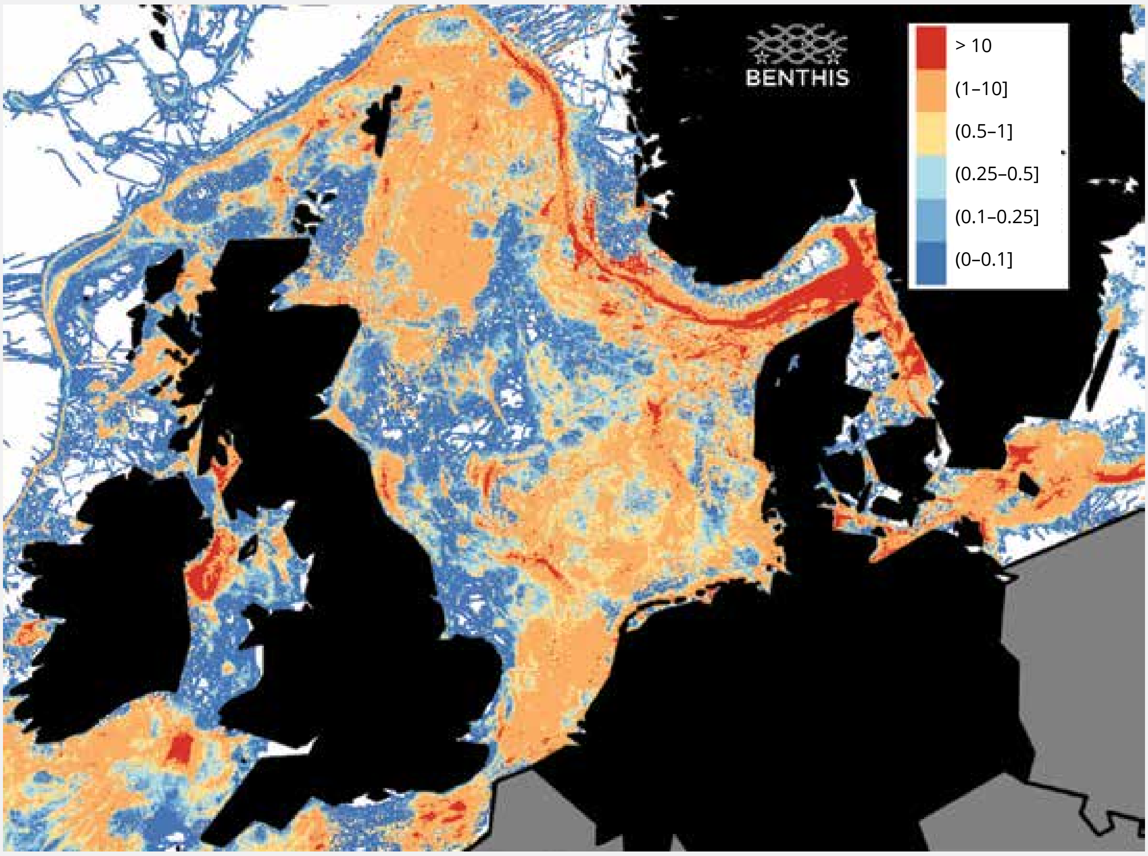
Box 4.4 Spatial distribution of fishing disturbance in the North Sea

The introduction of the vessel monitoring system (VMS) as a surveillance and enforcement tool has revolutionised the study of the spatial and temporal distribution of fishing effort. VMS provides high-resolution data for most of the larger fishing vessels in European fleets. This source of information makes it possible to form estimates of one aspect of fishing pressure: trawling intensity. Trawling intensity is a measure of the number of times that the sea bed is trawled per year, taking into account the gear dimensions of the various bottom-trawl gear used. The map below of the North Sea region, one of the most heavily fished areas of Europe, shows for the period 2010–2012 that large parts of the sea floor are disturbed by bottom-trawl gear. It also shows that the distribution of this disturbance is very uneven (Figure 4.2).

However, this information alone is not sufficient to assess impact, because the level of fishing intensity must be looked at in conjunction with the vulnerability of species to determine the state of habitats and their associated species (Eno et al., 2013). While some habitats can be seriously damaged by a single trawling event (e.g. biogenic reefs like corals), there are many species that can withstand a certain level of fishing intensity occurring at lower densities (Tillin et al., 2006). In fact, certain scavengers or opportunistic species may even increase in abundance at certain levels of fishing intensity as a result of shifts in ecosystem structure (Hiddink et al., 2008).

In the North Sea, 40% of the habitat areas (each area is measured as having a spatial resolution of 1 x 1 'minute' — an area of approximately 2 km^2) are trawled less than once every 10 years, while approximately 31% of the habitat areas are trawled 1–10 times per year, and 3% are trawled more than 10 times per year. These results suggest that species that can withstand a trawling intensity of once every 10 years will be able to survive in almost 40% of the studied area. However, it should be noted that these estimates are based on a three-year study period. Fishing patterns will usually change over a longer time period, which increases the area exposed to fishing intensity. And this cumulative pressure will in turn disturb more frequently the area inhabited by species that are the most sensitive to trawling.

Figure 4.2 Bottom-trawl fishing intensity in the North Sea over the period 2010–2012 expressed as the average number of times per year a unit area is fished

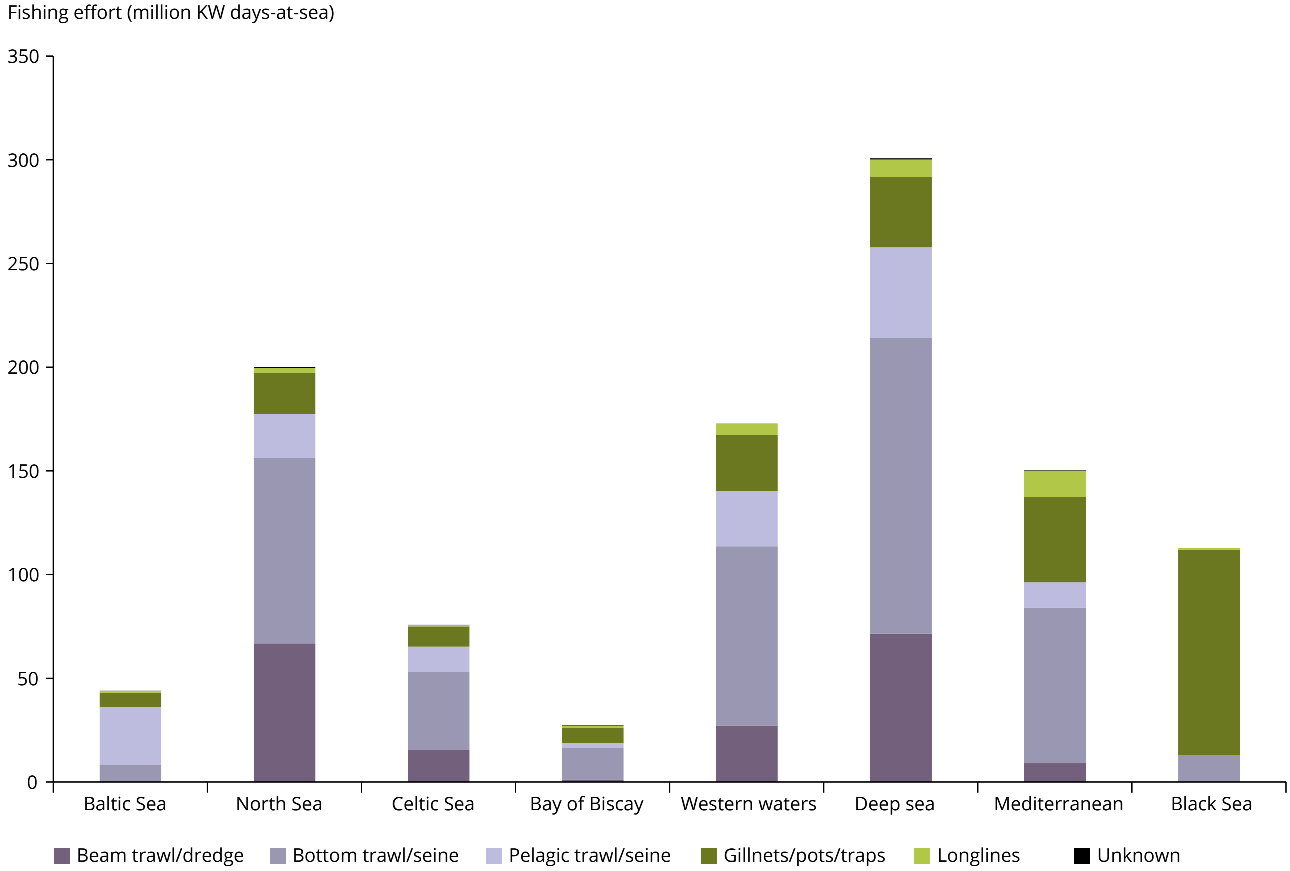


Note: VMS data only from countries in black.

Source: BENTHIS.

extend their activities into previously untrawlable grounds (Morato et al., 2006; Puig et al., 2012). This has resulted in an increase in deep bottom trawling. This is of particular concern, as deep-sea ecosystems are particularly sensitive to such disturbance and the wider effects of deeper trawls are still not well understood (Norse et al., 2012; Martín et al., 2014). The sustainability issues of deep-sea fisheries are increasingly becoming recognised by EU Member States and by regional-level organisations. For example, in the Mediterranean, a coordinated effort between scientists, the International Union for Conservation of Nature (IUCN), and the Worldwide Fund for Nature (WWF) resulted in the legal ban by the General Fisheries Commission for the Mediterranean of bottom-trawling below 1 000 m depth. Similarly, an off-shore area spanning 2 280 000 km^2 in the North-east Atlantic Ocean has been recently prohibited by Portugal to deep-sea trawling and any other fishing techniques with bottom-contacting gear.

Figure 4.3 Regional fishing effort (Kilowatt-days-at-sea) per fishing technique/gear category, 2011



Note: Five categories are distinguished based on fishing technique and gear type. Each of these impacts the seafloor differently and this list is presented in descending order of impact on the seafloor relative to the most impacting gear: mobile gears with high (beam trawl and dredge); medium/low (bottom trawl and seine); and no impact (pelagic trawl) on the seafloor; passive gears with low (gillnets, pots and traps) or no impact on the seafloor (longlines).

4.3 Extraction of fish and shellfish

Messages on extraction of fish and shellfish

- Due to the partial decrease in fishing pressure since 2007, some stocks in the North-east Atlantic Ocean and Baltic Sea are now exploited at sustainable levels. In the Mediterranean and Black Seas, the majority of commercially-fished species remain overfished.
- Recovery signs are starting to appear for some assessed fish stocks. The reduction in fishing pressure has contributed to this, showing positive results from stock management.
- Fishing affects the wider ecosystem beyond fish stocks. It causes changes to ecosystem structure and functioning, altering species interactions and ecosystem resilience. These ecosystem impacts remain insufficiently assessed and managed.

Fishing has been transforming Europe's seas for over a thousand years

Fishing is the main human activity responsible for the extraction of fish and shellfish. It is also one of the oldest human activities at sea, which has been altering significantly ecosystems throughout time (Jackson et al., 2001b). Archaeological records show that Europeans have been sea fishing as early as the 11th century AD (Roberts, 2007). By the 14th century, sea fishing had evolved to a commercial activity spanning the North-east Atlantic Ocean. The rise of industrial fishing dates back to the end of the 19th century, with the advent of the steam engine. A series of other technological advances allowed fishing power and efficiency to dramatically increase over the global ocean throughout the 19th and 20th century (Roberts, 2007; Gartside and Kirkegaard, 2002).

The cumulative effects of fishing started to reflect on catches and their composition, and thus, by the end of the 19th century, the gathering of scientific evidence on the state of fish stocks was initiated. By the beginning of the 20th century, signs of overfishing were apparent but it was only with the final intensification of fishing, after World War II, that major collapses occurred in fish stocks (Roberts, 2007; Gartside et al., 2002). In Europe, the collapse occurred in one of its most productive fisheries — herring in the North Sea. This resulted in a moratorium on herring fishing in 1977, the first fishing moratorium imposed by the then-European Communities. Soon after that, in 1983, the European Common Fisheries Policy (CFP) introduced limits to the total tonnage of fish landed from European waters.

Fishing has thus been transforming Europe's seas for over a thousand years, but it has only been regulated and managed within scientific boundaries for less than 40 years. This knowledge of the past is fundamental to understand the effects of fishing on fish stocks and the wider ecosystem, as it shows today's ecosystems are but a portrait of human legacies in changing seas (Jackson et al., 2011).

The effects of fishing are far-reaching

Fishing is one of the greatest pressures affecting marine ecosystems (Jackson et al., 2001a); Costello et al., 2010). It uses a wide variety of fishing gear, which differ in their capacity to extract fish and shellfish, and also in the pressure and impact they cause to the ecosystem. Bottom-trawling gear has highest impact on the ecosystem. Fishing effort (i.e. the amount of time spent at sea fishing) and the characteristics of the gear determine the pressure exerted on the ecosystem.

Even though fishing only targets those species and size-classes that are of commercial value, the extraction of fish and shellfish affects the wider ecosystem beyond what is targeted or physically disturbed (see Section 4.2 for effects of fishing in seafloor integrity). It does so through different mechanisms involving direct and indirect effects.

The direct effects of fishing, other than mortality of the targeted species and damage to the seafloor, are the result of by-catch of non-target fish species, such as sharks and rays, or other species such as marine mammals, seabirds, and turtles. Large marine animals are often more vulnerable to these direct effects as they cannot withstand the additional mortality. This is because they are slow-growing, mature late, and have few offspring (Box 3.6). Beyond direct effects on the abundance of large marine animals, declines in these large predators lead to major changes in ecosystem functions and processes. This 'trophic downgrading' has been found to affect species interactions and nutrient cycling, and facilitate the introduction of alien species across a wide range of aquatic and terrestrial ecosystems (Estes et al., 2011).

Despite its potential impact on the ecosystem, by-catch is poorly reported and thus poorly estimated, because it requires considerable resources and trained observers on board (Gilman et al., 2012). Recent estimates for the EU fishing fleet report by-catch of seabirds in EU waters at about 200 000 individuals annually (EC, 2012b).There is also growing evidence that by-catch has reached worrying magnitude at global level, and thus requires urgent action (Lewison et al., 2014).

In addition to the problem of by-catch, the practice of discards (i.e. unwanted catch which is thrown back, often dead, into the sea) adds to additional mortality. Like by-catch, discards are mostly not accounted for. However, recent estimates show that discards are significant (EC, 2011c). For instance, in the North Sea, the discard rate (i.e. the proportion of fish catch that is discarded) has remained relatively constant since the 1970s at around 30–40% by weight for the main demersal fish species (cod, haddock, whiting, and plaice), while the discard rate of pelagic fish is lower at around 10% (Heath et al., 2014). Discard rates reach 30–60% for the finfish fishery off the Iberian Peninsula and 50% of the catch in North Sea beam-trawl fleets (MRAG, 2007). Recognition of these large discard rates has led to the adoption of a landing obligation in the new CFP to eliminate this harmful practice.

A final effect of fishing that is important to highlight is the 'cascading' of indirect effects of fisheries through the entire food web. Fisheries affect many networks of species interconnected by predator-prey relationships. By inducing mortality (intentional or not) at several trophic levels, fishing affects complex species interactions that keep the ecosystem stable. As discussed above, the removal of apex predators results in further degradation to the marine ecosystem. However the depletion of lower trophic level species such as sardines, anchovies and herring (also known as forage fish) can also cause important declines in the abundance of upper trophic-level predators, such as larger fishes, sea birds and marine mammals (Pikitch et al., 2012). By disrupting these interactions, fishing can bring ecosystems to undesirable states that are often less predictable and more unstable (Myers et al., 2007; Travis et al., 2014).

Overfishing is still a challenge but recovery signs are starting to appear

Scientists frequently conduct stock assessments of the main commercial fish species. These assessments are the basis for fishing quotas, which are decided at European level and determine how much of each stock can be caught in the coming year. The stock assessments deliver information on fishing mortality rates and reproductive capacity. These assessments are mostly made for fish species in the North-east Atlantic Ocean and the Baltic Sea, whereas stocks in the Mediterranean and Black Seas remain largely unassessed (see Section 3.6 and EEA, 2015g).

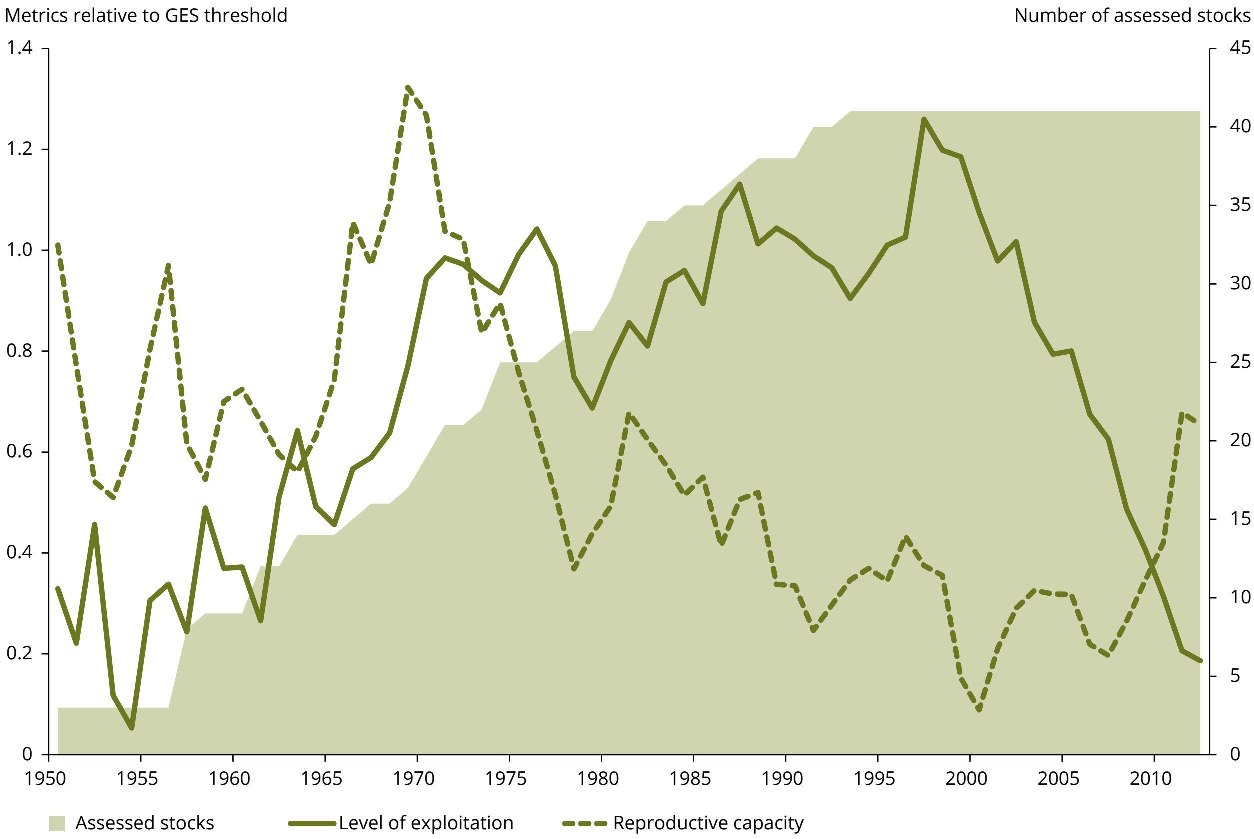
Overfishing of assessed stocks (i.e. stocks fished above Maximum Sustainable Yield — MSY) has been a long-standing problem in European waters. However, there are now signs of improvement. In 2007, 94% of assessed fish stocks in the EU North-east Atlantic Ocean and the Baltic Sea were fished above MSY rates. Promising trends have been observed since then, with the number of overfished stocks falling from 94% in 2007 to 39% in 2013 in those regional seas (EC, 2014a). However, in 2014, the number of overfished stocks rose again to 41%. In the Mediterranean and Black Seas, the level of knowledge is still very limited, making it impossible to assess change over time. The small number of stocks that are assessed in these waters do not show positive signs: 91% of the assessed stocks in the Mediterranean are overfished and 5 of the 7 assessed stocks in the Black Sea are overfished (EC, 2014a).

It is crucial to reduce fishing pressure above sustainable levels otherwise there is a risk of depleting fish populations to their eventual collapse. However, reaching sustainable levels of exploitation for all fish stocks is not enough on its own to improve the status of fish stocks. To improve the status of fish stocks, the level of fishing pressure has to be to be looked at in conjunction with other indicators such as the reproductive capacity of the fish stock. However, stock assessments that provide time trends for both of these indicators are only available for a limited number of stocks. Figure 4.4 shows such an analysis — including both reproductive capacity and level of exploitation — for a small subset of stocks in the North-east Atlantic Ocean and Baltic regional seas. It shows how, on average, the level of exploitation increased over time, from slightly above sustainable levels in the 1950s until a maximum of overfishing was reached in the late 1990s. This was then followed by a steep decline back towards sustainable levels.

The increase in overfishing until the early 2000s resulted in a gradual decrease in the reproductive capacity of these stocks. Reproductive capacity reached its lowest level soon after the overfishing peak, at which point it was almost at risk of being impaired. However, since the early 2000s, reproductive capacity began to recover for a number of stocks. This recovery in reproductive capacity is strongly linked to the decrease in fishing pressure.

This analysis shows that properly implemented management measures have a positive effect on the state of fish stocks. However, it also shows that there is

Figure 4.4 **Average deviation of status of fish stocks based on two indicators (i.e. level of exploitation and reproductive capacity) compared to policy thresholds for 'good environmental status' (GES) (*)**



Note: (*) Fish stocks belong to the North-east Atlantic Ocean and Baltic Sea.

For the level of exploitation, 0 is a target representing Maximum Sustainable Yield, above which exploitation is unsustainable. For reproductive capacity, 0 is a precautionary limit below which there is high risk that reproductive capacity is impaired and hence a need for management measures to recover stocks. Period covered 1950–2012. The figure is based on stocks for which both indicators could be estimated against reference points. Also indicated is the number of assessed stocks, which is stable from 1993 onwards.

Source: EEA, 2015g.

a considerable time lag between a management action and a biological response.

The long-term impacts of overfishing on the ecosystem remain unclear

The recovery signs observed for the assessed fish stocks are important. However, fishing affects not only the fish stock, it also affects species interactions and ecosystem resilience. These systemic changes are still complex and — to a large extent — poorly understood. This complexity is shown in a recent study conducted on the best available data from the major fishing regions in Europe (i.e. the North-east Atlantic Ocean and Baltic Sea) (Gascuel et al., 2014). Using long-term landings data, stock-based indicators, and ecosystem-based indicators, the authors showed that in spite of the significant decrease in fishing pressure (i.e. fishing mortality) observed in the last decade and the increase of the reproductive capacity for certain stocks, no clear recovery of the biomass (and thus catches) and ecosystem is yet apparent.

In addition, there is also already enough evidence to show that fishing can push ecosystems beyond their tipping points, from which recovery is unlikely (Travis et al., 2014; Möllmann, 2011). In fact, overfishing has already triggered or contributed to regime shifts in Europe's seas. These regime shifts have been observed in the Baltic and Black Seas (Möllmann, 2011). Furthermore, these changes affect not only the natural system, but also the livelihoods that depend on it. Managing fish stocks following an ecosystem approach is thus a challenge that the new CFP, which entered into force in early 2014, will have to embrace (see Chapter 8).

4.4 Introduction of non-indigenous species

Messages on the introduction of non-indigenous species

- Non-indigenous species (NIS) that become invasive are a key threat to biodiversity and ecosystem health. Their impacts are generally widespread and irreversible.
- The number of NIS in European waters continues to increase, with around 320 new species observed since 2000.
- There are important regional differences between seas in terms of how many NIS they contain. The eastern Mediterranean has the most.
- More than 1 400 non-indigenous marine species have been introduced in Europe's seas but their impacts remain largely unassessed. Where studies exist, they show severe perturbations to the introduced ecosystems.
- The main pathway of introduction is shipping. In the Mediterranean, the Suez Canal plays a large role in introducing NIS. Other pathways for introduction of NIS include aquaculture-related activities, and, to a much lesser extent, the aquarium trade and inland canals.

Non-indigenous species are a serious threat to ecosystems

Biological invasions, both terrestrial and marine, are widely perceived as one of the main threats to biodiversity (CBD, 2000; Costello et al., 2010). Non-indigenous species (NIS) that become invasive (Box 4.5) may induce complex multi-level impacts on the ecosystems to which they have been introduced. This can lead to far-ranging effects on fundamental ecosystem services and their benefits to human health and well-being (Hulme, 2007; Simberloff et al., 2013). The introduction of NIS can bring benefits to specific sectors of society (e.g. fisheries) and produce high economic profit and social welfare in the short term. However, they may have far-reaching and harmful effects on biodiversity and natural resources for generations (EEA, 2012d).

Europe's seas are facing unprecedented rates of NIS introductions

NIS are being introduced in Europe's seas with increasing regularity (Figure 4.5). Currently, Europe's seas harbour around 1 400 NIS, 80% of which have been introduced since 1950 (EEA, 2015i). The Mediterranean is the European sea with the largest number of NIS. 63% of these species are invertebrates — mostly crustaceans and molluscs. 25% are primary producers such as marine plants and algae, while 12% are vertebrates — mostly fish.

The current rate of introductions of NIS is unprecedented (Streftaris et al., 2005). Approximately 323 new species have been registered in Europe's seas since 2000, although there are important regional differences. The Aegean-Levantine Sea in the eastern Mediterranean Sea is the most affected region, with over 160 new species recorded from 2000 to 2010. The lowest rates are recorded for the Celtic and Baltic Seas, with 16 and 13 new species respectively for the same time period (EEA, 2015i).

How are NIS affecting ecosystems?

Assessing the number of species being introduced within a study region is important, in particular for management purposes. This is because areas that already have large numbers of NIS are likely to receive more. However, assessing the numbers of NIS is only of limited value for assessing impact on ecosystems, because numbers are not necessarily correlated to magnitude of the potential impact (Olenin et al., 2010).

Box 4.5 Non-indigenous species and invasiveness

Non-indigenous species (NIS), also known as alien species, are species introduced to new areas outside their natural environment. They are referred to as 'invasive alien species' (IAS) if they find adequate conditions to survive, reproduce, spread, and cause widespread harm to biodiversity and human livelihoods. NIS are used as a proxy for IAS, but it is recognised that only a small proportion of NIS will become invasive.

Sources: Adapted from EEA, 2012d, and Olenin et al., 2010.

There is little comprehensive evidence for most impacts of invasive marine species in Europe (Keller et al., 2011). The known impacts are based on the study of a few examples, which have shown that impacts can be quite severe. Such examples are the invasion of the algae *Caulerpa taxifolia* into the Mediterranean (Longepierre et al., 2005) or of the jellyfish *Mnemiopsis leidyi* in the Black and Caspian Seas (Dumont et al., 2004). These introductions caused strong alterations to native biodiversity, disrupted food-web dynamics, and lowered ecosystem resilience. In the case of *Mnemiopsis leidyi,* it ended up strongly influencing a regime shift (together with other anthropogenic pressures such as overfishing) (Möllmann, 2011; Galil, 2007).

There are also some examples of short-term economic benefits from NIS introductions. For example, after the red king crab (*Paralithodes camtschaticus*) spread from the Barents Sea to the Norwegian coast, Norwegian fisheries benefited from fishing this high-value species (Galil et al., 2009). Nevertheless, these benefits need to be considered in the wider context of ecosystem functioning, as NIS may undermine ecosystem resilience and therefore drive ecosystems to undesired states with potentially unforeseen costs (Simberloff et al., 2013; Galil, 2007). It is therefore important to assess NIS impacts on ecosystem services, both positive and negative, in order to achieve a more holistic assessment (Katsanevakis et al., 2014).

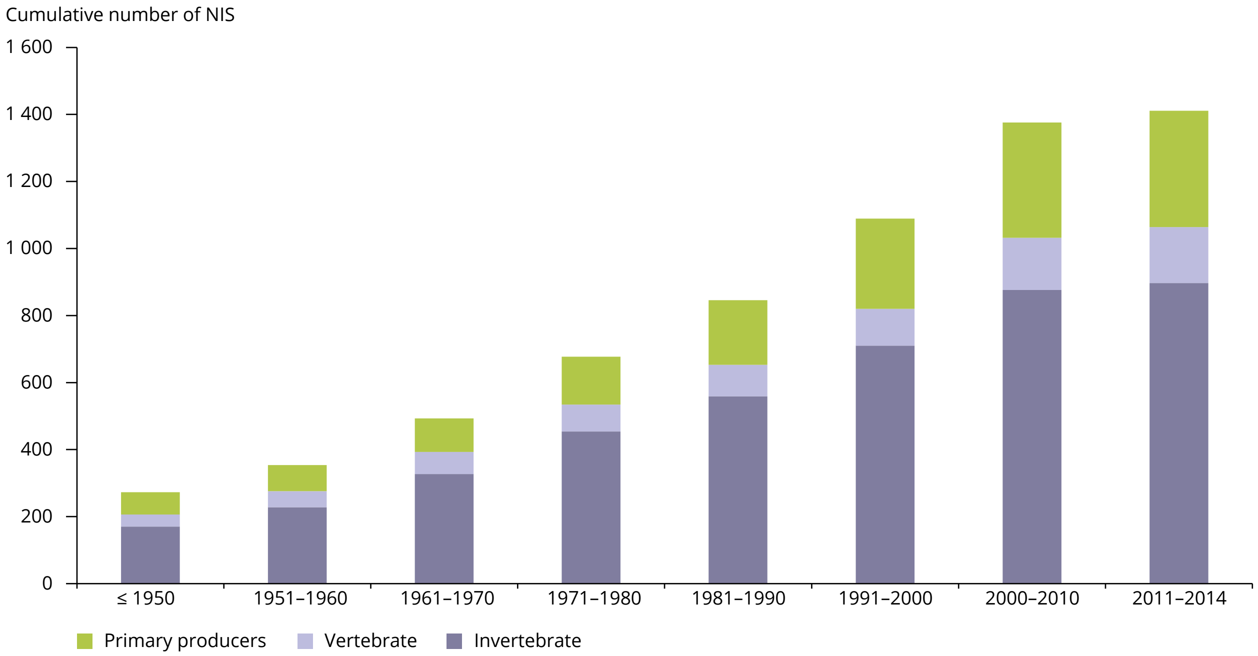
Pathways of species invasion

An increase in trade and tourism, as well as the development of aquaculture and fisheries, has provided new and enhanced pathways for the spread of alien invasive species (Hulme, 2007; Keller et al., 2011). However, researchers find it difficult to be certain which precise pathway assisted in the introduction of a particular NIS. Hence, the assessment of pathways at the EU level is based on best estimates.

Available information shows that the main pathway of NIS introduction in Europe's seas is shipping (51% of NIS are introduced this way) and the Suez Canal (37%), followed by aquaculture-related activities (17%), the aquarium trade (3%), and inland canals (2%) (EEA, 2015f). It should be noted that some species may have been introduced by more than one pathway. These findings are supported in previous studies (Streftaris et al., 2005; Katsanevakis et al., 2013). In their reporting for the MSFD, the majority of EU Member States also ranked shipping as the main pathway of invasion, followed by aquaculture (ETC/ICM, 2014).

This pattern in pathways of NIS introduction is observed in all Europe's seas, except the eastern Mediterranean. There, the introductions via the Suez Canal exceed those by shipping, enabling Red Sea species to migrate into the south-eastern

Figure 4.5 Cumulative number of NIS in Europe's seas, by decade, from 1950 to 2014



Note: Last period only covers 2011 to 2014.

Source: EEA, 2015i.

Mediterranean Sea and vice versa (Figure 4.6). Other regional differences are also noteworthy. Shipping is the major pathway for NIS introductions in all regional seas, but its contribution ranges from 41% in the Aegean-Levantine Sea in the eastern Mediterranean to approximately 84% in the Black Sea. The contribution of aquaculture is highest in the North-east Atlantic Ocean, accounting for 54% of the introductions in the Bay of Biscay and Iberian Coast, and approximately 45% of introductions in the Greater North Sea and Celtic Sea. Introductions from aquaculture are lowest in the central and eastern Mediterranean, in particular in the Aegean-Levantine Sea, where they account for approximately 5% of NIS introductions.

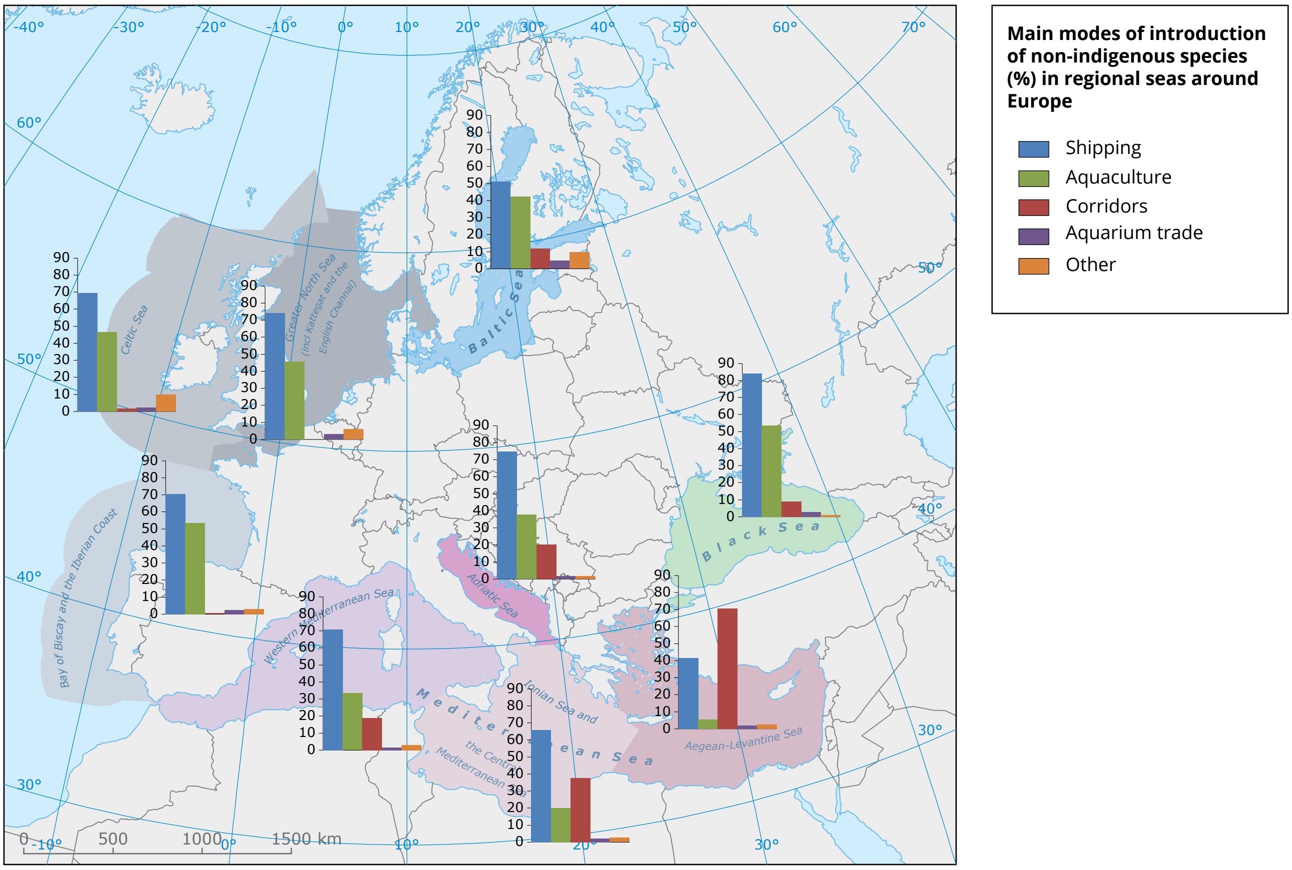
The large majority of NIS has been introduced unintentionally in Europe's seas. Existing evidence shows the main dispersal mechanisms for invasive species are ship hull fouling (the build-up of algae and other marine life on the hulls of ships) and ballast water (Mineur et al., 2007; ICES, 2012a).

Trends show that the rate of species introduction via aquaculture activities (whether imported on purpose or accidentally introduced) is decreasing. However, trends also show that NIS introductions from shipping and from canals are not declining. The rate of species introductions via the Suez Canal reduced in the 1980s, but rose abruptly in the 1990s following the deepening and widening of the Suez Canal (EEA, 2015f).

How can we safeguard native biodiversity and ecosystems from this expanding threat?

NIS represent a growing regional and global threat to the environment. It therefore requires a policy response at several levels of governance (Bax et al., 2003; Ojaveer et al., 2014). A significant time lag often exists between species introduction and species expansion. Therefore, it is likely that many future invasions have already been set in motion (Keller et al., 2011). In addition, climate-driven changes will also become an important factor in promoting the distribution and abundance of NIS (Van der Putten et al., 2010). The Mediterranean is particularly exposed to introductions of NIS due to its connection to the Red Sea via the Suez Canal (Lejeusne et al., 2010; Katsanevakis et al., 2014).

Figure 4.6 Main pathways of introduction of NIS per regional sea (relative importance in %)



Source: EEA, 2015f.

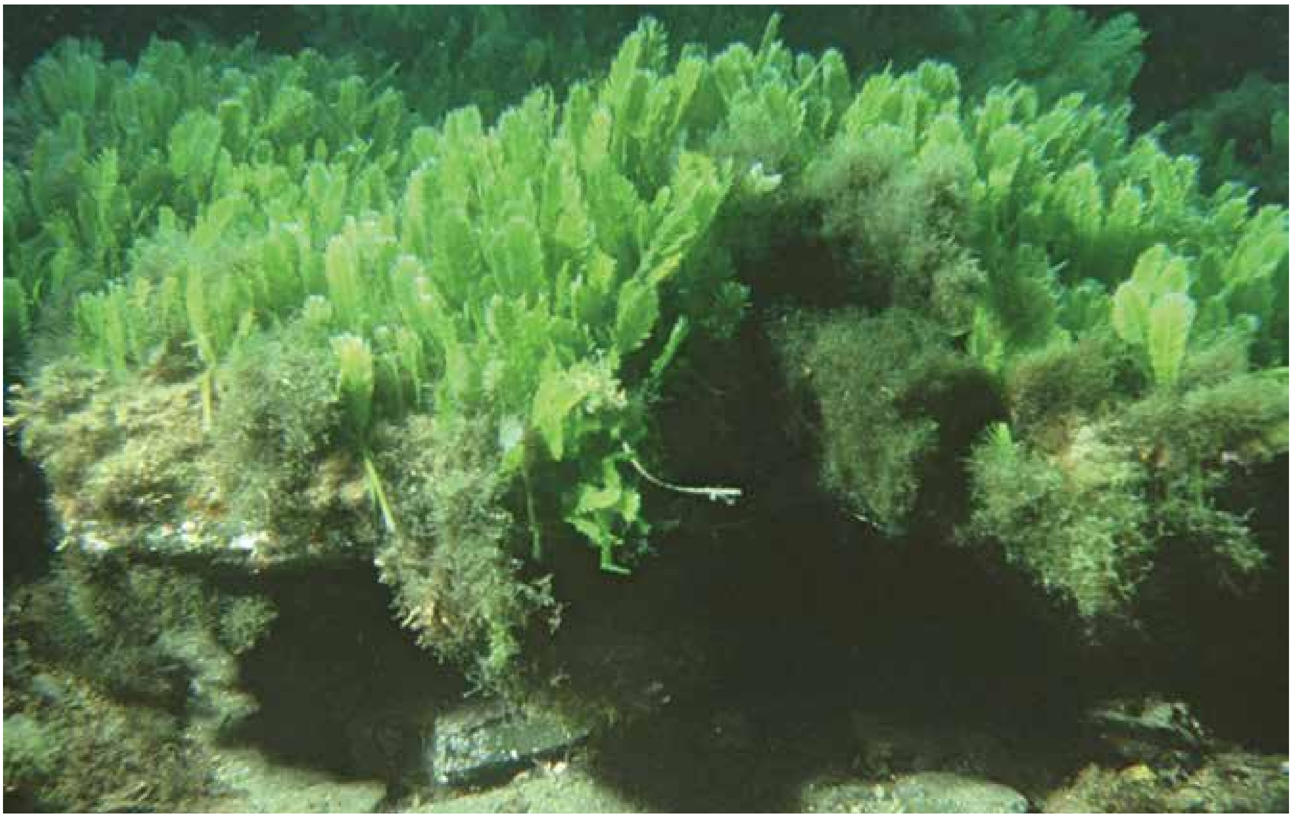


Photo: Invasive alien algae *Caulerpa taxifolia* in the Mediterranean Sea.

Source: © Leonardo Tunesi

In Europe, it has been recognised that the problem of invasive alien species is the result of two problems. Firstly, it is the result of an ecological problem, caused by the entry, establishment, and spread of invasive alien species. Secondly, it is a policy problem, caused by fragmented and incoherent policy at EU and national levels. This policy failure has allowed the ecological problem to grow (EC, 2013a).

Acknowledging this policy failure, the EU recently adopted an EU regulation that seeks to address the transboundary problem of invasive alien species in a comprehensive manner (EC, 2014d). The regulation aims at protecting native biodiversity and ecosystem services, as well as minimising and mitigating the economic or human-health impacts that these species can have. It will do so by focusing on three types of interventions: prevention, early warning/rapid response, and management. Prevention is the most important intervention, because once invasive alien species are introduced, they are difficult if not impossible to control.

The MSFD already recognises non-indigenous species as one of the main threats to the good environmental status of the marine environment. The new regulation will help Member States (who are now defining the measures they will take against NIS as part of their obligations under the MSFD) to better tackle the problem. It should also be noted that although the existing legislation on invasive species is currently fragmented, full implementation of existing regulations and international conventions (namely from the International Maritime Organization) remains crucial. It is particularly important for more countries to ratify the 2004 Ballast Water Management Convention, which has not yet entered into force due to insufficient ratification by countries.

A good example of the effectiveness of legal instruments in controlling NIS is the recent decline in NIS introductions via aquaculture. This decline can be strongly linked to the entry into force of a dedicated regulation (EC, 2007a) to limit the environmental risks related to the introduction and translocation of non-indigenous species in aquaculture. As a result, aquaculture is the only pathway for which the trend of introductions has been substantially decreasing over the last decade (EEA, 2015f; Katsanevakis et al., 2013).

4.5 Eutrophication

Messages on eutrophication

- In spite of the recent reduction in nutrient pollution, eutrophication continues to be a major environmental problem. It is responsible for widespread environmental degradation in the Baltic and Black Seas. Further reductions in nutrient emissions will be necessary to meet the objectives of the Water Framework Directive and the Marine Strategy Framework Directive across Europe.
- The environmental problems created by eutrophication reduce the quality of ecosystem services. They also reduce the socio-economic potential of ecosystem services.
- Oxygen-depleted zones are a serious and growing consequence of eutrophication. They are likely to be exacerbated by the increased water temperature induced by climate change. Addressing this issue will require large reductions in nutrient input.

The problem of eutrophication in Europe's seas and the need for a policy response

Eutrophication is the enrichment of water by the nutrients nitrogen and phosphorus. It leads to increased plant growth, changes in the balance of organisms, and water quality degradation. As plant material decays, increased oxygen consumption in bottom waters is promoted, potentially leading to hypoxia (a reduction of oxygen in water). Hypoxia results in the deterioration of the impacted ecosystems and the loss of marine life. The environmental problems created by eutrophication reduce the quality of ecosystem services related to fisheries, aquaculture, and recreation.

Europe's four marine regions have different sensitivities to nutrient enrichment and eutrophication. The sensitivity is determined by the characteristics of the marine region, such as the depth of the ocean, the internal mixing properties of the water, and fresh water inputs to the marine region. These characteristics are important because they establish the conditions under which the marine environment would be able to naturally process nutrient inputs. These characteristics are also important because they affect the balance between oxygen supply (usually from water exchange and mixing) and oxygen demand (which comes from the decomposition of organic material). When oxygen demand is higher than oxygen supply for a prolonged period of time, bottom waters become 'anoxic' (the complete absence of oxygen in water).

The semi-enclosed Baltic and Black Seas have high sensitivity to eutrophication as they have very little exchange of water with outside seas. Those seas also have relatively large catchment areas (i.e. the rivers that feed into these seas cover a wide area of land) and large inputs of freshwater and nutrients. Both seas suffer from widespread anoxia. Once nutrients enter into those enclosed seas, they remain there for a long time, sometimes for decades. Nutrients are stored in the sea floor and anoxic conditions initiate a chain of chemical reactions that release in particular phosphorus back into the water column.

Seas with very different characteristics can have similar levels of eutrophication, or can be equally free of eutrophication. For example, the Greater North Sea receives very high nutrient loads, but it is an open sea with low residence time of water, and so does not suffer from hypoxia (Artioli et al., 2008). In contrast, although the Mediterranean Sea is also semi enclosed, it has very few freshwater inputs (primarily from the Rhone, Ebro, Nile and Po rivers), and therefore does not receive many nutrients and does not suffer from the widespread hypoxia observed in other seas.

In recognition of the damage caused by eutrophication, the EU has adopted several directives intended to reduce it: the Nitrates Directive, the Urban Waste Water Treatment Directive, and the Water Framework Directive (91/676/EEC, 91/271/EEC, and 2000/60/EEC). The Water Framework Directive requires River Basin Management Plans and Programmes of Measures to be developed in order to achieve 'good chemical status' and 'good ecological status' in river-basin districts (which include transitional and coastal waters). The MSFD requires Member States to minimise eutrophication and its effects in marine waters.

The policy response to eutrophication should not only come from the EU level. Regional Sea Conventions and their secretariats (HELCOM in the Baltic, OSPAR in the North Sea, the Barcelona Convention in the Mediterranean, and the Bucharest Convention in the Black Sea) also works to map the impacts of eutrophication and establish coordinated actions and targets for nutrient reductions.

Sources of nutrient pressure

Anthropogenic nutrients derive from aquaculture, urban wastewater, and the artificial fertilisers and manure used in agriculture. They are also released by the combustion of fossil fuels used for energy, road transport, and shipping.

Anthropogenic nutrients are usually split into 'diffuse', 'point', or 'atmospheric' sources to assist policymakers in formulating an appropriate policy response. Diffuse sources are nutrient inputs to rivers that come from fertiliser run-off that is washed off farms by rainwater or that leaches into the groundwater. Diffuse sources are a reflection of the excessive use of nutrients in agricultural land use. Point sources refer to emissions from very specific single locations like urban wastewater treatment plants or industry. Atmospheric sources are emissions of nitrogen from fuel combustion and fertilisers used on land that enter into the atmosphere, and are re-deposited to the sea, primarily during rain showers. Typically, the seas receive the largest share of phosphorus from point sources, whereas the largest share of nitrogen comes from diffuse sources. Diffuse sources are also the most difficult to reduce.

Nutrients enter transitional, coastal, and marine waters in a variety of different ways. These include rivers, direct discharges from sources along the coast, or sources in the sea itself such as aquaculture and shipping. Although there are differences between the regional seas in the contribution of the various sources and pathways, agriculture (through runoff and leaching) makes the largest contribution to nitrogen inputs, accounting for more than 50% of nitrogen inputs to Europe's seas. Point sources contribute the most to phosphorus inputs, accounting for between 40% and 80% (Bouraoui et al., 2011).

Atmospheric deposition of nitrogen can make a significant contribution to eutrophication. For the Baltic Sea, it accounts for 25% of the total anthropogenic nitrogen load (HELCOM, 2009b). According to a tracer-based modelling study, atmospheric deposition accounts for 6% of the external nitrogen inputs to the North Sea (Troost et al., 2013). However, this percentage varies strongly by region.

In the sea, nutrients are redistributed by ocean currents. Both in the atmosphere and in the sea nutrients can be spread over large areas, often crossing national boundaries.

Load changes over time

Fertiliser use, and the associated input of nutrients into the environment, increased tremendously after World War II. For example, the emissions of anthropogenic

Photo: Overgrown *Zostera* in the Baltic Sea.

Source: © Metsähallitus, 2007

nitrogen to water at European scale increased by 50% between 1900 and 1950, but then increased by almost 150% from 1950 to 1980 (Sutton et al., 2011). In the North Sea and the Baltic Sea, the increase in nutrient inputs from 1950 to 1980 has been even higher; increasing by approximately 400% (Voss et al., 2011). This resulted in a proliferation of algae blooms, anoxic events, and associated fish kills. In response, Member States made efforts to reduce nutrient inputs, and nutrient loads to Europe's seas have mostly fallen since 1985 (Figure 4.7). Overall phosphorus loads are generally decreasing, although not as much as they should be. Nitrogen loads to the Mediterranean and Black Seas may be increasing.

The largest reductions have been achieved for phosphorus. Helcom reports an 18% reduction in phosphorus emissions to the Baltic Sea between 1994 and 2010 (Helcom, 2013b). OSPAR reports that six out of nine countries bordering the North and Celtic Seas achieved a 50% or greater reduction in their phosphorus emissions between 1985 and 2005 (OSPAR, 2010). These reductions have primarily been due to systematic implementation of urban wastewater treatment.

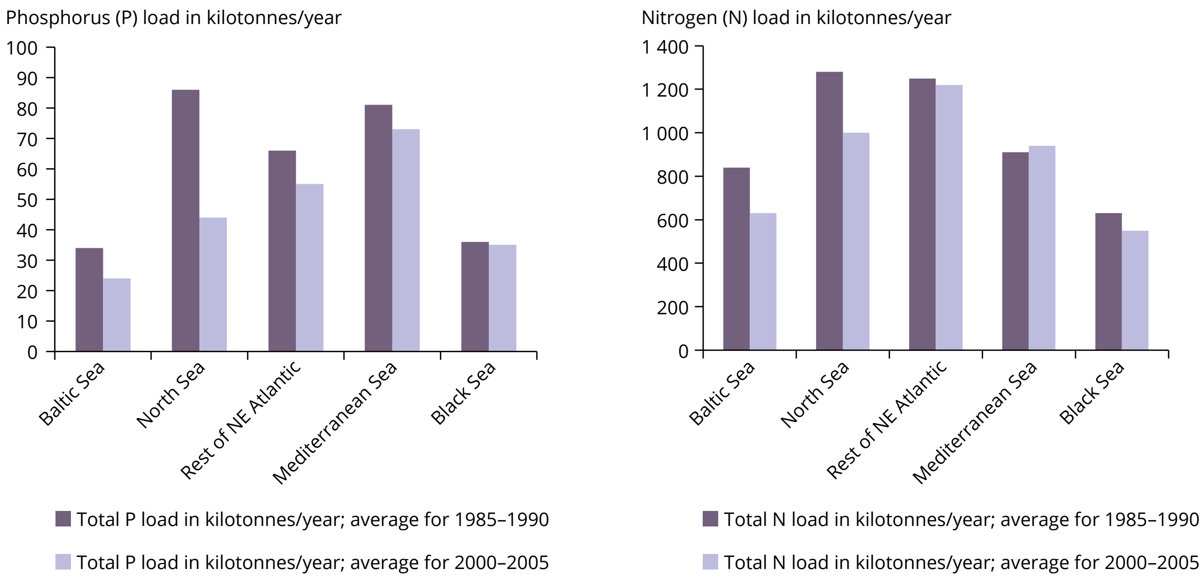
Nitrogen emissions have also been reduced. Helcom reports a 16% reduction in emissions to the Baltic Sea between 1994 and 2010 (Helcom, 2013b). Calculations suggest that nitrogen loads to the North Sea have been reduced by approximately 30% since 1985 (Figure 4.7 right). The greatest part of this reduction has been achieved by targeting agricultural use of fertilisers, and by increasing urban wastewater treatment. But in spite of these improvements, reductions are not as large as they should be and many countries are still not meeting their targets for reductions of nitrogen emissions. For example, although all member countries of OSPAR reduced waterborne nitrogen emissions between 1985 and 2005, only Denmark achieved the 50% reduction target (OSPAR, 2010).

Status of eutrophication in marine waters

The EEA monitors the status of eutrophication in Europe's seas through its indicators on nutrients — CSI 021 (dissolved inorganic nitrogen (DIN) and phosphate) and chlorophyll-a — CSI 023 (EEA, 2015e); EEA, 2015b). Both of these indicators are indirect measures of eutrophication. EEA assessments analyse levels and trends in nutrient and chlorophyll-a concentrations at specific monitoring stations. The assessments show that between 1985 and 2012, nutrient and chlorophyll-a concentrations have mostly been unchanged across Europe's seas (Table 4.1), in spite of the achieved nutrient load reductions (Figure 4.8).

CSI 021 shows decreasing phosphate and dissolved inorganic nitrogen concentrations along the east coast of the North Sea (all of the North Sea coast except for the UK coast area where no data were provided). Concentrations of dissolved inorganic nitrogen (DIN) also decreased in the western part of the Baltic Sea (Figure 4.8). In the Baltic Sea, phosphate concentrations increased at some stations as a consequence of phosphate released from the sea floor.

Figure 4.7 Nutrient loads to Europe's seas (including atmospheric deposition)



Source: Based on data from Bouraoui et al., 2011.

Table 4.1 Percentage of stations reported to EEA showing decreasing, unchanging, or increasing trends in the period 1985–2012

Trends (% of stations)	Decreasing	Unchanging	Increasing
DIN	14	84	2
Phosphate	13	83	4
Chl-a	7	89	4

Note: EEA, 2015b; EEA, 2015e.

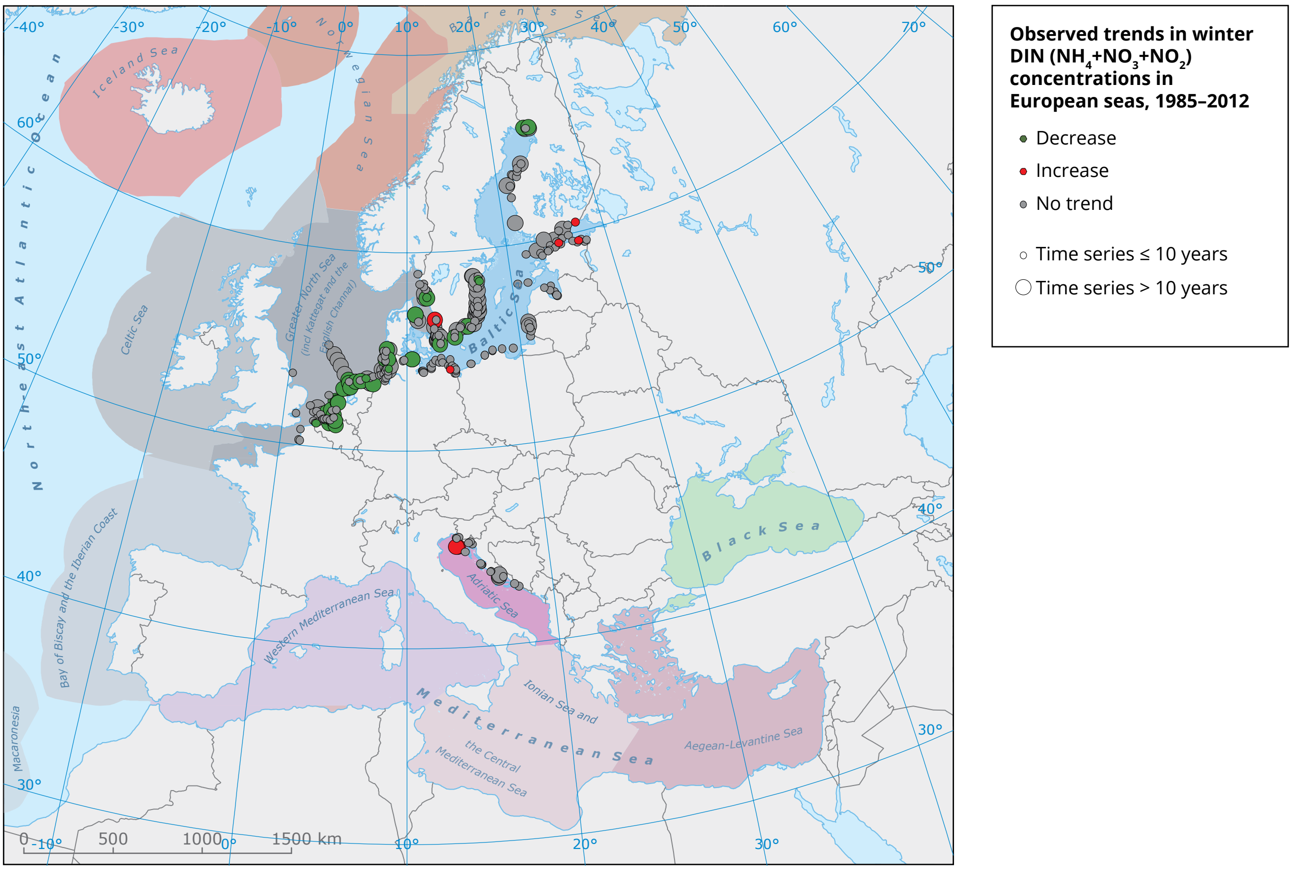
CSI 023 showed decreasing chlorophyll-a concentrations at 7% of the monitoring stations reported to the EEA. Decreases were mainly observed for coastal stations in the North East Atlantic, and for some stations in the Adriatic Sea. In the Baltic Sea, some stations showed an increase in chlorophyll.

Very little information has been provided to the EEA (either by Member States or by Regional Sea Conventions) in support of assessments of the Mediterranean and Black Seas.

Assessments of ecological status under the Water Framework Directive

Assessments of 'ecological status' under the Water Framework Directive suggest that further nutrient reductions — beyond those already achieved — are needed in many parts of Europe. The 'ecological status' of transitional and coastal waters was assessed in 2009. Ecological status is a measure of the quality of the structure and functioning of surface water ecosystems. It is based upon assessment of 'biological elements' (phytoplankton (often chlorophyll-a), phytobenthos, benthic fauna, macrophytes, and fish), and 'supporting elements' (hydromorphology, physico-chemical quality, and non-priority pollutants like nutrients). In 2009, two thirds of 712 transitional waterbodies, and half of 2 394 coastal waterbodies, failed to reach good ecological status. This shows that Europe was still far from achieving the target of good status for all waterbodies by 2015.

Figure 4.8 Map showing a statistically significant decrease (green), increase (red) or no trend (grey) of winter dissolved inorganic nitrogen (DIN) concentrations within the period 1985 to 2012



Note: Selected stations must have data at least in the period 2007 to 2012 and at least five years data in all. See also EEA, 2015e.

In the Baltic Sea (except in the Bothnian Bay), along the Danish, German, Dutch and Belgian North Sea coast, along the coast of Ireland, and in the Black Sea, the vast majority of transitional and coastal water bodies fail to achieve good status. Ecological status is generally better in the Mediterranean, although a large proportion of water bodies in France, Italy, and Greece are also in less than good status (Figure 4.9).

The reason that transitional and coastal waterbodies fail to achieve good ecological status is usually nutrient pollution or hydromorphological pressures (man-made physical changes), often in combination (EEA, 2012c).

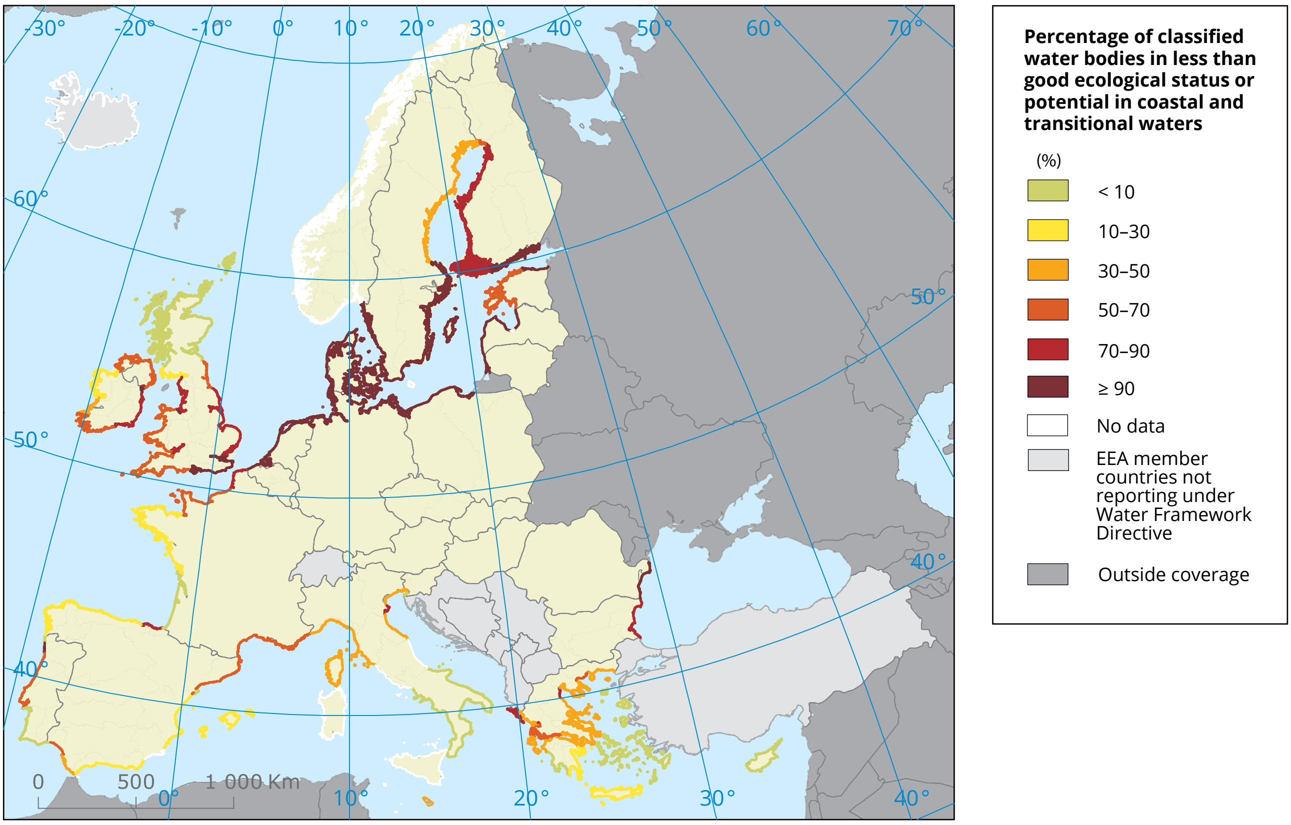
Apart from the Water Framework Directive, other EU instruments (such as the MSFD) also require reporting on the status of marine waters. Unfortunately, the quality of information reported under the MSFD did not allow for the compilation of a more consistent overview of the status of marine waters (ETC/ICM, 2014).

The effects of eutrophication

In the Baltic Sea, eutrophication combines with the physical characteristics of the sea to cause widespread hypoxia. The sea floor area where hypoxia occurs has increased 10-fold over the last 115 years (Carstensen et al., 2014). Although hypoxia is in part a natural phenomenon, it has increased in recent decades due to excessive nutrient inputs. The bottom area of the Baltic Sea impacted by eutrophication during the years 1961–1990 was 49 000 km² on average. This hypoxia affects ecosystem functioning through changes in nutrient cycling, stimulation of cyanobacteria blooms, mortality of benthic fauna, and reproduction of fish. Harmful blooms of cyanobacteria during summer lower the aesthetic and recreational value of the marine environment, but are also potentially toxic to animals and humans (Box 4.6).

In the North Sea, eutrophication creates high-biomass algal blooms along the coast from France to Denmark. The shallow coastal waters of the southern and eastern North Sea are naturally nutrient rich. This makes them already prone to high levels of algal blooms (Billen et al., 2011). Since the 1970s, these algal blooms have become even larger. Massive green macro-algae blooms on confined beaches have now become an annual occurrence in Brittany in northwest France. Nitrogen inputs are the main

Figure 4.9 Proportion of transitional and coastal water bodies holding less than good ecological status or potential per River Basin District



Box 4.6 Regional eutrophication assessments

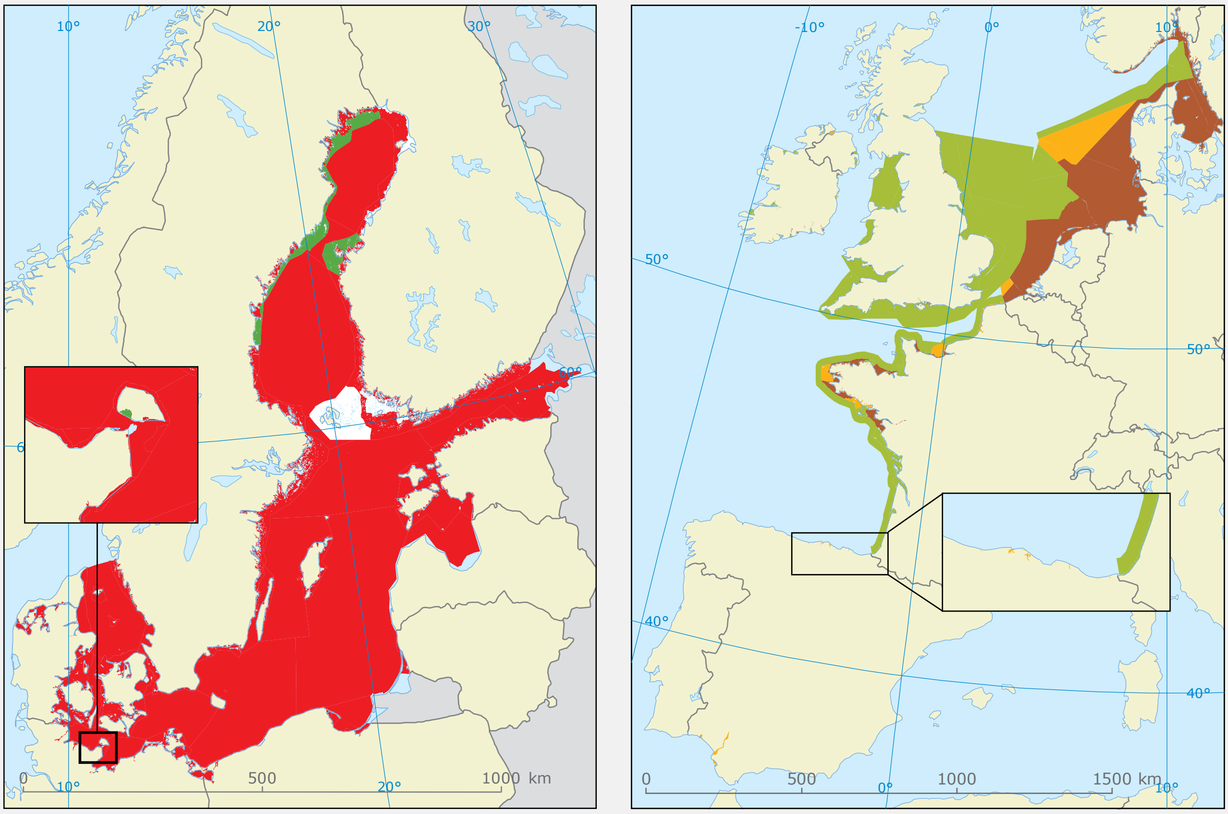
The Baltic Sea

Eutrophication is of major concern in both the marine and coastal waters of the Baltic. High nutrient loads combined with long residence times mean that nutrients discharged to the seas will remain in the basin for a long time. In the period 1994–2010, total inputs of nitrogen and phosphorus decreased by 17% and 20% respectively. Atmospheric deposition of nutrients has changed much less (HELCOM, 2010). HELCOM has assessed eutrophication within and beyond the coastal zone using its eutrophication assessment tool, HEAT. It found the entire open Baltic Sea to be eutrophic (HELCOM, 2014). Good ecological status was found in coastal areas in Orther Bucht (Germany), outer coastal Quark (Finland), outer coastal Bothnian Bay (Sweden), outer coastal Bothnian Sea (Sweden), and inner and outer coastal Quark (Sweden). These assessments showed that further reductions in nutrient loads are needed beyond those already agreed. The contracting parties of HELCOM have agreed specific national targets for these reductions in the Baltic Sea Action Plan, which was updated and adopted by a HELCOM Ministerial Meeting in 2013 (Figure 4.10).

The North-east Atlantic Ocean

OSPAR monitored nutrient reductions to its regions II (North Sea) and III (Celtic Seas) between 1985 and 2005. Most countries achieved the agreed 50% reduction in phosphorus emissions in that time, whereas only Denmark achieved the 50% reduction target for nitrogen in 2005 (Germany and the Netherlands came close to achieving it). However, all countries reduced nitrogen emissions by some amount (OSPAR, 2010). The most widely affected area is region II, with large areas along the east coast of the North Sea, from France to Norway and Sweden (and a number of estuarine areas in the UK North Sea coast) affected by eutrophication.

Figure 4.10 Regional eutrophication assessments



Results from 2013 Baltic eutrophication assessment (left) and results from the 2010 OSPAR eutrophication assessment (right)

- GES
- SubGES
- EEZ
- Outside coverage
- Problem area
- Potential problem area
- Non-problem area

factor contributing to these 'green tides', which affect ecosystem services through loss of biodiversity and lost revenues from tourism and the cultivation of shellfish (Perrot et al., 2014). Along the east coast of the North Sea, blooms of the alga *Phaeocystis* (which is responsible for 'sea foam') are a regular phenomenon during late spring, and are also related to high nitrogen inputs. This algae forms foam colonies, which affect the food web and have knock-on effects on fisheries. The algae also cause large foam deposits on beaches, potentially impacting on recreation opportunities (Lancelot et al., 2011).

The Mediterranean Sea is an oligotrophic (nutrient poor) sea with low nutrient concentrations. Nevertheless, nutrient enrichment is a problem in some near-coastal zones, in the Gulf of Lion, the Adriatic Sea, and the northern Aegean Sea. The shallow northern Adriatic Sea is particularly vulnerable. It receives high nutrient loads from the river Po, which have caused algal blooms, the production of mucilaginous substances, and hypoxia. This has had impacts on benthic habitats, tourism, and fisheries. However, there have been some signs of reductions in eutrophication in the Adriatic in the past ten years (Billen et al., 2011; Giani et al., 2012).

In the Black Sea, eutrophication is most pronounced in the shallow north-western shelf, which receives nutrients from the large Danube and Dniepr rivers. In the 1970s and 1980s, nutrient enrichment caused algal blooms, resulting in hypoxia and high mortality of benthic fauna. Since the political changes in the 1990s, fertiliser use in the Danube catchment has decreased and the sea has begun to show some signs of recovery (Mee et al., 2005; Billen et al., 2011). In general, the Black Sea is strongly stratified (it has different levels of dissolved oxygen at different depths), with permanent anoxia at depths below 125–200 metres (Oguz, 2008).

Eutrophication in the future

Climate change is likely to influence eutrophication in the marine environment by increasing water temperatures and changing rainfall patterns.

Across Europe, sea surface temperature has increased (EEA, 2014d). Warmer water will affect phytoplankton growth and organic material mineralisation rates, both of which increase with increasing temperature. Higher water temperatures reduce the solubility of oxygen in water, and global warming can thus amplify the effects of high nutrient inputs on the occurrence of hypoxia. In parts of the Baltic Sea, water temperatures have increased by about 2 °C over the last century, which has contributed to the increase in the extent of sea floor areas with hypoxia (Carstensen et al., 2014).

In contrast to the uniform warming of the seas under climate change, patterns of precipitation will change in different ways in different regions. In the Baltic, regional scenario simulations have shown there will be increases in annual precipitation of about 20% in the next century (Kjellström et al., 2011). In contrast, rainfall is already decreasing in the Mediterranean region, and the Mediterranean Sea has already experienced an approximately 20% decrease of river inflows to the sea over the past 40 years (Ludwig et al., 2009). Because there is a link between diffuse inputs and precipitation, changes in rainfall amounts will change nutrient loads to Europe's seas.

The Baltic Sea is particularly vulnerable to eutrophication under the effects of climate change. Changing river inflow rates and changing sea levels already affect nutrient inputs as well as water salinity (Gustafsson, 2004), which in turn can impact the living conditions for many plants and animals. Climatic factors already influence stratification, vertical mixing and hypoxia, which can increase phosphorus mobilisation from the sediment in the Baltic Sea (Jutterström et al., 2014).

Therefore, in the Baltic Sea the effects of climate change are likely to require nutrient reductions beyond those already anticipated. Future warming is expected to increase areas of hypoxia, because temperature controls several factors that influence the amount of oxygen available in the water. These projected changes indicate that, even if nutrient loads are reduced according to the Baltic Sea Action Plan, it will only stabilise the Baltic ecosystem close to its present state (HELCOM, 2013).

4.6 Contamination

Messages on contaminants

- Hazardous substances are widespread in the marine environment, due to the persistent nature of many substances and the continuous introduction of new ones.
- Targeted policy efforts have led to a reduction in the use of some of these contaminating substances, and some substances have been banned. Unfortunately, there are many more substances in the environment where the status is not known.
- Hazardous substances can accumulate through the marine food chain and can pose health risks to humans who regularly consume significant amounts of seafood.
- Hazardous substance pollution and its impacts may be exacerbated by climate change.

Chemicals are an essential part of our daily lives. Europe's chemical and associated industries have developed rapidly in recent decades, making a significant contribution to Europe's economy and to the global trade in chemicals. Synthetic chemicals clearly bring important benefits to society, but some of them are hazardous, raising concerns for human health and the environment (depending on their pattern of use and the potential for exposure). Under the Water Framework Directive, environmental quality standards are set for a list of 45 priority hazardous substances, or groups of substances (e.g. PBDE, cyclodiene pesticides, dioxins) (2013/39/EC).

These hazardous substances are also widespread in the marine environment. Some are naturally present, and are found at low concentrations in the earth's crust and in seawater. Other synthetic hazardous substances are introduced into the marine environment by human activities. Hazardous substances are toxic to plants and animals in the marine environment, are persistent (do not break down naturally), and liable to bio-accumulate through the food chain ([11]). Substances with endocrine-disrupting properties (affecting hormone systems in animals) can impair reproduction in fish and shellfish, and if the substances accumulate in the food chain, effects become more pronounced with the age and size of an animal. Humans can be exposed to hazardous substances through the consumption of contaminated seafood.

Status of chemical contamination in the marine environment

The presence of hazardous substances in the marine environment has been documented by numerous information sources. These include national monitoring programmes, reporting under the Water Framework Directive, Regional Sea Conventions, and European research studies. The substances can be dissolved in water, stored in sediments, or ingested by animals. The substances can also be spread over large distances. Through repeated deposition and evaporation, they are brought into the ocean or atmosphere, and redistributed to areas remote from the original source of pollution.

The need to reduce pollution from hazardous substances across Europe is widely accepted, but difficult to achieve due to the persistent nature of the chemicals. Under the Water Framework Directive, more than 90% of transitional and coastal water bodies in Belgium, Denmark, northern France, the Netherlands, and Sweden were classified as having poor chemical status (EEA, 2012c). The same reporting under the Water Framework Directive found that good status was achieved in the eastern Baltic and western United Kingdom. Chemical pollution is also monitored by all four Regional Sea Conventions, expanding the assessment coverage beyond the European Union.

The assessments of marine waters conducted by Member States under the MSFD do not provide results that are easily interpretable at a regional scale. In the Baltic, Finland has reported that it is not able to detect the status of its waters in terms of non-synthetic and synthetic contaminating substances, whereas Estonia reports 'good status' for both substances, and Lithuania reports 'not good status' for both substances. In both the North-east Atlantic Ocean and the Mediterranean marine regions, Member States frequently report either 'other' or 'unknown' chemical status.

([11]) Bio-accumulation occurs with substances that cannot naturally be processed and excreted by animals. Once the substance is consumed, it remains in the body of that animal until it dies. If an animal higher in the food chain eats another animal that has consumed the bio-accumulating substances, then the animal higher in the food chain will also ingest this bio-accumulating substance and not be able to excrete it out. Thus, the higher in the food chain an animal is, the more at risk it is from bio-accumulating substances.

The EEA indicator on hazardous substances on marine organisms addresses concentrations and trends for a small subset of eight hazardous substances found in marine organisms: mercury, lead, cadmium, HCB, lindane, PCB, DDT and BAP (EEA, 2015d). The first seven substances have been banned from use, and whilst the combined riverine inputs and direct discharges of these substances has declined (OSPAR, 2009b; EEA, 2011b), they are still found in the coastal and marine environment.

MAR 001 uses either EQS limits (Environmental Quality Standards — as set out by the Water Framework Directive) or limits established by EU directives on foodstuffs. The foodstuff limits were used for two measurements: mercury in fish muscle; and mercury, cadmium and lead in mussels.

MAR 001 shows that concentrations of HCB and lindane are generally Low or Moderate, and that concentrations of cadmium, mercury, and lead are Moderate. It also shows that concentrations are Moderate or High for PCB and DDT. Between 1998 and 2012, there was a general downward trend in the Northeast Atlantic Ocean for lead, lindane, PCB, and DDT. In the Mediterranean, there was a general upward trend for mercury and lead in the same period. Across all Europe's seas, BAP is found at moderate levels, predominantly with unchanging or decreasing trends between 1998 and 2012. For 75 cases out of 5 143, foodstuff limits were found to be exceeded. Of those 75, only 3 were in fish (flounder). The rest were in mussels.

In addition to these eight substances, there are many other substances emitted into transitional, coastal, and marine waters. Whether or not these substances are considered problematic varies widely among Member States, making it very difficult to produce a European assessment. One example is the use of paint that contains tributyltin (TBT) compounds. These compounds have been widely used to prevent biological 'fouling' (build-up of algae) of ship hulls. These paints have been shown to cause imposex (the growth of male sex organs in female species) in sensitive species. Because of this, the use of paints containing TBT has gradually been phased out, and reduced concentrations of TBT in marine waters have since been observed. Concentrations of TBT in marine waters are slow to reduce, in part because of continued leakage from sediments. They may therefore continue to be a problem across Europe for some time.

Sources of hazardous substances in marine waters

Emissions of hazardous substances arise from a wide range of land-based and marine activities, including agriculture, aquaculture, industry, oil exploration, mining, transport, shipping, waste disposal, and residential homes. Hazardous substances are emitted to the sea both directly and indirectly through a range of diffuse and point-source pathways. The main sources are treated wastewater, untreated waste water, agriculture, the burning of fossil fuels, mining, industrial manufacturing, shipping, port activities, offshore oil exploration, and aquaculture (Box 4.7).

The impacts of hazardous substances on marine waters

Persistent hazardous substances found in aquatic environments can bio-accumulate throughout the food chain, raising implications for human health with respect to the consumption of seafood (fish, crustaceans, and molluscs). The bio-accumulation of mercury and other persistent organic pollutants (POPs) can cause particularly severe health concerns for vulnerable population groups (EC, 2004; EFSA, 2005). For example, dietary mercury is almost completely absorbed into the blood and distributed to all tissues, including the brain. In pregnant women, mercury readily passes through the placenta to the foetus and foetal brain (Sundseth et al., 2010). Monitoring of contaminant levels in the Arctic population over the past decade indicates that human exposure to POPs and metals is declining, reflecting a dietary shift away from wild-caught food and towards consumption of store-bought products (AMAP, 2009). Nonetheless, human bio-monitoring data for PCBs, mercury, and lead indicate that more than 75% percent of women in Greenland exceed the US evaluation levels for mercury of 5.8 mg per litre of blood (AMAP, 2009). This is a consequence of their consumption of seafood, polluted by substances among others emitted from Europe (Figure 4.11).

A number of European studies examining the potential for exposure to hazardous chemicals via seafood have been undertaken. The results of these studies vary by region, population group, and the substance of concern: For example, in the Baltic Sea, organochlorine levels in salmon and herring were found to exceed EU maximum permissible levels (Isosaari et al., 2006), with Finnish consumption levels of herring likely to exceed recommended intake limits for these substances (Kiljunen et al., 2007).

The EU limits for mercury are exceeded in the blue mussels of Horsens Fjord, Denmark (HELCOM, 2010).

In Flanders, exposure of recreational fishermen to PCBs through eel consumption is of concern, with the Belgian

PCB standard for fish being exceeded in 80% of sampled localities (Bilau et al., 2007).

In Italy, levels of dioxin-like PCBs were found to be twice as high in farmed sea bass as in those caught wild, a finding attributable to contaminated feed (Carubelli et al., 2007).

In a Norwegian study, seafood was found to be a major source of perfluorinated compounds in humans. However, tolerable daily intakes were not exceeded (Haug et al., 2010).

In Catalonia, the average exposure of children to a range of contaminants through seafood consumption was found not to exceed tolerable daily intake (Martí-Cid et al., 2007). In a separate study, organochlorine compounds in seafood from the Spanish Atlantic south-west coast were also below EU regulatory levels (Bordajandi et al., 2006).

For some pollutants, awareness of potential negative effects has only emerged recently, and the scientific understanding may still be incomplete. These 'emerging pollutants' include substances that have existed for some time, such as pharmaceuticals and personal care products. But emerging pollutants also include relatively new substances such as nano-materials. The effects of these pollutants have not been assessed at a larger scale.

How will climate change affect the presence of contaminants in the sea?

The changing climate in Europe may change the dispersal patterns of hazardous substances in the environment. Many of the changes will first be visible on land and in freshwater, but will nevertheless contribute to chemical pollution of coastal and marine waters.

Climate change is expected to change precipitation patterns across Europe. In most of northern and central Europe, it will likely lead to more rainfall. This may increase the frequency and severity of polluted urban stormflows, which often discharge directly into coastal waters (Nie et al., 2009; Waters et al., 2003). An increase in the frequency of extreme floods may cause old contaminants and contaminated sediments to be released to the aquatic environment (Hilscherova et al., 2007). More frequent intense rainfall is also likely to exacerbate the flushing of agricultural pollutants, including pesticides and veterinary medicines, into water bodies (Bloomfield et al., 2006; Boxall et al., 2009).

Climate change is also likely to encourage land-use change, which will have knock-on effects on surrounding ecosystems. An increased prevalence of pests, weeds, and diseases may lead to wider and more

Box 4.7 Microplastic toxicity

Plastics have extensive social benefits, but there has been increasing concern over their environmental impact. Production of plastics has increased rapidly since mass production began in the 1940s, and today the annual global demand for plastics stands at about 245 million tonnes. They are now extensively used worldwide. Plastic comprises several general groupings. Nearly half of global plastics production is made up of low-density (lighter than water) polyethylene and polypropylene. Plastic itself is generally inert. However, the physical damage to wildlife caused by larger forms (more than 5 mm in size) has been well documented, whilst the impact of micro-plastics is still under investigation.

Two issues of growing concern are the potential effect of additives to plastics and the absorbent characteristics of plastics.

Additives include phthalates (softeners), bisphenol (a structural constituent), and polybrominated diphenyl ethers. These compounds can leach from plastic particles into the sea or when ingested. Phthalate effects include genotoxic damage, inhibited locomotion, and intersex conditions. Bisphenol A is known for being an endocrine-disruptor and can lead to sexual disruption in human adults. It is also acutely toxic to some groups of animals, and has been associated with chronic health effects in humans.

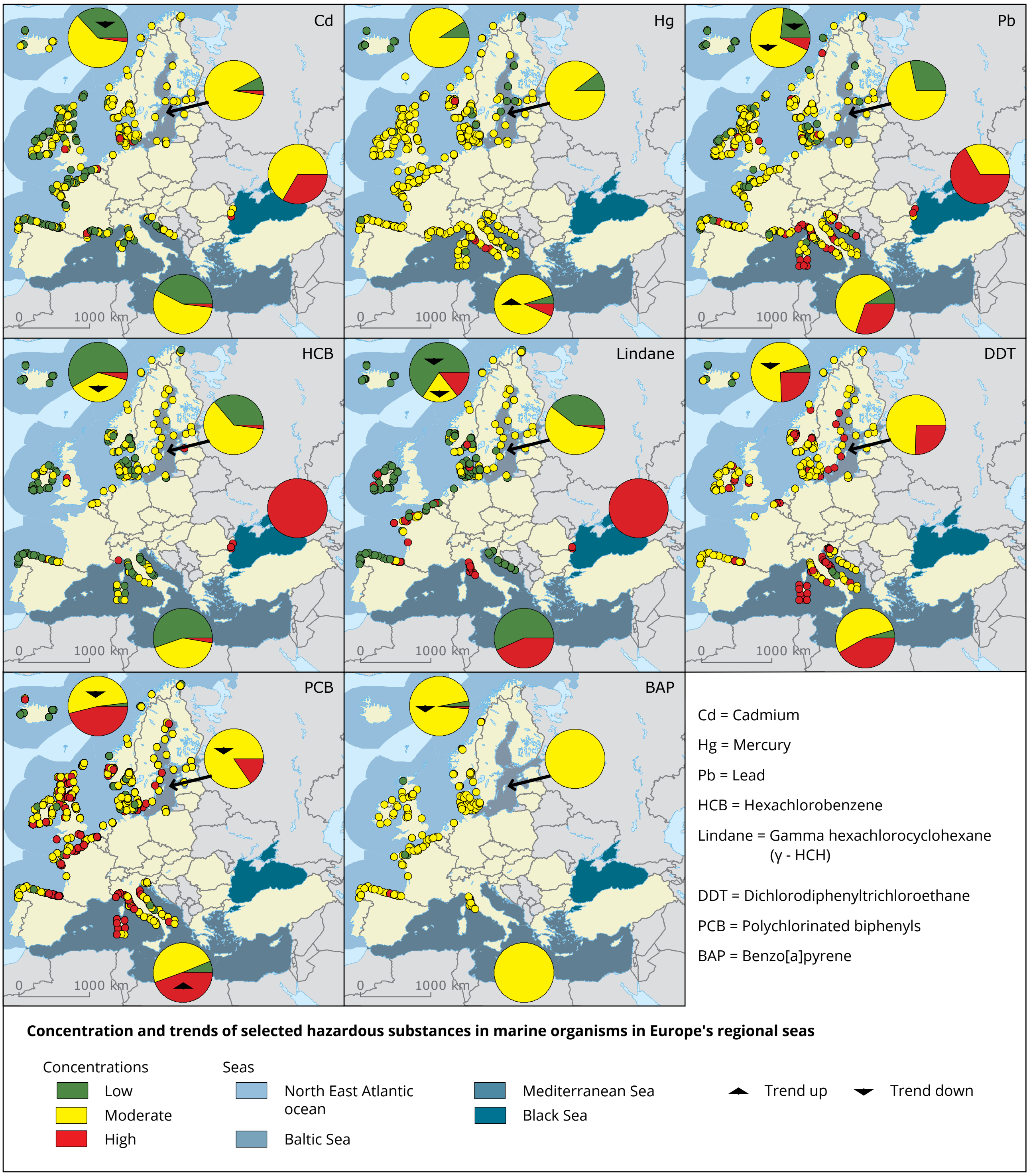
The absorbent characteristics of plastics attract many contaminants, including metals, endocrine-disrupting chemicals, and POPs (persistent organic pollutants). Several studies have identified PCBs, nonylphenol, DDTs (and metabolites of DDTs), and bisphenol A in micro-plastic debris. Concentrations of these contaminants in micro-plastic debris can be thousands of times greater than in ambient seawater. Hence, the ingestion of micro-plastics can introduce harmful chemicals to organisms, which can induce endocrine disruption, mutagenesis, and carcinogenesis. There still remain serious research and monitoring challenges to adequately understand and quantify the impact that plastics have on the marine environment.

Source: Andrady, 2011; Cole et al., 2011; EC, 2011b.

frequent application of both pesticides and veterinary medicines (Bloomfield et al., 2006; Boxall et al., 2009).

Coastal erosion is likely to be exacerbated under climate change, and has already led to the exposure of landfill sites in Europe. This has a clear potential to contaminate coastal waters.

Figure 4.11 Aggregated assessment of hazardous substances in biota measured in the North East Atlantic, Baltic Sea and Mediterranean Sea, 1998–2012



Soure: EEA, 2015d.

4.7 Marine litter

Messages on marine litter

- Marine litter — and plastic in particular — is accumulating in the world's oceans. European seas are also experiencing this problem.
- Most of the litter comes from land-based sources, except in the North-East Atlantic where sea-based litter is equally important. The main sources of litter also vary considerably between regions.
- Micro-plastics are of growing concern because they build up in the food web. Their effects on wildlife and the risk they pose to human health are still poorly understood.

Marine litter — in particular plastic — is accumulating in the ocean

Marine litter is now found in marine and coastal habitats throughout the world. It washes ashore, floats on the water's surface, or accumulates on the seafloor (UNEP, 2009) (see Box 4.8 for a definition).

Plastic is the most abundant type of marine litter (Barnes et al., 2009; Thompson et al., 2004; Ryan et al., 2009). Due to its light weight and durability, once plastic enters the sea it can travel far away and end up in oceanic currents as it slowly starts to degrade into ever-smaller pieces (Cózar et al., 2014). As the size of the plastic fragments declines, they can be ingested by a wider range of organisms. This causes impacts throughout the food-web that are still not fully understood.

Plastic litter is strongly linked to modern lifestyles, in which plastic products are widely used and are mostly discarded after a single use. Global mass production of plastic started in the 1950s and has increased dramatically from 1.5 million tonnes per year then to 288 million tonnes per year in 2012 (PlasticsEurope, 2013). The first worldwide estimate of the mass of land-based plastic waste entering the oceans estimated that in 2010, out of the 275 million metric tonnes (MT) of generated plastic waste, between 4.8 million and 12.7 million MT (between 1.7% and 4.6%) ended up in the ocean (Jambeck et al., 2015). In addition, as many as 5.25 trillion particles have been estimated to be floating in our oceans (Eriksen et al., 2014).

Litter in Europe's seas and coasts

Although the present knowledge base on marine litter in Europe's seas is growing, it is still insufficient to allow for a coherent assessment at a European level. The information reported under the MSFD was generally not reported consistently over the EU marine areas. However, all EU Member States have recognised marine litter as a problem in their waters (ETC/ICM, 2014).

Beach litter has been assessed on a regular basis in the North-east Atlantic Ocean since 1998. On average, 712 items per 100 m stretch of beach were recorded in recent assessments (OSPAR, 2010d; OSPAR, 2010a). Similar research from the Baltic Sea conducted between 2011 and 2013 suggests that amounts are lower, with an average of 237 items/100 m stretch of urban beach and 75.5 items/100 m stretch of rural beach (MARLIN, 2013). Volumes (in kg) of marine litter have also been monitored, especially in the Mediterranean countries, where more than 100 kg/100 m stretch of beach can be found in some areas (Interwies et al., 2013).

Litter is also found on the seafloor and in the deepest areas of Europe's seas. A recent large-scale seafloor survey off several European coasts has found widespread presence of bottles, plastic bags, fishing

Box 4.8 Marine litter

Marine litter is any persistent, manufactured, or processed solid material, discarded or unintentionally lost, disposed of or abandoned, that ends up in the marine and/or coastal environment. It includes, but is not limited to, plastic, metal, glass, construction materials, paper and cardboard, rubber, textiles, timber, and hazardous materials (such as munitions, asbestos, and medical waste).

Source: UNEP, 2009.

nets, and other types of human litter at all sample locations. These ranged from depths between 35 m and 4 500 m, covering coastal areas to the Mid-Atlantic Ridge, 2 000 km out in the ocean (Pham et al., 2014).

Plastic is the dominant litter material in all European regional seas, although significant regional differences exist (Interwies et al., 2013). Over 50% of the plastic litter was found to be packaging waste, in particular plastic bottles and bags (ARCADIS, 2013).

Where does marine litter come from?

Across Europe and the world, marine litter mostly results from activities on land. This litter is then carried into the marine environment by rivers, drainage systems, sewage systems, or the wind (UNEP, 2009; Interwies et al., 2013). Various human activities at sea also generate litter, including shipping, fishing, mining platforms, oil extraction platforms, and aquaculture facilities.

Member State reporting under the MSFD showed there are strong regional differences in the sources of marine litter in Europe (ETC/ICM, 2014), a conclusion that is also supported by other studies (Interwies et al., 2013; ARCADIS, 2013). Currently, it is difficult to quantify the sources of marine litter, but the available information allows to better understand the activities contributing to this problem and also important patterns.

Land-based activities seem to generate most of the marine litter in the Mediterranean, Baltic and Black Sea. In the North-East Atlantic Ocean, sea-based activities are as important as the land-based sources of marine litter. In the North-East Atlantic, the main sources of marine litter are tourism and recreational activities (mostly on the beach/coast) together with diverse maritime activities, in particular fishing and shipping. In the Mediterranean and Baltic Sea, household related waste is an important fraction of marine litter, mostly coming from solid waste disposal and urban waste water discharges. This type of litter is relatively less important in the North-East Atlantic. In the Black Sea, tourism and recreational activities together with household related waste are the main sources of litter.

What are the impacts of marine litter on ecosystems and human well-being?

Marine litter has many impacts on marine life and human well-being. The effects of marine litter on biodiversity vary depending on the type and size of the items and the organisms that encounter it. The broadly documented impacts of entanglement and ingestion by animals can cause a range of negative impacts, leading to injury, general debilitation, or death (Barnes et al., 2009; GEF, 2012; Ivar do Sul and Costa, 2014; Gregory, 2009; Gall and Thompson, 2015).

Encounters between marine wildlife and marine litter have been reported for nearly 700 species worldwide (GEF, 2012; Gall and Thompson, 2015). In GEF (2012), over half of the species experienced entanglement and ingestion of marine debris, an increase of more than 40% since the last review in 1997. Many of these species were already listed in the IUCN Red List and thus threatened by other forms of human pressures. Although it is difficult to assess these impacts at EU level, a recent study in the Mediterranean showed that 66% of 171 seabirds studied were found to have plastic fragments in their stomachs. The critically endangered Balearic shearwater was among the worst affected (Codina-García et al., 2013). The analysis of stomachs of beached fulmars in the southern North Sea showed that 95% of these seabirds contained plastics, with the average fulmar stomach containing 35 pieces (van Franeker et al., 2011).

Other effects from marine litter include alteration, damage, and degradation of benthic habitats. This can cause disruption to the assemblages of organisms living on or in the sediment (Katsanevakis et al., 2007; Chiappone et al., 2002). For instance, lost fishing gear has been identified as causing decreases in coverage of the vulnerable deep-sea coral gardens in the north-western Mediterranean Sea (Bo et al., 2014). Furthermore, marine litter items can assist in invasions of alien species (Barnes and Milner, 2005).

One of the least understood impacts is the effect on the environment and on the exposed organisms — humans included — of certain chemicals that are either in plastic (additives such as Bisphenol A, phthalates, and flame retardants) or transported by plastic waste (Box 4.7). Micro-plastics (i.e. items smaller than 5 mm) are of particular concern due to their potential toxicity in animals that ingest them (Browne et al., 2013, Ivar do Sul et al., 2014). Micro-plastics are directly added to products such as cosmetic exfoliants or toothpaste (as microbeads), or used as raw material in industrial processes in the form of plastic resin pellets. They are also created indirectly, by fragmenting from larger pieces of plastic, or from fibres when clothes are washed (and carried by sewage). Micro-plastics are now widespread in the marine environment (Browne et al., 2011; Fendall and Sewell, 2009).

Moreover, given their size, micro-plastics are considered bioavailable to organisms (i.e. can be absorbed into a living system and become physiologically active) throughout the food-web. For instance, recent evidence from the Mediterranean region has shown that harmful chemicals resulting from the ingestion of micro-plastics can accumulate in the tissues of large filter-feeding animals, such as whales and sharks (Fossi et al., 2014). The high abundance of micro-plastics in the water can also confuse smaller filter-feeders, which feed on plankton and are the base of marine food webs. These smaller filter-feeders often cannot tell the difference between micro-plastic and plankton given the plastic concentrations in the water. For instance, the north-western Mediterranean, the ratio between micro-plastics and zooplankton weights in the water samples was found to be 1:2 in offshore waters (Collignon et al., 2012). The consequences of micro-plastic build-up in the food chain are still largely unknown. However, the fact that many fish and shellfish are a source of food for humans has made this issue of growing importance for human health (Thompson et al., 2009; EC, 2011b).

Marine litter can also have important socio-economic impacts, especially where the livelihood and health of local coastal communities are affected (Tinch et al., 2012). It affects a range of maritime activities including aquaculture, fisheries, shipping, and coastal tourism (Mouat et al., 2010). The social harm caused by marine litter includes the reduction in recreational, aesthetic, or educational values of an area as well as risks to human health and safety. Economic harm includes loss of fish catches trapped in lost fishing gear, costs for cleaning activities, damage to navigation equipment, and collision.

Photo: Beach litter is the most visible part of a growing problem.

Source: © Ryan Metcalfe

Although information on the socio-economic impacts of marine litter is relatively scarce, it can be substantial in the particular case of beach clean-ups. UK municipalities spend approximately EUR 18 million each year removing beach litter; a 37% increase in cost compared to the early 1990's (Mouat et al., 2010). Removing beach litter costs municipalities in the Netherlands and Belgium approximately EUR 10.4 million per year (Interwies et al., 2013).

How can we tackle it?

The problem of marine litter is linked to all sectors of society, and must therefore be addressed at several levels. No single measure will suffice to address the complex problem of marine litter but rather integrated mitigation strategies. Remedial clean-up of litter along beaches and in the sea is time-consuming, costly, and only captures a fraction of overall litter. However, beach clean-up initiatives remain important as they raise awareness and engage local communities in this issue. This engagement is important since people's behaviour and perceptions play a key role in littering, together with context specific factors (such as cleanliness of the area or administrative capacity to handle litter) and available waste infrastructure and facilities (RPA, 2013; ARCADIS, 2013). Plastic waste is the main source of concern, especially since the global quantity of plastic waste available to enter the oceans from land is predicted to double between 2010 and 2025 (Jambeck et al., 2015). Specific measures targeting the reduction and smarter use of plastic are called for, namely through better product design or developing alternatives (such as biodegradable plastics or bioplastics) (Koushal et al., 2014).

At the EU level, marine litter has been recognised as a key environmental challenge in the 7th Environment Action Programme, which determines the reduction of marine litter as a main environmental target. Specific management measures will also be implemented by EU Member States under the MSFD, and are likely to feature in the implementation of the recently revised EU waste legislation package as well. Being a trans-boundary issue, action to address marine litter should be taken wherever possible at the regional level. Recognising this need, several Regional Action Plans are now being developed and implemented by the Regional Sea Conventions. These measures, together with industry innovation and greater awareness of the problem by citizens, should help to begin addressing this problem at its source.

4.8 Underwater noise and other forms of energy input

Messages on underwater noise and other forms of energy input

- Europe's seas are increasingly the site of industrial activities. This results in increased underwater sound — the most widespread kind of energy introduced by man.
- Shipping, renewable energy, oil and gas extraction, and defence activities are some of the most common noise-producing activities in our seas.
- Underwater noise can cause a range of impacts in marine animals, from subtle behavioural changes to injuries and death in extreme cases. However, the effects of underwater sound are still not well understood.

Energy introduction in the sea

Energy can be introduced into the marine environment in the form of heat, light, electromagnetic emissions, and underwater sound. Information on the effects of energy introduction is still very limited, although it is growing — in particular for underwater sound, the most widespread and pervasive form of energy (Van der Graaf et al., 2012). Underwater sound is directly caused by human activities, such as construction, transport, recreation, and energy production. Its impacts on marine life are increasingly debated among scientists, regulators, and stakeholders.

Sound is an important means by which marine life gathers information about the environment. Many marine life forms use sound for communication, for finding prey, to navigate, and perhaps even as a weapon to stun or kill prey (see reviews by Tyack and Clark, 2000; Popper et al., 2003; Ladich et al., 2006). Human activities can change normal sound levels, turning the sound to noise. 'Noise' is used to mean sound that has the potential to cause negative impacts on marine life (Box 4.9).

Sources of underwater noise

Humans can introduce sound into the marine environment either deliberately (e.g. military sonar, seismic surveys) or as a by-product of other actions, such as shipping, pile-driving, or dredging of the seafloor. Each human activity that produces underwater noise may have different effects, depending upon the frequency range, its intensity, and whether it is an intermittent, pulsed, or continuous sound (overview in OSPAR, 2009b).

Because the knowledge on underwater noise impacts is relatively recent, there has been little work on the exact distribution of sources of sound in EU waters. This lack of information is also reflected in the EU Member State assessments in the MSFD reporting, which show only a few entries on human activities causing noise pressure. In those Member State assessments that do make reference to sound-related activities, the most frequently identified sources of underwater noise are shipping, renewable energy, oil and gas extraction, and defence activities (ETC, 2014).

Data from OSPAR indicate that pressures due to underwater sound emissions might be relatively high in the Greater North Sea and Celtic Sea due to the comparably high amount of human activities there. These sound emissions could increase in the foreseeable future as these regions undergo further development. For example, there are plans for large increases in offshore wind farms in Germany, the Netherlands, and the United Kingdom (for details, see OSPAR, 2009a). Shipping has also been identified as an

Box 4.9 The difference between sound and noise

Sound is a dominant feature of the underwater marine environment as a result of natural (e.g. biological sources, underwater earthquakes, wind) and human-made sound sources. The term 'sound' is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference to its function or potential effect. The term 'noise' is only used where adverse effects are specifically described, or when referring to specific technical distinctions such as 'masking noise' and 'ambient noise.'

Source: Adapted from Tasker et al., 2010 and Van der Graaf et al., 2012.

important source of noise pressure in the Baltic and the Mediterranean seas (Breen et al., 2012).

Noise levels and impacts

Noise can impact marine life in many ways, depending on the type of noise (OSPAR, 2009a; Tasker et al., 2010). Low-mid frequency impulsive sound, such as that emitted during pile driving or seismic surveys, are usually relatively intense and can lead to injury, displacement and / or other behavioural changes. A second type of sound — low frequency continuous sound (ambient sound), such as that emitted by shipping, can lead to communication difficulties and can cause long-term stress. The effects of underwater noise are still not well understood. The variety of sounds and their characteristics, the different time and space scales at which they occur, and the different sensitivities of marine organisms to sound all influence the impact of noise on marine animals (Tasker et al., 2010; Van der Graaf et al., 2012).

As was the case with marine litter, no methodological approaches or monitoring programmes existed for the assessment of energy and noise introduction in the European marine environment. Therefore, the Member State reporting under the MSFD has not been able to provide an initial assessment on the levels and impacts of marine noise (JRC, 2014; ETC 2014). However, it is likely that the levels of sound inputs and the associated effects on the marine ecosystem have been increasing (Van der Graaf et al., 2012).

Over the last century, the world's oceans have witnessed a significant development and expansion of human activities in and near the water (Slabbekoorn et al., 2010). Technological developments (such as the shift to mechanical ship propulsion or the use of sonar for non-military purposes), the increase in number and size of vessels (fishing, transport and recreational), and the development of maritime activities such as extraction of non-living resources and renewable energy have all contributed to the rise of artificial sound levels in the oceans (NRC, 2003; Hildebrand, 2004; Hatch and Fristrup, 2009). Nevertheless there have been very few studies that have quantified the change in underwater sound levels (Van der Graaf et al., 2012).

Introduction of other forms of energy to the marine environment

The effects of heat and light on marine animals are largely unknown, although adverse consequences are likely to be restricted to specific offshore areas (e.g. oil and gas platforms) or coastal areas (e.g. cooling-water emissions from coastal power plants) where the activities causing the input of this kind of energy exist. There is very little information on the number and distribution of power and telecommunication cables that can emit electromagnetic fields in the EU as a whole (Tasker et al., 2010).

At least theoretically, electromagnetic fields can affect marine mammals and fish, as both seem to orientate using the earth's magnetic field (see Tasker et al., 2010). Current knowledge suggests that electromagnetic fields from subsea cables may interact with migrating eels (*Anguila* sp.), and possibly other diadromous fish, if their movement routes take them over the cables, particularly in shallow water (less than 20 metres in depth). However, the only known effect is a temporary change in swimming direction. Whether this represents a biologically significant effect (which, for example, could delay migration) cannot yet be determined.

Policy responses to the problem of underwater noise

The MSFD identifies underwater noise and other forms of energy input that have the potential to impact marine animals as one of the key pressures threatening ecosystem health. The MSFD also determines an ecosystem approach to the marine environment where the cumulative effects of pressures and impacts should also be assessed. The current availability of data on man-made energy input is however insufficient to adequately assess its pressure and impact. Therefore it was recognised that additional scientific and technical progress is still required to support the assessment and monitoring of energy introductions made by human activities for MSFD purposes (Tasker, 2010; Van der Graaf et al., 2012). In addition, there is an urgent need for a better understanding of the biological impacts of underwater noise. The challenge is to define the functional relationships between behavioural responses to sound (or physiological responses) and population effects. Without this definition it will be difficult to conduct a comprehensive assessment (Boyd et al., 2010).

At the current stage of the MSFD implementation, the measurement of underwater noise has been identified as a first priority in relation to assessment and monitoring. The EU has now provided very detailed further advice on the implementation of the MSFD (see the TG noise monitoring guidance (Dekeling et al., 2014)). This will greatly increase the standardisation of terms, monitoring methods and data analysis procedures for both impulsive and ambient sounds. Member States are now expected to implement registers to map activities generating impulsive sounds in their national waters and quantify the level of this pressure over time and space. Once operational, the register will thus provide Member States a baseline for the current situation on impulsive noise levels and help inform adequate policy targets and management measures. Monitoring ambient noise is more complex. It will require a combination of measurements and modelling as part of a noise monitoring network, and international standards for doing so are still missing (Dekeling et al., 2014).

Once monitoring programmes are started, data reporting and analysis will improve in the future allowing to define further priorities. These are on setting future targets for adequate noise levels; addressing the biological impacts of anthropogenic underwater noise; and to evaluate new information on the effects of sound on marine biota with a view to considering indicators of noise effects (Dekeling et al., 2014).

4.9 Marine climate change

A changing climate system influences the world's oceans

Together with the loss of biodiversity, climate change remains one of the key policy challenges of our age. Climate change affects the health and resilience of natural systems, and it increases existing vulnerabilities and social imbalances.

Two major physical effects of climate change on the global oceans that affecting marine ecosystems are increased water temperature and ocean acidification. Both of these changes are driven by an increase in concentrations of atmospheric carbon dioxide (CO_2). These concentrations have increased by 40% since pre-industrial times (IPCC, 2013). As the average temperature of the ocean increases it becomes less able to absorb CO_2.

This in turn causes changes to sea ice, sea levels, frequency of extreme weather events, salinity, and ocean circulation. These changes can have substantial impacts on marine biodiversity, ecosystem functioning, and ecosystem-service provision (Walther et al., 2002; Lotze et al., 2006; Ruckelshaus et al., 2013).

The effects of climate change are now being seen in all Europe's seas (e.g. Conversi et al., 2010), although the extent to which impacts have been documented varies among the seas. Climate change is expected to have different effects on different European regional seas in the future.

Increasing sea temperatures

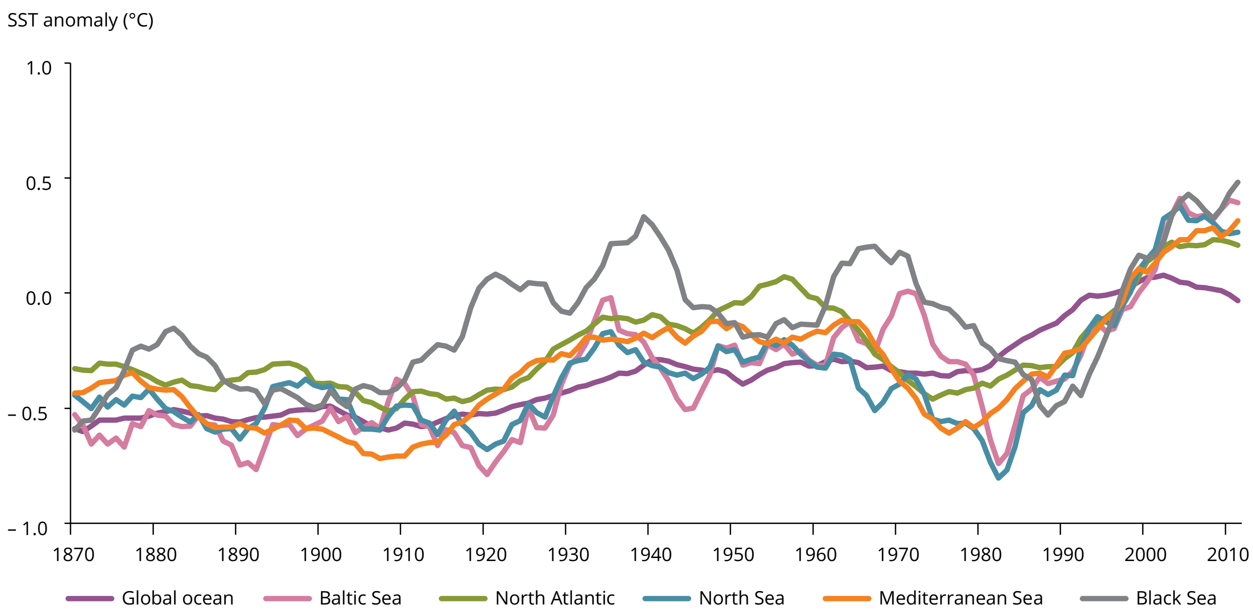
Ocean warming dominates the increase in energy stored in the climate system accounting for more than 90% of the energy accumulated between 1971 and 2010, causing a 0.88 °C rise in global sea surface temperature over the past hundred years (IPCC, 2013). The rate of increase in sea surface temperature in all Europe's seas during the past 25 years is the largest ever measured in any assemblage of regional seas in any previous 25-year period. It has been about 10 times faster than the average rate of increase in Europe's seas during the past century and beyond (EEA, 2012a; Figure 4.12).

Marine organisms respond to changes in temperature because their life cycles are adapted to a certain temperature range. When temperature changes, organisms either move, die, or adapt to living under sub-optimal conditions. In the sea, these adjustments are happening much faster than on land, but they differ from species to species.

In Europe's seas with an increased surface temperature, there is a tendency for species to move northward, e.g. grey triggerfish and the pipefish. A similar expansion northward can be seen in warmer-water plankton (*Calanus helgolandicus*) in the North-east Atlantic Ocean. There has also been a northward retreat of colder-water plankton (*Calanus finmarchicus*).

Such behavioural responses cascade through the marine ecosystem, altering bio-geochemical

Figure 4.12 Annual average sea surface temperature anomaly in different European seas, 1871–2011



pathways and food-webs. This in turn changes overall production of marine ecosystems. For example, *C. helgolandicus* has lower nutritional value than C. *finmarchicu* (Reid et al., 2010), which means that changes in the distribution of these species have consequences for both marine life and for humans. For this reason, changes to primary production are expected in Europe's seas, with southern regions in the North-east Atlantic Ocean becoming up to 10% more productive and northern regions up to 20% less productive.

This has clear implications for fisheries (MCCIP, 2013). One recent example of the effects of climate change on fisheries came as a result of the northward movement of mackerel stocks. This shift in mackerel stocks led to a debate between the EU, the Faroe Islands, Norway, and Iceland on the distribution of the quota available for mackerel. This shows that what seem to be minor changes in distribution can create serious political challenges, which are of great importance for local communities.

Ocean acidification

When atmospheric carbon dioxide is absorbed by the ocean, it reacts with water to produce carbonic acid, causing ocean acidification. In recent decades, ocean acidification has been occurring a hundred times faster than during previous natural events over the last 55 million years (EEA, 2012a). Surface-ocean pH has declined from 8.2 to 8.1 over the industrial era due to the growth in atmospheric CO_2 concentrations (Figure 4.13; EEA, 2012; IPCC, 2013). This decline corresponds to a 26% change in oceanic acidity (EEA, 2012a; CBD, 2014).

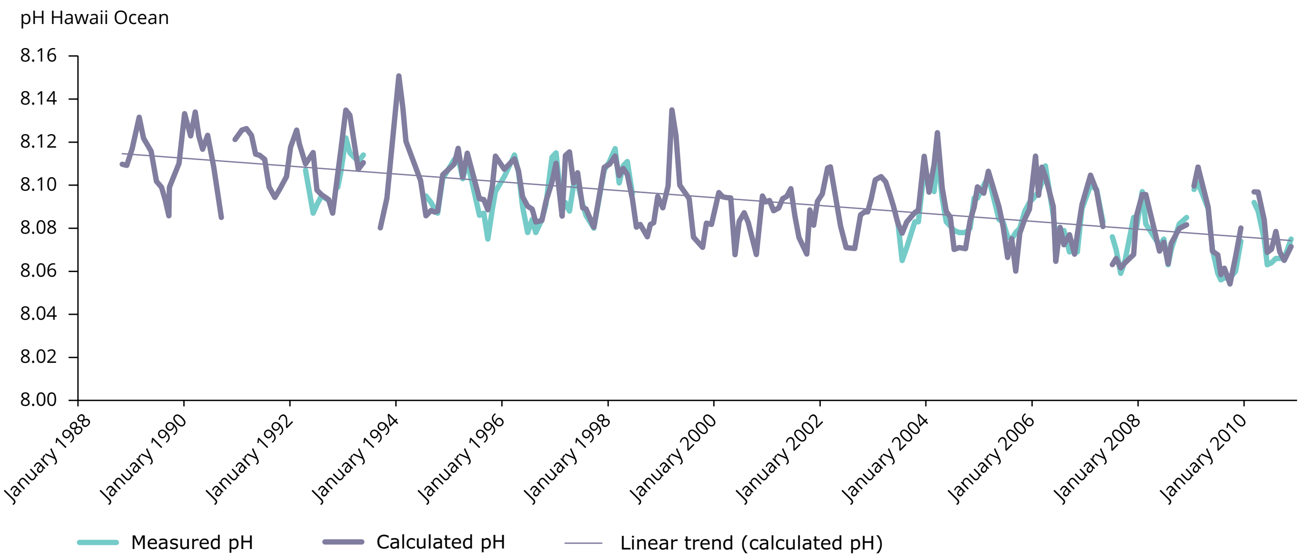
Acidification is bad for marine ecosystems because acidified water has lower concentrations of carbonate ions. Corals, mussels, oysters, and other marine calcifiers have difficulties constructing their calcareous shell or skeletal material when the concentration of carbonate ions in water decreases. Of equal importance is the effect of acidification on primary producers (such as phytoplankton) as it changes the bioavailability of essential nutrients, such as iron and zinc. Primary producers are responsible for a significant part of global carbon fixation (Reid et al., 2009) (Box 2.2). Plankton forms the basis of marine food webs, underpinning food security for millions of people worldwide (for more on the effects of climate change on marine species, see Box 4.10).

Today, the ocean absorbs approximately 25% of all the CO_2 that humans emit each year. Average surface-water pH is projected to decline further to values between 8.05 and 7.75 by 2100 (the precise level depends on future CO_2 emissions). The largest projected decline would represent more than a 100% increase in acidity compared to today's levels. This would very likely cause severe damage to marine ecosystems.

Climate change exacerbates other pressures on our seas

The impacts of climate change are not restricted to individual species. By influencing a multitude of physical properties of the oceans, climate change can cause abrupt changes across whole ecological systems. Such abrupt changes are called regime shifts, and lead to new regime conditions. These new conditions often cannot provide the same services and benefits to humans that they enjoyed under the previous ecological regime. The new conditions can last for

Figure 4.13 Decline in pH measured at the Aloha station as part of the Hawaii Ocean time-series



Box 4.10 Observed impacts of climate change on marine biodiversity in Europe's seas

Increases in regional sea temperatures have triggered a major northward expansion of warmer-water plankton in the North East Atlantic. They have also triggered a northward retreat of colder-water plankton. This northerly movement is about 10° latitude (1 100 km) over the past 40 years, and it seems to have accelerated since 2000 (EEA, 2012a).

- Sub-tropical species are occurring with increasing frequency in European waters, and sub-Arctic species are receding northwards (EEA, 2012a).
- There is increasing evidence that the overwintering distributions of many waterbirds have changed. In recent decades, in response to warming, their distributions have shifted north and eastwards out of the United Kingdom (MCCIP, 2013).
- Some plankton species have advanced their seasonal cycle by 4–6 weeks in recent decades (EEA, 2012a).
- Increasing sea temperature is affecting the spawning behaviour of fish. For example, mackerel and horse mackerel are spawning earlier in the English Channel, and both earlier and further north on the Porcupine Bank (off the west coast of Ireland) (MCCIP, 2013).
- The timing of spawning in sole (in the Irish Sea, east-central North Sea, southern North Sea, and eastern English Channel) has shifted to earlier in the year, at a rate of 1.5 weeks per decade since 1970, in response to increasing sea-surface temperatures (MCCIP, 2013).
- International commercial landings from the North-east Atlantic Ocean of species identified as 'warm-adapted' (e.g. grey gurnard, red mullet, and hake) have increased by 250% in the last 30 years while landings of cold-adapted species (e.g. cod, haddock, whiting) have halved (MCCIP, 2013).
- Long-term changes in the phytoplankton communities in the northern Baltic and Gulf of Finland have occurred over the past 30 years. This can be seen in a decline in the spring bloom, but an increase in the phytoplankton biomass during summer in this period. These changes appear to reflect both climate-induced changes and the eutrophication process.

decades. In some cases, there may be no return to a previous state (Conversi et al., 2010).

In the 1980s, the Mediterranean Sea underwent a major climate-induced change, which encompassed atmospheric, hydrological, and ecological systems. It appears that this event in the Mediterranean was linked to similar ecological shifts in the North Sea, Baltic Sea and Black Sea, indicating that local hydrography is linked to large-scale changes in the northern hemisphere (Conversi et al., 2010). Between 1988 and 1990, a climate change-induced shift was also observed in Europe's third largest lake, Lake Peipsi. This shift caused long-term changes to the fish community in the lake (Kangur et al., 2007).

Climate change-induced regime shifts thus affect all trophic levels of the food-web and their associated bio-geochemical cycles. As a result, the overall resilience of ecosystems decreases, making marine ecosystems even more vulnerable to other high-intensity ecological stressors. Such high-intensity stressors include the individual and cumulative impacts from human activities (e.g. overexploitation, pollution, and non-indigenous species).

These stressors are already causing large-scale impacts across Europe's seas. For example,

Photo: Loggerhead turtle (*Caretta caretta*).

Source: © N. Fayos — ALNITAK

non-indigenous species are a major concern in the Mediterranean Sea, due to a high influx of new species, most of which come to the Mediterranean through the Suez Canal (Occhipinti-Ambrogi et al., 2010). In the Black Sea, non-indigenous species and pressures from fisheries have caused a well-documented regime shift, which saw a collapse in fish stocks (Möllmann et al., 2011). In the Baltic Sea, hypoxic areas have expanded from 5 000 km^2 in roughly the year 1900 to cover an estimated area of 60 000 km^2 in 2012. Despite significant efforts to reduce nutrient input to the Baltic Sea, hypoxic areas could still expand due to temperature increases. Even a 1° C temperature increase will raise oxygen demand and potentially further expand the hypoxic area. This means that in order to counteract the effects from increased sea temperatures, further nutrient reductions (beyond those already planned) will be necessary (Carstensen et al., 2014).

It should be noted that the interactive effects and relative importance of multiple pressures on the physiology, life history, and ecology of species are increasingly complex and remain poorly understood (Godbold and Calosi, 2013).

Perhaps the most worrying prospect presented by climate change is that elevated atmospheric CO_2 concentrations (and the related increased surface temperature and acidification) are directly associated with the five mass extinction events that have occurred over the last 540 million years. The elevated CO_2 concentrations we are now experiencing are thus particularly dangerous, especially when they occur alongside other high-intensity ecological stressors (Barnosky et al., 2012; Box 4.11). This raises concerns that we may now be on the brink of another mass extinction event. Thus, the challenge of halting the loss of biodiversity is deeply intertwined with climate change mitigation, and with the urgent need to reduce the cumulative impact of human activities on the seas.

Box 4.11 Climate change is inexorably intertwined with the loss of biodiversity

Biological diversity is driven by evolutionary processes that cause new species to evolve while others become extinct. It has been estimated that approximately 4 billion species have evolved on Earth over the last 3.5 billion years, of which 99% are now extinct (Novacek, 2001). The extinction rate has normally been balanced by 'speciation' (the emergence of new species), although on five occasions over the last 540 million years 'mass extinctions' (the so-called 'Big Five') have occurred. Mass extinctions are conservatively defined as periods when extinction rates increase dramatically, leading to a loss of over 75% of estimated species (Raup and Sepkoski, 1982).

Scientists are now recognising an acceleration in the rate of terrestrial and aquatic extinctions of species (Pereira et al., 2010; IUCN, 2008) and populations (Ceballos and Ehrlich, 2002). Although these recent losses are serious, they do not yet qualify as a mass extinction event equal to the Big Five (Barnosky et al., 2012). However, even the loss of a few species from mature ecosystems can lead to decreases in biomass production and in the long-term sustainability of ecosystem functioning (Reich et al., 2012). Evidence also shows that extinctions are altering key processes important to the productivity of ecosystems. It also indicates that the ecosystem consequences of species loss are as quantitatively significant as the direct effects of several global change stressors (Jackson et al., 2001a; Hooper et al., 2012). This means that the rate of extinction could be accelerating with each loss of a species, but it also means that action can be taken locally to remediate species loss and population loss in order to secure ecosystem functioning.

It is notable that the occurrence of multiple high-intensity stressors is a common feature for all the Big Five extinctions. These stressors included increased global warming, ocean acidification, and increased hypoxia. This suggests that there are synergetic effects between climate dynamics, atmospheric composition, and abnormally high-intensity ecological stressors. When taken together these synergetic effects damage biodiversity (Erwin, 2008; Veron, 2008; Barnosky et al., 2011). Other examples of high-intensity stressors could include a super volcano, a meteorite strike, or the cumulative impacts from human activities. Scientists now fear that the additional loss of currently endangered species could spin the world into a new mass extinction event within a few generations. The recovery time from such an event is between hundreds of thousands of years and millions of years (Barnosky et al., 2011).

4.10 Are our seas clean and undisturbed?

A multitude of pressures affect our seas

It is clear that Europe's seas are under pressure from a range of human activities. The impacts of these activities can be local or widespread. Physical loss and damage to the seafloor is occurring in all Europe's seas. The extent of this loss and damage differs depending on the region, activity, and affected benthic communities. However, seabed habitats can take as long as 15 years to recover after the initial disturbance.

Due to its widespread nature, fishing is the main activity causing seafloor disturbance. Today, most of the EU fleet is still geared towards bottom-trawling and expanding into the deep sea. This puts at risk vulnerable and poorly assessed ecosystems. Nevertheless, there has been a slight shift since 2004 towards gear that has less impact on the seabed. The extraction of fish and shellfish has also been decreasing. Since 2007, there has been a reduction in fishing pressure in fish stocks in the North-east Atlantic Ocean and Baltic Seas. Consequently, an increasing number of stocks are fished at or above levels which can produce their Maximum Sustainable Yield in these regions. The situation in the Mediterranean and Black Seas remains dire, with most of the assessed stocks overfished. Also of concern are the levels of by-catch and discards from fishing, which can reach levels of more than 50% of the catch of certain fisheries. This induces additional mortality, and often affects vulnerable species that cannot quickly recover (such as sharks, rays, seabirds, and other large animals).

The increase in trade and tourism brought about by globalisation has generated a surge of introductions of non-indigenous species to Europe's seas since the 1950s. Shipping is the main pathway of introduction in the EU, but in the Mediterranean the Suez Canal is an open doorway for Red Sea species. Many of these species have spread and caused profound changes to native biodiversity and the affected ecosystems.

Pressures on the marine environment also come from the land. New contaminants and nutrients continue to enter the marine environment via rivers or atmospheric deposition (although there have been load reductions of both contaminants and nutrients in certain areas). This is particularly evident in the Baltic Sea, where eutrophication continues to be a major issue, in spite of long-standing management efforts to address it. Marine litter is an emergent form of pollution, mostly coming from land, although in certain areas (such as the North-east Atlantic Ocean) sea-based activities are an equally important contributor. Marine litter is increasingly widespread, and ranges from the shores to the water column, and to the deepest parts of the seas. Worldwide encounters between marine wildlife and litter have almost doubled since 1997, and many have led to injury or death. Plastic is the main material found in all Europe's seas. As it breaks down into ever-smaller pieces, it can become ingested by wildlife.

Other marine pressures have also only recently emerged, and their impacts remain poorly understood. These include underwater noise, and other forms of energy input such as electromagnetic fields created by telecommunications cables. However the knowledge base of underwater noise and its ecological impacts is expanding.

Marine pressures, and pollution in particular, also raise concerns for human health although the effects of pollution on human health are mostly poorly understood. Some of the contaminants reaching the seas are endocrine disruptors and carcinogens, but their impacts are largely unassessed. Eutrophication can also trigger toxic algal blooms in coastal areas, affecting bathing water quality and aquaculture production. Micro-plastic ingestion by wildlife can lead to the uptake in the food-web of its potential toxicity, and may end up in our plates in fish or shellfish.

Overall, Europe's seas paint a picture of multiple pressures and widespread impacts, affecting several components of the ecosystem including humans. However, it is important not to focus solely on individual pressures, as these may mask the effects of the interaction between these pressures on overall ecosystem integrity. In addition, the effects of climate change are now being seen in all Europe's seas. The increase in concentrations of atmospheric carbon dioxide (CO_2) by 40% since pre-industrial times is raising the water temperature and ocean acidification. These physical changes can lead to additional physical changes (e.g. ocean circulation patterns) and substantial impacts on marine biodiversity. These disturbances further affect ecosystem functioning and ecosystem-service provision.

The cumulative effect of pressures and impacts are driving ecosystem change

Although the marine environment is increasingly threatened by a multitude of pressures and impacts, little is still known about the cumulative effects of these pressures and impacts on marine species, communities, and ecosystems. However, evidence of the synergistic effects of human impacts is growing, and shows that these effects can push ecosystems to altered states (Jackson, 2008). Therefore, it is critical to monitor the condition of ecosystems and manage them as a whole. This is the goal of the holistic approach called ecosystem-based management (EBM). Ecosystem-based management seeks to overcome the shortcomings of traditional management approaches, which are conducted by using a range of indicators mostly focusing on the parts of the ecosystem (e.g. different species or habitats, physical parameters like water temperature). These ecosystem components, although necessary, do not provide for a full understanding of ecosystem condition. Ecosystem condition also requires an understanding that considers the relationships between its components.

As our knowledge base of the complexity of ecosystem structure, processes and functioning evolves, so does our capacity to better manage the human interactions to it. Over the last few years, pragmatic management solutions have thus emerged that indicate that it might be possible to move from these individual indicators towards more holistic approaches for measuring human impact on marine ecosystems. These holistic approaches make ecosystem-based management possible. One example of a holistic approach to support ecosystem-based management can be seen in the first attempt to create a global 'map' of human impact on marine ecosystems. This map has shown that today no area in the global ocean is unaffected by human influence, and a large proportion of the ocean (41%) is affected by multiple pressures (Halpern et al., 2008b).

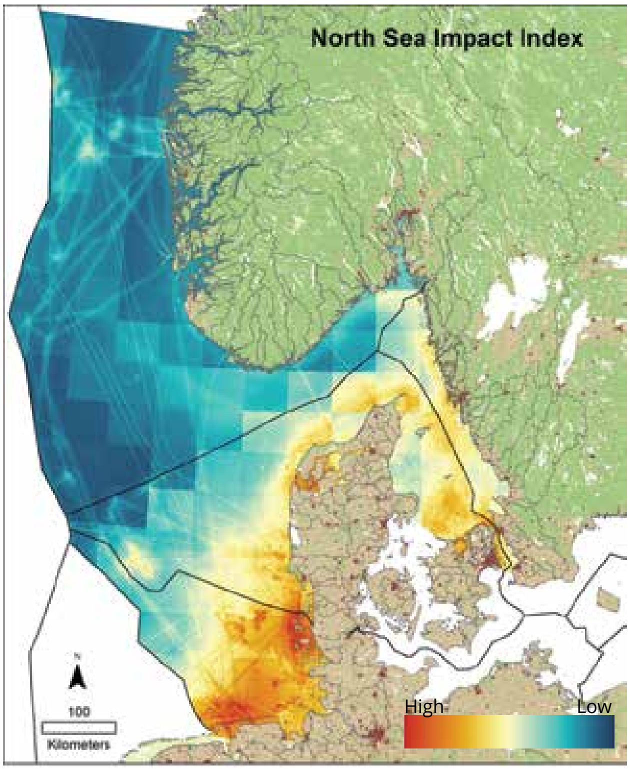
This map approach to measuring human impact on marine ecosystems has also been tested in Europe, showing the relative distribution of impact in regional seas (comparing the sensitivity of ecological feature with the level of pressures presented in a spatial context). For example, HELCOM, the Regional Sea Convention in the Baltic Sea, has shown that it is possible to make a spatial description of the relative impacts on a regional scale. In its work, HELCOM managed to combine ecosystem features with pressures resulting from human activities in a spatial analysis (HELCOM, 2010). Researchers have also refined this technique for studying the eastern North Sea (Figure 4.14; Andersen and Stock, 2013). Similarly, a Mapping analysis performed in the Mediterranean and Black Seas shows that 20% of both regions and 60–99% of the territorial waters of EU Member States in these regions are subject to high impact from human activities, while less than 20% are classed as low impact. Very few areas — less than 1% — remain relatively unaffected by human activities (Micheli, Levin, et al., 2013).

Furthermore, recent research documents a correlation between the status of biodiversity (indicator-based analysis) and the amount of cumulative pressures and impacts occurring in a certain area (Andersen et al., 2015).

In conclusion, the evidence presented in this chapter shows that the patterns of change occurring in Europe's seas are not indicative of clean and undisturbed seas. It also shows that pressures and impacts need to be assessed not only individually, but also with regard to the cumulative effects they have on the ecosystem. As ecosystem-based management evolves, the management tools available to it will improve. These tools will ultimately allow for testing different scenarios of the effect of potential management measures upon the environmental status of a marine region.

However, if these tools are to be effective, it is still important to answer two questions: what are the activities causing these pressures and impacts? And how large is their individual contribution to the current pattern of change? These questions will be explored in the next chapter.

Figure 4.14 Cumulative environmental impacts in the eastern North Sea



Note: Colour grading shows impact magnitude.

Source: From Andersen and Stock, 2013.

5 Productive seas

Key messages on productive seas

- The EU maritime economy is a thriving economic engine and job creator.
- Maritime activities and exploitation of marine resources continue to increase, and are likely to do so in the future.
- Maritime activities provide socioeconomic benefits by making use of natural capital. While these activities increase human well-being, they also put pressure on marine ecosystems. This pressure directly affects natural capital.
- Continued loss of natural capital poses a significant risk to marine resources and the activities and communities that depend on them.
- Adequate planning and management are needed to ensure the health of the seas and to maximise the sustainable socio-economic benefits they provide. This include the full integration and implementation of EU policies.

5.1 Introduction

This chapter focuses on the human activities that most affect the marine and coastal environment. It seeks to understand if our seas can be considered productive. For the purpose of this chapter, 'productive' is understood as producing (or able to contribute to the production of) the goods and services that are needed to run our socio-economic systems within the ecological limits of our seas (Figure I.1). This definition therefore includes elements of sustainability, such as avoiding pollution and conserving resources. The chapter concludes that Europe's seas are very productive at present, but warns that current and future pressures are threatening this productivity.

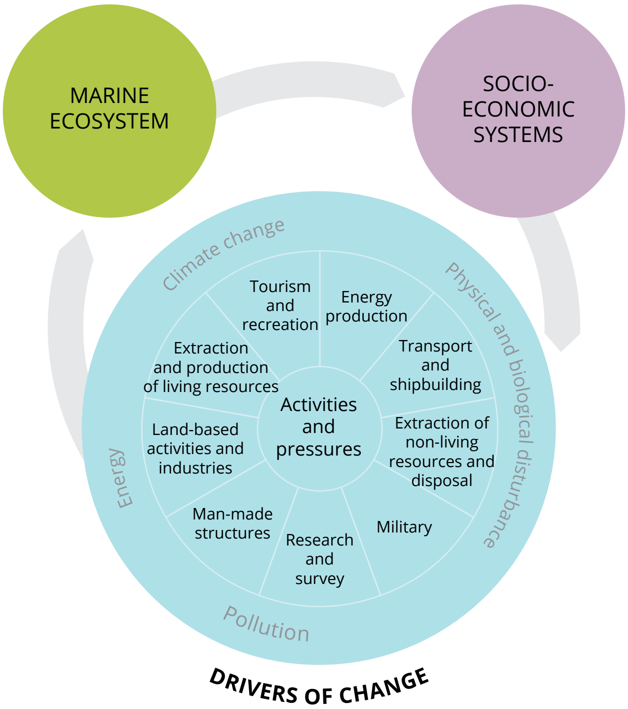
The chapter covers ten activities: land-based activities/industries (Section 5.2); extraction of living resources (Section 5.3); production of living resources (Section 5.4); extraction of non-living resources and disposal (Section 5.5); transport and shipbuilding (Section 5.6); tourism and recreation (Section 5.7); man-made structures (Section 5.8); energy production — offshore renewables, and oil and gas (Section 5.9 and 5.10); research and surveys (Section 5.11); and military (Section 5.12) (Table 5.1).

For each of the activities, a socioeconomic presentation (e.g. Gross Value Added and employment) is provided where data is available to give an indication of the relative size of the activity. Trends in each of the activities are also given in order to indicate the likely future use of marine resources. The pressures that each activity places on the sea's natural capital (Figure 5.1) are also described, and case studies are used to provide examples that are more detailed. This information is then used to tentatively assess whether Europe's seas can be considered productive today, and where they might be in the future (Section 5.13).

By taking this approach, this chapter makes the connection between the state of biodiversity in Europe's seas presented in Chapter 3, and the pressures leading to biodiversity/ecoystem changes presented in Chapter 4. This chapter also forms a bridge to the integrated understanding of how meeting people's basic needs, and supporting our well-being and livelihoods (and the economy more broadly) depends on the condition of marine ecosystems as this determines the sea's potential to generate marine ecosystem services (presented in Chapter 7).

The data upon which this chapter is based comes from a variety of different sources in order to form a European assessment. A very small portion of the data for this chapter comes from the Initial Assessments of EU Member States, which were produced in 2012 as a requirement of the Marine Strategy Framework Directive (MSFD). The Initial Assessments provided information on activities that use marine resources, the dependency of these activities on natural capital, and the potential costs associated with environmental degradation.

Figure 5.1 Linking human activities: from indirect drivers to direct drivers to direct pressures



Note: See also Figure I.1.

Human activities and European seas: the need for sustainability

European societies depend on seas and coasts to provide food, building materials, opportunities for transport, energy, and recreational benefits. These resources support the livelihoods of all Europeans, sustaining life, providing jobs, and contributing to the economy.

Maritime activities are expected to play a large role in sustaining economic growth in the future, as part of the 'Europe 2020' strategy for a smart, sustainable, and inclusive economy (EC, 2010b). This potential has been promoted by the EU's current 'Blue Growth' strategy, which is a long-term strategy to support sustainable growth in the marine and maritime sectors (EC, 2014a).

Maritime activities today contribute significantly to the European economy, accounting for about EUR 467 billion in Gross Value Added (GVA) and 6.1 million jobs (Table 5.1) ([12]). At the same time, activities that exploit marine resources affect the sea's natural capital through a range of pressures that affect the marine environment (Table 5.1; see Section 6.13 for further discussion).

The sustainable growth envisioned by the EU therefore requires a reconsideration of our current models of development. Sustainability in the 21st century will require us to reconcile increasing resource demand and economic growth on the one hand with ecosystem resilience and human well-being on the other. This new and sustainable model will enable Europeans to live within the finite resources of our ecosystems, supported by a resource-efficient, green, and competitive low-carbon economy (Box 5.1). By not moving towards this new model of development (in which the maritime sector plays a key role) Europe runs the risk of failing to meet its sustainability targets (EEA, 2014b).

The current model for economic development is shaped by a number of different drivers. These include demographic drivers (e.g. urbanisation and population growth); economic drivers (e.g. consumption, production, and globalisation); socio-political drivers; cultural and religious drivers; scientific drivers; and technological drivers (Nelson et al., 2006). These drivers all have an effect on the marine environment (Table 5.1). Thus humans are connected to the marine environment through a complex web of interactions as they seek to satisfy their basic need, increase our well-being, have jobs and run their economy.

Box 5.1 Green economy

The green economy is one in which environmental, economic, and social policies and innovations enable society to use resources efficiently, thereby enhancing human well-being in an inclusive manner, while maintaining the natural systems that sustain us. At its core is the twin challenge of improving resource efficiency whilst ensuring that our ecosystems are resilient and can deliver the many ecosystem services we rely on. Such an economy marks a shift away from the 'business-as-usual' economic paradigm to an economic system that can enhance social equity and fair burden sharing, in terms of both financial and environmental costs and benefits (EEA, 2013c).

([12]) Uncertainties are related to estimations of GVA and jobs added.

Table 5.1 European coastal and maritime activities; their estimated economic value (GVA); number of people employed; expected future trends; current dependency on natural capital; and current impacts on natural capital (years vary)

Human activities		GVA (million EUR) or turnover (TO)	Employment	Expected trend	Dependency on marine natural capital and/or marine space		Pressure on marine natural capital	
				Abiotic	Abiotic	Biotic	Abiotic	Biotic
1: Land-based activities/ industries	Industry (discharges and emissions)	6 142 000 (1)	133 200 000 (2)	-	√			X
	Agricultural and forestry (run-off and emissions)	176 289 (3)	11 935 000 (4)	-				
	Municipal waste water (discharges)	72 000 (TO) (5)	600 000 (6)	-				
2: Extraction of living resources	Fisheries incl. recreational fishing (fish and shellfish)	3 400 (7)	127 686 (8)	↘	√	√		X
	Seaweed and other sea-based food harvesting (bird eggs, shellfish, etc.)	-	-	-				
	Extraction of genetic resources/ bio-prospecting/maerl (blue technology)	-	-	↗				
3: Production of living resources	Aquaculture (fin fish and shellfish)	1 500 (9)	80 000 (10)	→	√	√		X
	Marine aquatic products (e.g. growing algae)	-		↗				
4: Extraction of non-living resources and disposal	Marine mineral and aggregates mining (sand and gravel, rock)	625 (11)	4 800 (12)	↗	√		X	X
	Dredging	558 (13)	25 000 (14)	↗				
	Desalination/water abstraction	700 (15)	7 000 (16)	↗				
	Extraction of salt	-	7 325 (17)	↗				
	Solid waste disposal incl. dredge material	-	-	↗				
	Storage of gases (carbon capture and storage)	-	-	-				
5: Transport and shipbuilding	Freight shipping (d = deep-sea shipping, s = short-sea shipping)	98 000 (d) + 57 000 (s) (18)	1 204 000 (d) + 707 000 (s) (19)	→	√			X
	Passenger ferry services	20 000 (20)	200 000–300 000 (21)	↘				
	Shipbuilding and ship repair	30 000 (TO) (22)	500 000 (23)	↗				
6: Tourism and recreation	Marine and coastal tourism	130 000 (24)	2 507 000 (25)	↗	√	√		X
	Recreational activities (e.g. bathing)	-	-	↗				
	Yachting and marinas	38 000 (26)	371 900 (27)	↗				
	Cruise tourism	15 000 (28)	303 000 (29)	↗				
7: Man-made structures (incl. construction phase)	Land claim, coastal defence, flood protection, saltwater protection	1 000–5 000 (TO) (30)	-	↗	√		X	X
	Port operations	-	1 500 000 (FTE) (31)	→				
	Placement and operation of offshore structures (other than for energy production)	-	-	↗				
	Submarine cable and pipeline operations	185 (32)	-	-				
	Protection of habitats (man-made structures)	-	-	-				

Table 5.1 European coastal and maritime activities; their estimated economic value (GVA); number of people employed; expected future trends; current dependency on natural capital; and current impacts on natural capital (years vary) (cont.)

Human activities		GVA (million EUR) or turnover (TO)	Employment	Expected trend	Dependency on marine natural capital and/or marine space		Pressure on marine natural capital	
				Abiotic	Abiotic	Biotic	Abiotic	Biotic
8: Energy production	Marine-based renewable energy generation (wind, wave and tidal power)	2 400 (wind) + 250 (wave/tidal) (33)	35 000 (FTE) (wind) + 100 (FTE) (wave/tidal) (34)	↗	√		X	X
	Marine hydrocarbon (oil and gas) extraction	100 000–135 000 (35)	25 000– 50 000 (35)	↘				
9: Research and surveys	Marine research	-	-	↗	√	√		X
	Survey and monitoring	-	-	↗				
10: Military	Defence operations	-	-	-	√			X
	Dumping of unwanted munitions	-	-	↘				

Note: √ means that the activity depends upon natural capital; X means the activity adds pressure upon the natural capital.

Total GVA from maritime activities is estimated to be EUR 467 billion: this is the sum of activities in Table 6.1, excluding category 1 (Land based activities/industries) and excluding those categories reported in turnover. Lower estimates were used when a range for GVA was provided. Total employment from maritime activities is estimated to be 6.1 million: this is the sum of activities in Table 6.1, excluding category 1 (Land based activities/industries) and excluding those categories reported in Full Time Equivalents (FTE).

Lower estimates were used when a range for employment was provided. Corresponding data sources are provided in the table. Estimates from the Blue Growth Study indicate GVA to be EUR 485 billion and employment to be 5.4 million (Ecorys, 2012).

Trends are a best estimate based on available sources and expert opinion. Also, note that many indirect or ancillary activities (such as processing of marine resources or manufacturing and supply of equipment) may not be included here.

Source: (1)–(2) Eurostat, 2013d;

(3) EC, 2012a; Eurostat, 2012b;

(4) EC, 2012a;

(5)–(6) EUREAU, 2009;

(7)–(8) Scientific, Technical and Economic Committee for Fisheries (STECF), 2013b;

(9)–(10) Scientific, Technical and Economic Committee for Fisheries (STECF), 2013a;

(11)–(12) Ecorys et al., 2012;

(13) Policy Research Corporation, 2011;

(14) EUDA, 2009;

(15)–(16) Ecorys et al., 2012;

(17) EU Salt, 2007;

(18)–(21) Ecorys et al., 2012;

(22)–(23) CESA, 2013;

(24)–(29) Ecorys et al., 2013;

(30) Ecorys et al., 2012;

(31) ESPO, 2013;

(32) Douglas-Westwood Limited, 2005;

(33)–(36) Ecorys et al., 2012.

5.2 Land-based activities

Messages on land-based activities

- The environmental impacts of European industry and agriculture have decreased in recent decades. These improvements are due to stricter environmental regulation, gains in efficiency, and a move away from certain heavy pollutants. In spite of these improvements, industry is still responsible for a significant burden of pollution on the environment.
- Land-based activities and industries affect the marine environment in two ways: through local pressures (i.e. when they are in close proximity to marine and coastal areas), and through more indirect, distant pressures, such as fertiliser run-off from inland farms that ends up in European marine waters.

Where land meets sea

Land-based activities create direct pressures on the marine environment. These direct pressures can be separated into three broad categories: industrial charges and emissions; agricultural and forestry run-off and emissions; and municipal wastewater discharge. This section therefore provides a description of the land-based activities that significantly contribute to these pressures in an effort to characterise their relative size compared to other direct activities (described in the following sections).

In Europe, there are about 21.7 million enterprises ([13]). In 2011, these enterprises accounted for about EUR 6 142 billion GVA and employed about 133.2 million persons in the non-financial business. Pollutants emitted into the air from industry, as well as from transport and power generation, have greatly reduced since the 1970s in Europe (EEA, 2013a). This is partly because manufacturing has shifted to countries outside the EU, such as China. Generally, water pollution from 'point' sources (i.e. urban wastewater, industry and fish farms) in Europe has also decreased over the last 30 years (EEA, 2008).

The GVA of the European agricultural sector was EUR 154 billion in 2011 (EC, 2012a). Agricultural activity is often concentrated in coastal regions, although this is not the case for all Member States (Figure 5.2). The EU has about 178 million hectares of forests and other wooded land, which account for approximately 42% of the Union's land area (Eurostat, 2012b). Logging and forestry activities provided about EUR 21 billion GVA at basic prices in 2008. Between 2000 and 2010, wooded areas in the EU increased by about 3.5 million hectares, or 2%, due to natural expansion and afforestation (Eurostat, 2011b). Employment in the agriculture, forestry, hunting, and fishing sectors was about 11.9 million in 2011 (EC, 2012a).

According to EUREAU, the European Federation of National Associations of Water Services (water and wastewater), there are 70 000 water services companies in Europe, and they employ 600 000 people. They have a combined annual turnover of about EUR 72 billion (EUREAU, 2009). About 80% of the population is connected to wastewater treatment plants in northern and southern European countries, while connection rates exceed 90% in Central Europe (EEA, 2013e).

The need to further improve environmental performance

Land-based industries affect the environment through discharges into the water or through atmospheric emissions. The former may lead to contamination by hazardous substances (e.g. synthetic compounds, radio nuclides), by phosphorus, and by nitrogen enrichment. Discharges to water also cause changes in pH, salinity, thermal regime, and water flow rates. Atmospheric emissions cause the introduction of hazardous substances in the marine environment (Koss et al., 2011). Rivers are often important pathways for pressures from land-based activities to reach the sea (Box 5.2).

([13]) An enterprise is the smallest combination of legally recognised units: constituting an organisational unit for producing goods or services; benefiting from a certain degree of autonomy in decision making, especially for the allocation of its current resources.

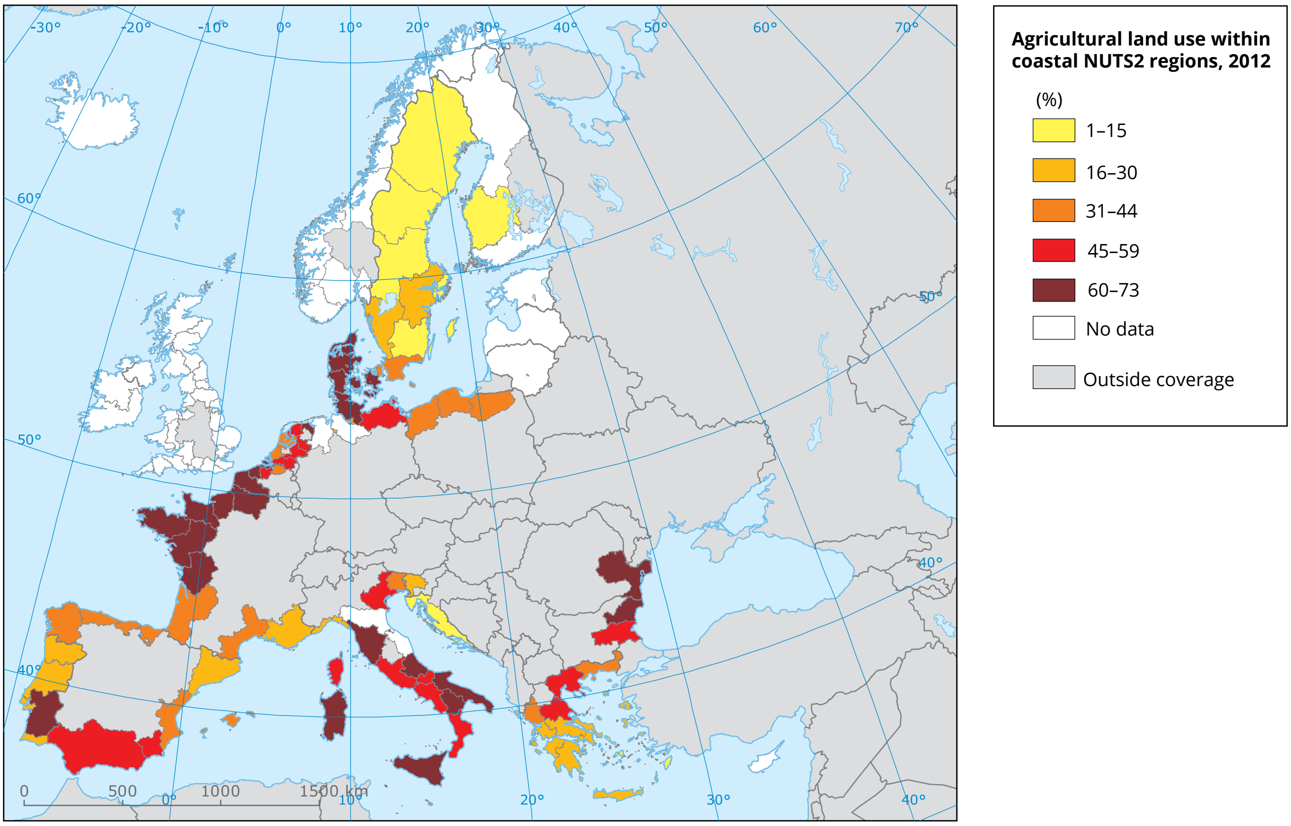
Box 5.2 European rivers: pathways to the sea

Rivers are important pathways for agricultural run-off, waste discharges, and litter to enter European seas. For example, German rivers are a major source of the nitrogen, phosphorous, pesticides, and other agriculture products that enter the Baltic Sea. Germany has around 374 500 farming operations covering about 17 million hectares of land (2007). The German industrial sector discharges about 26 787 million m^3 of wastewater run-off into German water bodies every year. There are about 3 338 wastewater treatment facilities in operation in Germany. The main impact of the German agricultural sector on the Baltic Sea is eutrophication (i.e. algae production and spumes), while the main effects of wastewater run-off are both eutrophication and contaminants, which end up in the marine food web (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), 2012).

Rivers also contribute substantially to bringing marine litter into the sea. A two-year survey (from 2010 to 2012) in the Austrian Danube using stationary driftnets estimated the plastic input via the Danube into the Black Sea to be 4.2 tonnes per day (Lechner et al. 2014). In another study, plastic was also identified as the major type of litter found in the Danube.

Over a three-month period from September to December 2012 at seven localities in the upper Thames estuary, 8 490 submerged plastic items were intercepted in eel fyke nets anchored to the river bed. Next to plastic, 20% of the litter items were components of sanitary products. The most contaminated sites were in the vicinity of sewage treatment works (Moritt et al., 2014).

Figure 5.2 Agricultural land use within coastal NUTS2 regions (%), 2012



Source: Eurostat, 2014a.

5.3 Extraction of living resources

Messages on the extraction of living resources

- Over the past ten years, EU-27 total catches in all fishing regions have been in steady decline. The EU is increasingly dependent on imports of the most widely consumed species: tuna, cod and salmon.
- Extraction of genetic resources from the sea for the purposes of biotechnology is in the early stages of growth. It is expected to increase significantly in the future. The sector is dominated by the United Kingdom.
- There is no universally accepted legal framework to protect and regulate the extraction of marine genetic resources from international waters. Thus there is no mechanism to ensure the sustainable exploitation of these valuable resources.

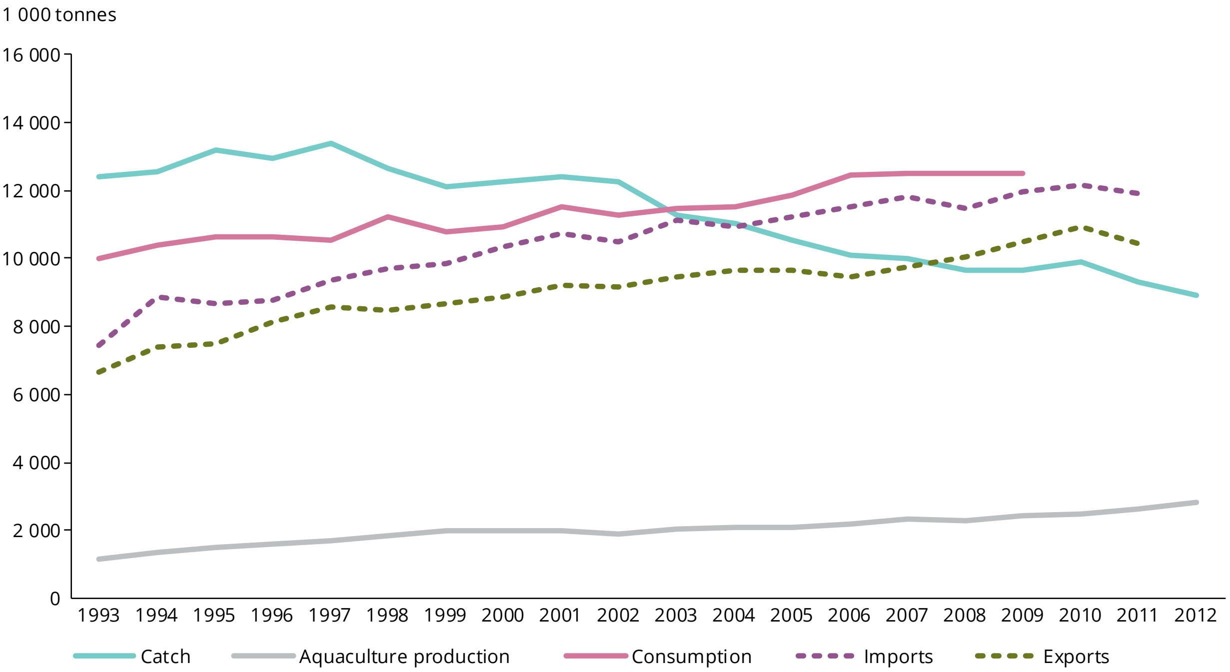
The declining catches of European fisheries

There has been a general decreasing trend in the EU's total fish catch over the past 50 years, and many fish stocks are over-exploited today. The GVA of European fisheries is currently 3.4 billion EUR, and they provide 127 686 jobs (STECF, 2013b). The EU is increasingly dependent on imports for the main species it consumes: tuna, cod and salmon (EUMOFA, 2014). It remains able to produce its needs for flatfish and small pelagic fish (EUMOFA, 2014). Since 1993, Europe's total fish catch has been decreasing, while human consumption of fish products has been steadily increasing. Aquaculture production has also been increasing in this period, as have the import and export of fish (Figure 5.3). EU aquaculture is produced almost entirely for the EU market, while the increase in EU exports has come mostly from wild 'capture' fisheries (EUMOFA, 2014).

Characterising the EU fleet

There are 83 590 fishing vessels registered in the EU fleet (STECF, 2013b). These can be broken down into two broad categories: large and small. In the Baltic, Mediterranean and Black Seas, vessels over 12 m in

Figure 5.3 **Total fish catch, aquaculture production, fish consumption, fish imports, and fish exports for EEA-32 countries and the western Balkans, 1993 to 2012**



Note: Data gaps exist for the following cases: Luxembourg 1993–2012 for total catch; Isle of Man and Luxembourg for 1993–2012 for aquaculture; Isle of Man and Channel Islands for 1993–2011 for imports/exports; Isle of Man and Channel Islands for 1993–2009 for consumption; no consumption data available after 2009; no import data available after 2011; no export data available after 2011.

Source: FAO Fishstat database.

length are classed as large, while all vessels under 12 m are classed as small. In all other regions, the threshold between large and small vessels is set at 15 m.

Small-scale vessels generally have smaller crews, spend less time at sea, and fish in coastal areas closer to land. They also often operate in areas with low employment opportunities (Macfadyen et al., 2011, FAO, 2005). Conversely, large vessels have larger crews, spend more time at sea, and fish in both coastal areas and farther into the high seas (Macfadyen et al., 2011).

Over the period 2004–2011, the capacity (number of vessels in the European fishing fleet (excluding the Black sea) decreased. The rate of decline was larger for large vessels (with annual declines of more than 7%) than for small vessels (which declined by roughly 1% a year) (CSI 034). The number of large vessels is decreasing in all areas, while in some areas it is partly replaced by smaller vessels (Figure 5.4).

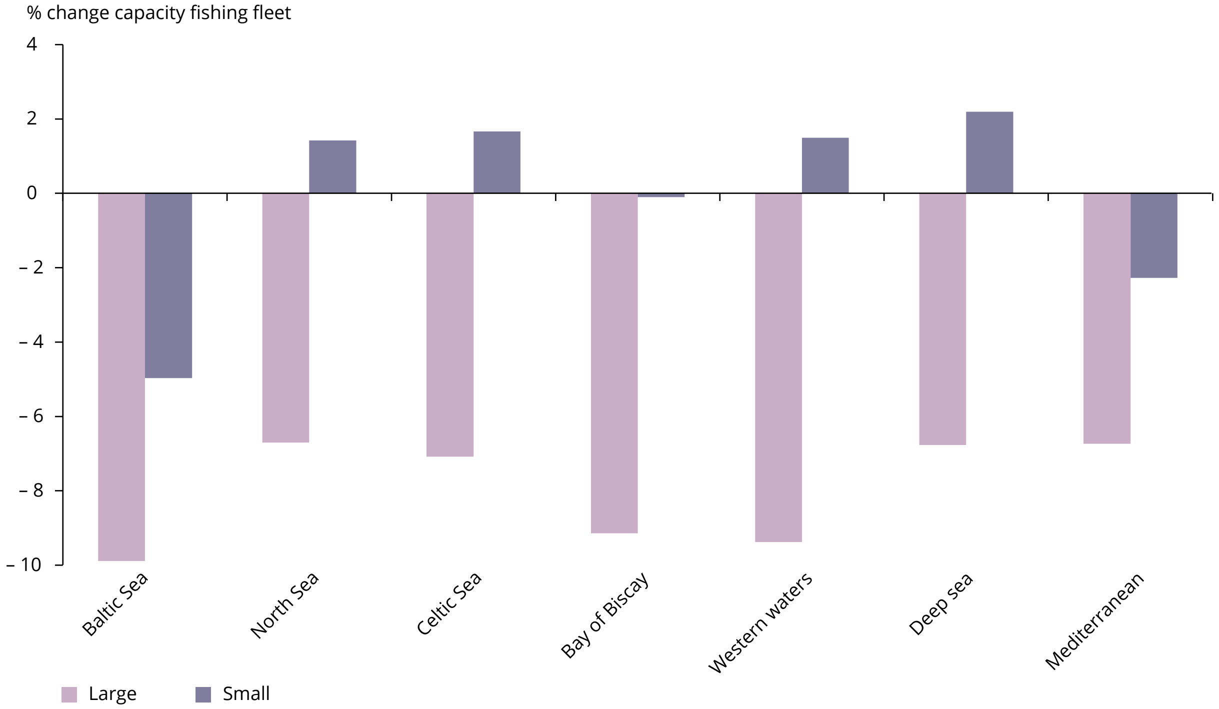
Other living resources

Seaweed is harvested for two main reasons: to produce alginic acids (for human consumption, cosmetics, pharmacology, gelling agents, thickening agents) or for use in agriculture (e.g. fertiliser and animal feed). Mechanical harvesting of seaweed started in the 1970s in order to meet increasing demand for raw materials from the alginate extracting industry. Manual harvesting of seaweed by diving, after coastal storms, or during low tides is also conducted using traditional equipment (such as rakes, pitchforks, knives, etc.) (NETALGAE, 2012b). European production of seaweed has decreased over the last ten years (NETALGAE, 2012a).

In addition to fishing and the collection of seaweed, communities in coastal areas also collect resources such as shellfish, bird eggs, and other products. However, limited information about these activities is available.

Extraction of genetic resources (sometimes called 'blue biotechnology') is in the early stages of development. Its future growth potential is considered extremely high (Ecorys et al., 2012). These organisms are used in a vast number of applications, including food, flavours, fragrances, enzymes, and medicines. The GVA of the industry is around EUR 800 million (Ecorys et al., 2012). The number of marine species being used by humans in this way is growing at an unprecedented

Figure 5.4 Relative change (% per year^{-1}) in the capacity (number of vessels) of large and small vessels of the EU-28 fishing fleet per region (CSI 034)



Note: Based on period 2004–2011.

The Black Sea was excluded as data were limited.

Source: STECF, 2013a.

rate. Over 18 000 natural products and 4 900 patents are associated with genes of marine organisms. The European industry for marine biotechnology is dominated by the United Kingdom. The European industry currently has a growth rate of more than 10% per year (Douglas-Westwood Limited, 2005). Estimates of future annual growth for the global marine biotechnology sector are around 4–5%, although less conservative estimates predict annual growth rates will be between 10% and 12% (Querellou et al., 2010).

The pressures of extraction

The main environmental pressures associated with fisheries are caused by intensive fishing activities, such as trawling. However, the level of impact varies according to the scale of fishing and the local biological characteristics of the sea. The number of fish being caught primarily influences the population size of the target species, but it can also lead to a change in the age-profile of the target species as larger specimens are often targeted by the fishing effort. This may cause a change in the genetic structure of the population. This can impact food-web dynamics, stock resilience, and ultimately the overall stock levels. The by-catch of non-target species (including fish, mammals, sea-turtles, and seabirds) causes unwanted impacts on the population size of these species. Furthermore, the physical impact of trawling and other active fishing gear damages the benthic flora and fauna in the fishing area. The catch of target and non-target species can therefore lead to reduced biodiversity or other changes in marine ecosystems.

Seaweed extraction affects the marine environment through interactions with the seafloor, and habitat removal. This leads to physical damage such as abrasion and smothering of the seafloor habitats, in addition to disturbing the biological equilibrium by selectively removing species. Water flow rates and wave exposure of the coast may also be Adapted through seaweed extraction (Koss et al., 2011).

Bio-prospecting of marine genetic resources only requires the collection of a limited amount of biomass for product discovery or to determine the organism's genetic details. It therefore poses a very limited threat to biodiversity. However, in order to make medicines from marine products, substantial harvesting is needed to run clinical tests of the drug. Given the limited distribution of many organisms, little is known about the potential impact of wild harvests of marine resources (Arrieta et al., 2010).

Moreover, very little is known about the conservation of marine genetic resources. The Red List of Endangered Species of the International Union for Conservation of Nature (IUCN) lists only 36 of the 340 marine eukaryotic species reported as a source of genes in patents.

Marine genetic resources are often accumulated in biodiversity hotspots such as coral reefs and sea mounts. They also accumulate in extreme environments, such as polar ecosystem vents and hydrothermal ecosystem vents. Thus, marine genetic resources are likely to suffer as these environments come under pressure (Arrieta et al., 2010).

Today, there is no universally accepted legal framework to protect and regulate the extraction of marine genetic resources from international waters. In other words, there is no mechanism to ensure the sustainable exploitation of these valuable resources (Arrieta et al., 2010).

Source: © www.freeimages.com/Marc Garrido i Puig

5.4 Production of living resources

Messages for production of living resources

- Aquaculture accounts for a significant portion of seafood supply in the EU. Marine aquaculture production is increasing in Europe, mostly due to salmon production in Norway.
- Fin fish production accounts for most of the increase in European aquaculture production in recent years. Aquaculture production of shellfish has been decreasing since 2004. Since 2007, production of aquatic plants has also been a growing sector.
- Production of marine living resources leads to direct environmental pressures during both the set-up and operational phases.
- The feed used in aquaculture has particularly severe environmental impacts.
- Addressing the wider ecosystem impacts of aquaculture is a critical part of making Europe's food system more resilient.

Production of marine living resources

Marine aquaculture is an important source of seafood in the EU, and algae cultivation is attracting attention as a source of biofuel. Living marine resources are artificially produced in all four marine regions.

In 2011, aquaculture products constituted 24% of the seafood supply in the EU-27, which was a 5% decrease compared to 2010 (EUMOFA, 2014). Imports from outside of the EU-27 make up a significant portion (14%) of consumption, and continue to grow in order to meet demand (EUMOFA, 2014). Volumes of EU-27 farmed products totaled 1.24 million tonnes in 2011, 1% less than in 2010 (EUMOFA, 2014). This is in contrast to global aquaculture production, which grew by 7% in 2011 (FAO, 2014b). This decline in European aquaculture is partly due to environmental concerns (Nunes et al., 2011; Guillen et al., 2012).

The GVA for aquaculture was close to EUR 1.5 billion in the EU-28 in 2011 (STECF, 2013c). Aquaculture generates employment for around 80 000 people (STECF 2013b), but most of these jobs are part-time, resulting in a full time equivalent of approximately 27 000 jobs (STECF, 2013c).

European aquaculture production has been rapidly increasing since the early 1990s (Figure 5.5) due to the expansion of marine production, which has doubled between 1997 and 2012. Most of this increase has come from countries outside the EU-28. For example, there has been a continuous increase in production of finfish outside of the EU-28, driven by marine Atlantic salmon culture in northwest Europe, mostly in Norway. There have also been increases in marine and freshwater rainbow trout culture throughout Western Europe and Turkey. Shellfish aquaculture production has been gradually declining since 2004 in Europe. The major cultivated species in 2012 in Europe were Atlantic salmon, followed by mussels, rainbow trout, European seabass, gilthead seabream, oysters, carps, barbels, and other cyprinids (EEA, 2011a). Within the EU-28, mussels are by far the main species by volume, followed by trout and salmon.

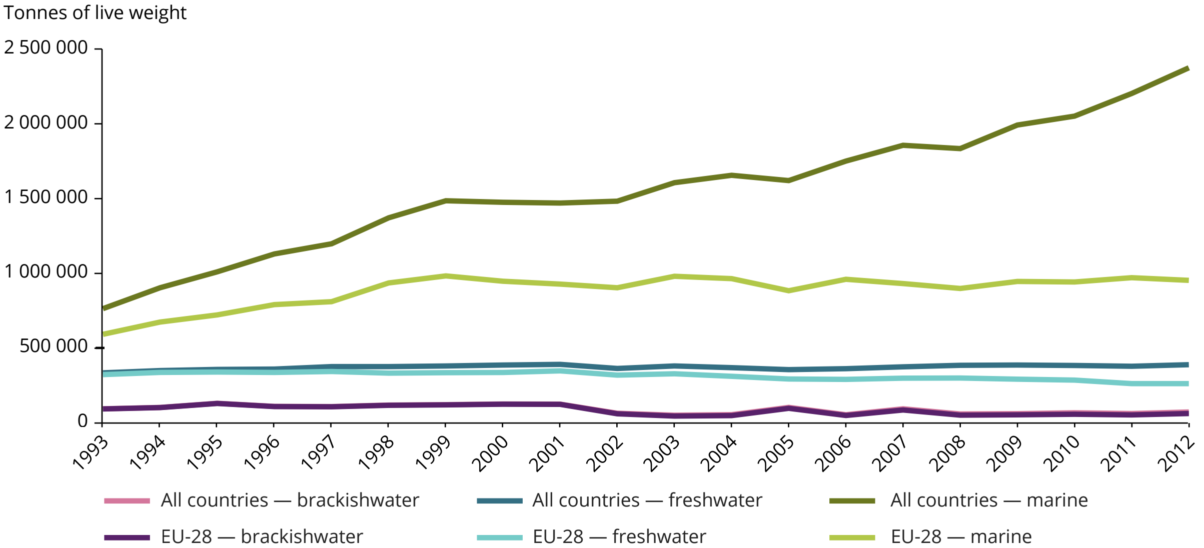
In addition to fish and shellfish being produced in Europe's seas, algae production has become an emerging aquaculture activity, as it is considered 'a potential source of renewable fuel, food and chemicals' (The Parliamentary Office of Science and Technology, 2011). Global aquaculture production of aquatic plants almost doubled from 2001 to 2010 (FAO, 2010). In Europe, the production of aquatic plants has been on the rise since 2007, although to a much lesser extent than fish or shellfish (CSI 033).

The multiple pressures caused by the production of marine living resources

The production of living resources (fish or plants) can put pressure on the marine environment. During both the set-up phase and the operational phase, several activities contribute to physical, chemical, hydrological, and biological disturbances (Koos et al., 2011).

Firstly, aquaculture puts pressure on adjacent water bodies and associated ecosystems, mainly from the release of nutrients and chemicals from aquaculture facilities. Marine aquaculture typically releases more effluents than freshwater aquaculture (Hofherr et al., 2012). The set-up phase for aquaculture of finfish or shellfish influences the environment through litter; the loss of gear such as nets; damage to the seafloor; removal of habitat-structuring species; and trampling of certain species. During the operational phase, the main threat to the marine environment becomes the generation of waste, accompanied by other pressures such as predator control; the presence of artificial infrastructure; disease; and the anchoring and mooring of boats (Koos et al., 2011). A second pressure created by marine aquaculture is the release of organic matter as a by-product. When organic matter such as surplus feed, decomposing fish, or fish excrement is released in the environment it triggers an organic enrichment near the fish cages, and consequently a reduction in dissolved oxygen. The decrease in oxygen availability disrupts the equilibrium of the immediate natural ecosystem. The cultivation of macro-algae is also linked to an input of organic matter in the marine environment (Koos et al., 2011). Thirdly, aquaculture can also introduce non-native species into an ecosystem. These species may be detrimental to the marine environment because of the way they alter habitats, compete with native species, alter the gene pool, and introduce diseases (Johnson et al., n.d.). A fourth environmental pressure caused by aquaculture relates to the source of feed and the use of fertilisers (Naylor et al., 2000). Fed aquaculture, such as finfish, requires fishmeal (FAO, 2014b) and vegetable meals (e.g. soya). Some species, such as carp, also require fish oils. Fishmeal is often made from wild-caught fish stocks already under pressure from fishing and other activities. Fishmeal is also made from fisheries by-products. There are no reliable data for the amount of fishmeal and fish oil used for each species group in Europe. Policymakers must therefore rely on estimates (Hofherr et al., 2012). Reducing dependence on wild fish is a challenge that needs to be addressed if the industry is to develop in a sustainable way and contribute to long-term food security (Troell et al., 2014). It is a challenge that the new Common Fisheries Policy seeks to address by promoting the development of guidelines for sustainable aquaculture (EC, 2013c). Fortunately, encouraging developments are already occurring in sustainable aquaculture. For example, plant-based feeds are being explored (Klinger and Naylor, 2012) (Box 5.3).

Figure 5.5 Annual production of major commercial aquaculture in different environments in Europe, 1993–2012



Note: 'All countries' refer to EU-28 Member States and to non-EU countries that are part of the EEA Eionet network — CSI 033.

Box 5.3 Enhancing plants and algae in order to improve feeds used in aquaculture

There is a widely recognised need to shift away from dependence on animal feed in aquaculture. Traditionally, the industry relies on imported fishmeal from small oily fish caught in the seas of the southern hemisphere. Researchers in the United Kingdom are currently exploring new methods to develop sustainable plant- and algae-derived alternatives to fishmeal through the application of fermentation processes. Improved methods are essential to ensure the long-term sustainability of the aquaculture industry. The process being explored in the United Kingdom builds on existing methods to improve the bio-availability of nutrients for farmed fish products. The technique has been used in other sectors, such as health food, but has not yet been applied to aquaculture. It will first be applied to soya, and then applied to UK-grown cereal and legumes in order to improve the bio-availability of protein. Algae is also being explored as a way to improve fish formulas, boosting protein and omega oils. Because small oily fish used in fishmeal are traditionally the source of omega oils, incorporating algae into fishmeal can potentially reduce dependency on small oily fish and help to improve the sustainability of the sector. Ultimately, these techniques may also bring advances in other food markets, such as meat and dairy products (Biosciences KTN, 2012).

5.5 Extraction of non-living resources and disposal of waste

Messages on the extraction of non-living resources and disposal of waste

- Europe's seas contain valuable mineral and aggregate resources, as well as space to store and dispose of unneeded materials.
- The disposal of waste and the extraction of non-living resources such as marine aggregates, sand, and gravel are often driven by growth in other industries, for instance the high-tech or construction industries.
- It is expected that marine mining will see continued growth to meet the demands of high-tech industries.
- Desalination has grown in recent years, and is expected to continue to grow in order to meet demand for drinking water.
- Climate change will put coasts under increased pressure from rising sea levels. This will lead to growth in activities such as dredging, beach nourishment, and sand reclamation.

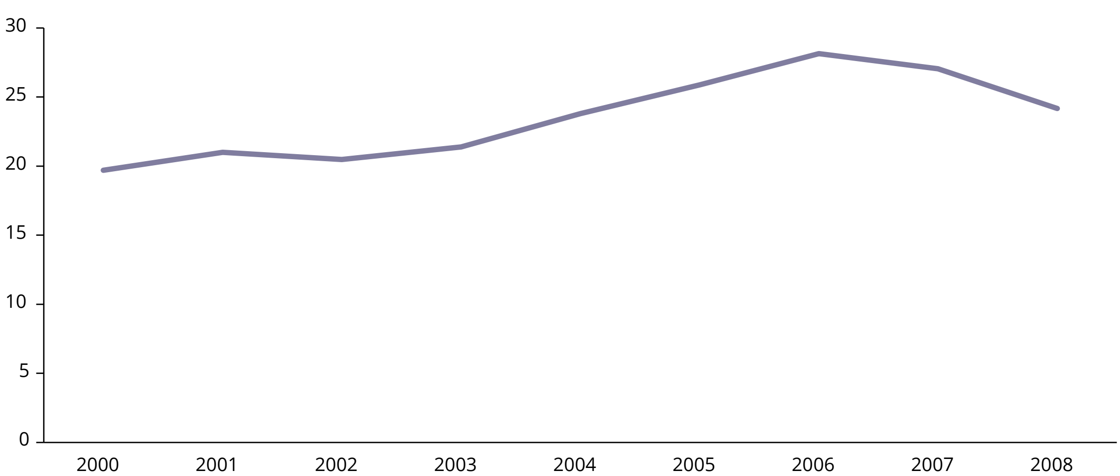
At the seafloor: mining and waste

Mining of raw materials — apart from aggregates — focuses on iron ore, tin, copper, manganese, cobalt, beryllium, germanium, graphite, gold, sulphides, phosphorites, diamonds, and lime. Increased demand for high-tech metals is driven by technological developments that require precious metals. Sand and gravel are mostly used for beach nourishment and for construction purposes, such as for making concrete. Sand is also used for industrial purposes, such as glass making, abrasives, and foundry making (Marinet, 2011).

Mining of aggregates has an estimated GVA of EUR 625 million and provides 4 800 jobs in Europe. Between 2000 and 2006, the industry experienced an increase in turnover. There was a slight fall in turnover between 2006 and 2008 (Figure 5.6). By 2020, it is estimated that 5% of the mined supply of metals such as cobalt, copper, zinc, and rare earths metals (e.g. neodymium) will come from ocean floors. This is expected to grow to up to 10% of total mined supply by 2030 (Ecorys et al., 2012).

In 2010, the gross value added of the dredging industry and the sand and gravel extraction industry in the EU was estimated at EUR 558 million. These industries (and particularly activities such as land reclamation and beach nourishment) are likely to become increasingly relevant because of climate change and rising sea levels (PRC, 2011). Dredging vessels are also expected to increase in size in order to reach distances further from shore (Ecorys et al., 2012). The European dredging industry operates about 750 vessels in ports and channels worldwide. In 2008, direct employment in European dredging companies was an estimated 25 000, while indirect employment accounted for an additional 48 300 jobs (EUDA, 2009).

Figure 5.6 Marine aggregate extraction in Europe



Source: Ecorys, 2012.

Desalination refers to a variety of different processes that can be used to remove salt and other minerals from marine waters. The ocean can be a large source of drinking water with proper desalination or water abstraction techniques. Desalination has seen considerable growth over recent years and is expected to continue to grow. The sector has a GVA of EUR 700 million and provides 7 000 jobs (Ecorys et al., 2012). The Mediterranean Sea region is considered highly active in desalination (Lattemann and Höpner, 2008; Box 5.4).

Salt occurs naturally in the marine environment. Marine salt extraction depends on an area's marine water quality and whether tidal cycles can provide 'salt pans' near coastal areas. Researchers assume that most extraction of salt from the marine environment is for food purposes (UKMMAS, 2010a). The industry produced 225 million tonnes of crystallised salt and employed about 7 325 people in 2007 (EU Salt, 2007). Increased interest in sea salt as a healthy alternative to traditionally mined salt may lead to future growth in the industry (UKMMAS, 2010a).

Waste disposed of in marine water includes hazardous and non-hazardous waste, as well as solid and dredged materials. The disposal of hazardous waste in the ocean has been banned since 1993 by the London Convention 1972 (Coenen, 2000).

Storing carbon dioxide below the seas floor is sometimes still discussed by scientists and policymakers. However, due to increased knowledge about the environmental implications of such actions, it is often no longer considered a viable option.

The increase of extraction and mining at sea

Deep-sea mining potentially causes environmental damage to the biological diversity and ecosystems in mining areas. Damage may arise from a range of pressures, including contamination of ecosystems by hazardous substances, changes in siltation at the seabed, and underwater noise (Koss et al., 2011).

Because dredging and nourishment affect the seabed, they may also affect some fisheries activities. Dredging may also lead to the unintended extraction of species (Ecorys et al., 2012). Dredging can mobilise contaminated materials that were often locked in sediment over extended periods of time. Disturbing the contaminated materials can pose threats to the environment and water quality in port areas and shipping channels (Barham, 2000). Environmental restrictions apply to the disposal of contaminated dredged materials through the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, commonly called the London Convention 1972 (Coenen, 2000).

Generally, salt extraction from sea water is a low-impact activity as evaporation is the primary technique used. However, the disposal of waste water and the use of fossil fuels or energy to speed up the process can increase the impact of extraction (UKMMAS, 2010a). For example, desalination can cause physical loss or damage through the intake process of water, which may lead to mortality in plankton, fish eggs, and fish larvae. Wastewater produced by the desalination processes may also contain chemicals and metals from the cleaning process (Lattemann et al., 2008).

Box 5.4 Desalination in Torrevieja, Spain

The second largest desalination plant in the world is located in the south of Spain: the Torrevieja desalination plant. The impressive structure has won awards for its design and advanced technology, and cost EUR 300 million. The purpose of the colossal complex is to convert sea water into freshwater, which can then be sold for human consumption or for all types of agricultural irrigation. The desalination plant has a capacity of 240 000 m^3/day (Cala, 2013).

The plant's designers aimed to make the facility as environmentally friendly as possible. Energy consumption was reduced through different methods, such as the use of energy recuperators and differentiated supply pumps. In addition, thermal and solar energy are integrated into the complex.

The environmental impact study revealed that there would be no impact on the flora and fauna from the discharge of brine, one of the byproducts of desalination (Acciona Agua, 2014). However, the validity of the environmental impact study has been contested, with a petition against the project being formally addressed to the European Parliament in 2009 (Barr, 2011). The petition arose from the fact that the desalination plant was constructed within a protected area. In addition, the environmental impact study was done for a plant with a capacity of 60 hectolitres, but the constructed plant has twice that capacity (Lopez Segovia, 2008).

This is not the only controversy surrounding the mega-project. The permit for the construction of the plant was only issued after construction (which lasted six years) had already been completed. And in addition, the building is currently used at a fraction of its capacity, as there are not enough customers for the freshwater it produces (Cala, 2013).

Source: Cala, 2013; Acciona Agua, 2014; Lopez Segovia, 2008; Barr, 2011.

5.6 Transport and shipbuilding

Messages on transport and shipbuilding

- Maritime transport of freight in Europe grew between 2002 and 2011, in spite of a small decline in 2008 due to the global financial crisis.
- Passenger ferry services have seen a slight decline in passengers in recent years, although the sector remains highly significant for some Member States.
- The shipbuilding and ship-repair industries are expected to grow in the coming years, driven by a demand for new technologies to reduce the environmental impact of the shipping industry.
- Shipping and ferry services cause a broad number of environmental impacts, ranging from localised pressures to large-scale, acute events. Environmental pressures from maritime transport have gained significant attention in recent years. New technologies and policy agreements are being put in place to address these pressures.

Steady movement of goods and passengers

The maritime transport of goods and passengers is vital to trade and tourism. Shipbuilding and ship repair give essential support to maritime transport, providing equipment and technical solutions.

Because shipping is an international industry with companies operating within and outside the EU, it is difficult to determine values for GVA and employment for the whole of the maritime transport sector. It is estimated that global deep-sea shipping has a GVA of EUR 98 billion and provides 1.2 million jobs. Short-sea shipping, or shipping on EU regional seas between Member States and neighbouring states, accounts for about 1.7 billion tonnes per year, with 1 billion accounted for by intra-EU trade. GVA for short-sea shipping is estimated to be about EUR 57 billion, with employment of about 707 000. Forecasts from 2012 suggest that the EU short-sea shipping sector will grow by between 3% and 4% annually over the next decade, in terms of goods handled (Ecorys et al., 2012). However, more recent indications suggest that these positive forecasts have reversed course, leaving the future of the global sector in question (AlixPartners, 2014). The European Commission has a clear policy vision for shipping, as evidenced by the Programme for the Promotion of Short-Sea Shipping. The programme contains legislative, technical, and operational actions aiming to develop short-sea shipping in all of the EU (Europa, 2011).

Maritime transport of containerised goods in large EU ports grew between 2002 and 2008 before dropping in 2009. The industry has continued to grow in 2010 and 2011, dropping slightly in 2012. Transport freight container volumes only regained their 2008 levels in 2011. The Netherlands, the United Kingdom, Italy, and Spain are the countries with the largest amount of freight handled in ports (Figure 5.7; Eurostat, 2013b).

An estimated 400 million passengers travelled on ships and boats in 2010 in Europe, 2% fewer than in 2009. Maritime passenger transport remains a very important sector for some Member States. In particular, both Italy and Greece each account for about 20% of total EU-27 maritime transport of passengers (Eurostat, 2012c). It is estimated that the sector provided between 200 000 and 300 000 jobs in direct employment in 2012, with a GVA of EUR 20 billion (Ecorys et al., 2012).

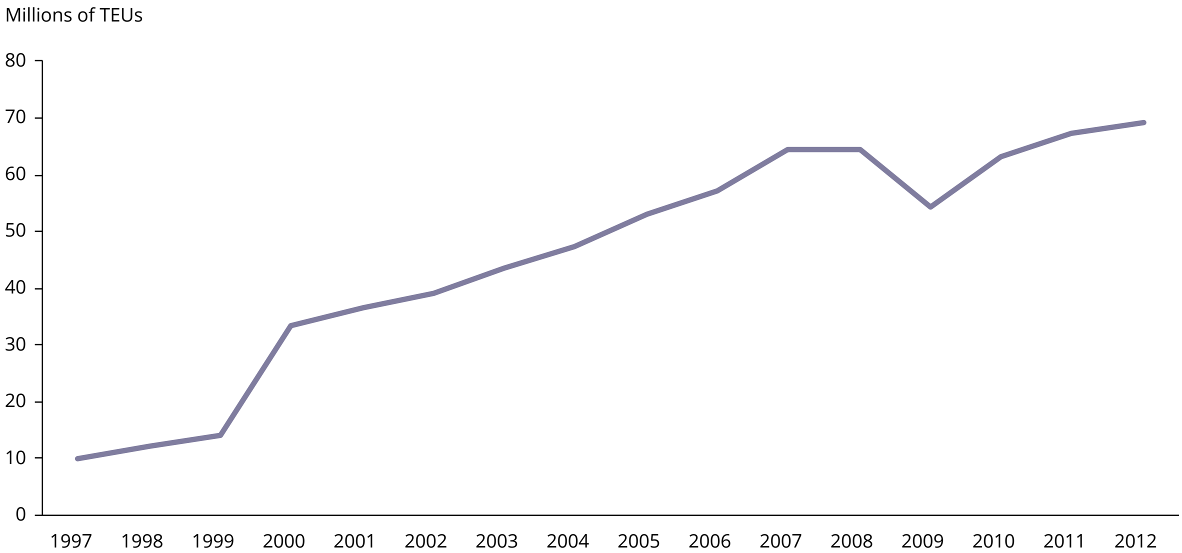
To support these activities, Europe has more than 300 shipyards producing, converting, and maintaining merchant ships, naval ships, and other hardware. It is difficult to estimate the value produced by shipbuilding because its related activities are so varied. Some estimates suggest that they account for about EUR 30 billion in turnover each year and about 500 000 jobs in Europe (CESA, 2013). The industry is expected to grow in the coming years, driven by technologies developed to address the environmental impact of the shipping sector (Ecorys et al., 2012).

Pressures from transport on the environment

Maritime transport and shipbuilding contribute to a broad range of environmental pressures and impacts:

- physical damage of the seabed due to abrasion;
- disturbances from noise and litter;
- contamination from the introduction of synthetic and non-synthetic compounds (e.g. anti-fouling paints on ship hulls);

Figure 5.7 Key trends: growth in volume (in Tonnes Equivalent Units (TEUs)) of containers (loaded and empty) handled in top 20 EU ports, 1997–2012



Source: Eurostat, 2013e (mar_mg_am_pvh).

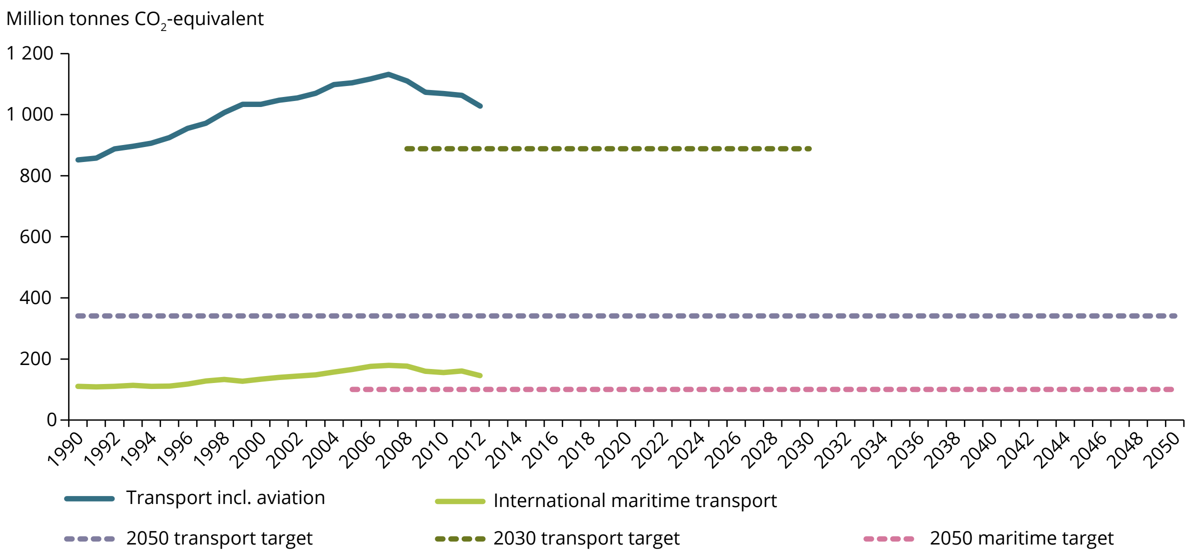
Source: © iStockPhoto

- contamination from acute pollution events;
- biological disturbances caused by the introduction of micro-pathogens and non-indigenous species (Box 5.5);
- death or injury to marine species caused by collision with vessels (Koss et al., 2011)M
- air quality degradation in coastal areas, caused by the increasing number of ships (Viana et al., 2014).

In spite of these disadvantages from shipping, shifting to maritime transport away from road or rail offers environmental benefits in decreased emissions of greenhouse gases, because shipping is a more efficient transport mode. Emissions of greenhouse gases from international maritime transport have grown since the 1990s, but began to decline in 2008 due to the global financial crisis and decreased sharply in 2012 (by 9.3%), reaching 2002 levels (EEA, 2013d; EEA, 2014f).

Shipbuilding produces significant emissions, and the impact of these emissions on the marine environment is linked to the proximity of these sites to the water. Metalworking activities, surface treatment operations, and maintenance and repair all affect the marine environment. Particulate matter emissions are a common effect of shipbuilding (OECD, 2010).

Figure 5.8 Transport emissions of greenhouse gases



Source: EEA, 2014f.

Box 5.5 Transport of non-indigenous species in the Baltic Sea

International shipping is a major source of non-indigenous species, which are carried in the ballast water of ships. In the Baltic Sea, nearly half (49%) of the non-indigenous species come from shipping activities. The 2004 International Convention for Control and Management of Ships' Ballast Water and Sediments (BWM Convention) under the International Maritime Organization (IMO) is the global instrument to regulate the management, treatment, and release of ballast water. However, it has not yet entered into force as it needs to be ratified by more countries (HELCOM, 2012).

It is essential that this convention be signed and ratified to address this international problem. At the same time, the shipping industry may struggle to meet increasing demands for improved environmental performance. One study estimated that around 60 000 ships worldwide would need re-fitting with one or more cleansing units, costing up to EUR 1.3 million each (King et al., 2012).

5.7 Tourism and recreation

Messages on tourism and recreation

- Tourism and recreation are an important motor of the European 'blue' economy. Coastal areas are the top tourist destination in Europe, and marine and coastal tourism are expected to continue to grow.
- A thriving tourism and recreation sector strongly depends on a healthy environment. It is important to ensure that the increase in marine and coastal tourism does not come at the expense of healthy marine ecosystems.

Destination Europe

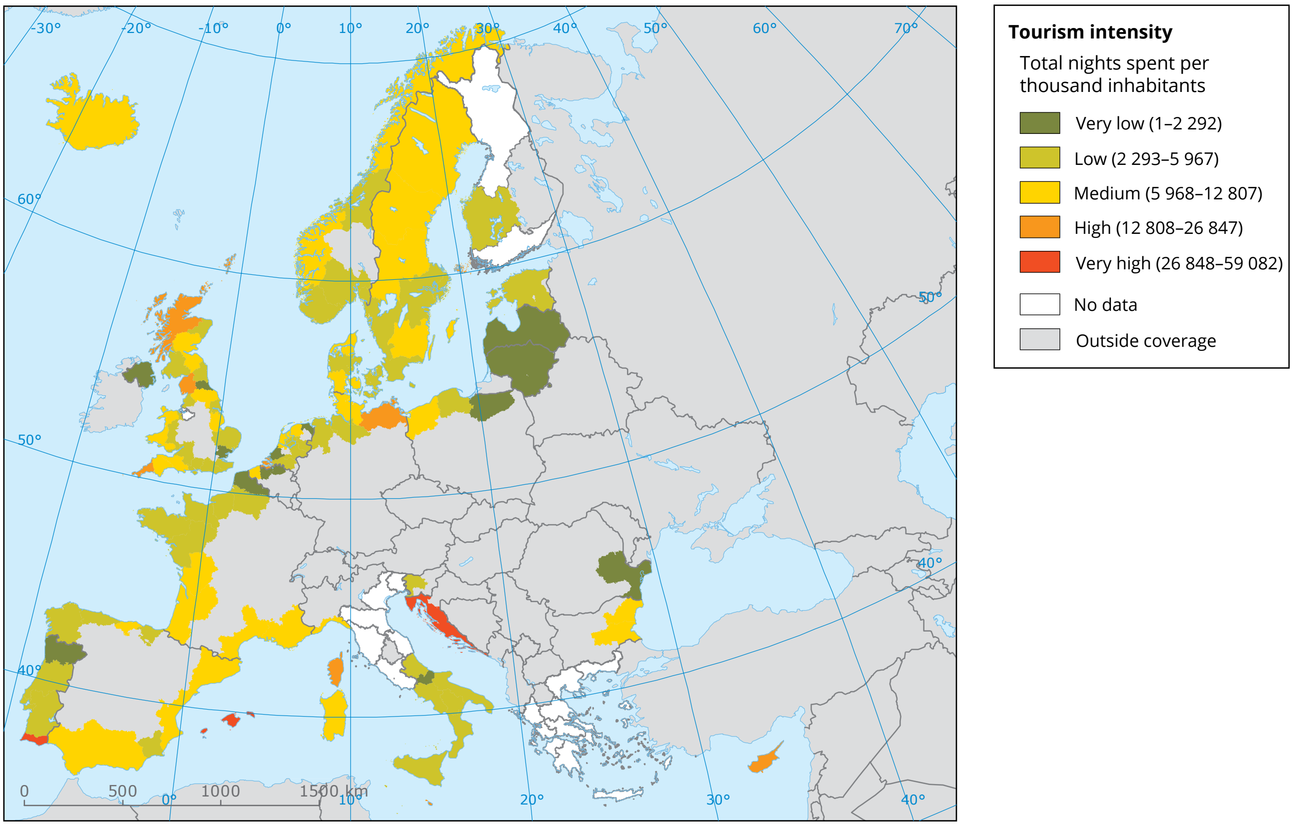
Tourism is a thriving economic sector, which is directly responsible for 5% of global Gross Domestic Product (GDP) (UNWTO, 2013). On a more local scale, tourism is often an essential source of income for remote regions and areas that lack other major economic activities (EC, 2012).

Marine and coastal tourism is a key sector in the European economy. In 2012, approximately half (51%) of total bed capacity in hotels was concentrated in coastal regions (European Commission, 2014a). In 2011, total GVA for coastal tourism was estimated to be EUR 183 billion, with employment in tourism at over 3.2 million (Ecorys et al., 2013). From 2003 to 2008, GVA from tourism and the number of people employed in tourism both grew by approximately 3% a year (Ecorys, 2012).

A broad range of recreational activities take place in marine and coastal areas, including bathing, whale-watching, and diving. It is difficult to determine specific GVA and employment values for these activities, as they are not well documented.

However, information does exist on the value of other marine and coastal activities. Yachting and marinas are two examples. In 2011, these two sectors had a GVA of EUR 38 billion in Europe, and employed 371 900 people (Ecorys et al., 2013).

Figure 5.9 Tourism intensity in coastal areas, 2012



Source: Eurostat, 2014b (Tour_occ_nin).

The cruise industry is another important contributor to the European economy. In 2011, cruise ships in Europe transported a total of 6.11 million passengers. There were 303 000 jobs in the cruise tourism industry in Europe in 2011, and in that year the GVA of the industry in Europe reached EUR 15 billion (Ecorys et al., 2013). The cruise industry is in the process of expansion through the addition of new ships. This expansion is reflected in the revenues of the European cruise industry, which increased by 12.3% in Europe from 2005 to 2009 (Ecorys et al., 2012). This expansion is expected to continue as the cruise industry is currently flourishing worldwide.

Visitors' footprints

Tourism intensity measures the number of overnight stays in an area in relation to that area's total permanent resident population. Tourism intensity in European coastal regions is significant along the Mediterranean coast in Spain, France, and Italy. It is also significant along the Adriatic coast in Croatia. Other areas that have significant tourism intensity include France's southern Atlantic coast; the Baltic coasts of north-east Germany and southern Denmark; northern Scotland; and south west England (Figure 5.9).

Marine and coastal tourism contributes to a number of pressures on the environment. Marine litter is a serious threat to marine ecosystems, species, and habitats. Tourism and recreational activities are considered to be the predominant sources of land-based litter on Europe's coasts (Interwies et al., 2013).

In addition, tourism modifies the coastal environment through the development of previously pristine areas, altering existing biophysical characteristics, and replacing the original landscape with concrete surfaces (WWF, 2014). This impact is particularly important because tourist sites often overlap with fragile ecosystems.

Man-made underwater noise is often caused by recreational boating (Rako et al., 2013). This noise threatens marine animals, as it often interferes with their means of communication, which operate on similar frequencies to man-made underwater noise (National Oceanic and Atmospheric Administration, 2014).

Changes in siltation often occur in tourist areas, as an increased number of visitors implies more sewage runoff. These changes are a significant disturbance to the organisms in a coastal environment (UNEP, 2014).

Although tourism undoubtedly contributes to these pressures, it also offers ways to protect the marine environment and fund conservation efforts (Box 5.6).

Box 5.6 Marine ecotourism: marine protected areas and underwater trails

The Maltese Government is developing underwater trails for divers and snorkelers to support the improved management of marine protected areas. The project, entitled MedPan North, receives funding from the EU and brings together 11 organisations from around the Mediterranean (MEPA, 2014).

The marine protected area where the trail is located is in the northwest coast of the Maltese islands, and covers 11 km of coastline from Rdum Majjiesa to Ras ir-Raheb. The area contains the main marine habitats occurring around the Maltese islands. A number of rare and threatened habitats (as well as species that are protected or of conservation interest) can also be found in the area.

The underwater trails start at the shore and follow a seaward route through 11 stations. Waterproof information booklets placed at each station explain the various habitat types, flora, and fauna that one encounters in the waters in the bays. This enables snorkelers and divers following the trail to learn more about the underwater environment in the area (Adi Associates, 2014).

The MedPan North project demonstrates the value of marine protected areas for recreational purposes and tourists. It will potentially be a draw for snorkelling and diving enthusiasts to the area and will support local communities through increased tourism revenues.

5.8 Man-made structures

Messages on man-made structures

- Man-made structures of various types in marine and coastal areas lead to multiple pressures on the environment. These pressures occur during both the construction and operation phases of these structures. Therefore it is essential that the environmental and socioeconomic effects of these structures are thoroughly assessed before the structures are built.
- Some structures can have positive effects on the environment, such as preventing coastal erosion or habitat loss. Other structures (for example pipelines and port infrastructure) may have negative impacts. These negative impacts include habitat destruction and the sealing of coastal areas.
- Changes such as sea-level rise and increased coastal storms may lead to new growth in the coastal-protection industry.
- The three largest European port operations, Rotterdam, Hamburg, and Antwerp are located on the North Sea coast.
- After setbacks stemming from the global financial crisis, port operations have returned to previous levels of activity.

Building up the coast and protecting the built environment

Various man-made structures are found in marine and coastal environments. They serve several purposes. Some are used to protect against erosion, storm surges, and rising sea levels. In the form of artificial reefs, some structures may be used to provide new habitats to fish and other marine life. Other man-made structures are built in ports, which require structures along coasts and in marine spaces to operate.

Coastal protection includes land-claim structures, and structures to protect against floods and saltwater intrusion (e.g. sea walls, breakwaters, and groynes). In Europe, coastal protection is a relatively mature industry and mostly concentrated on the North Sea and Mediterranean Sea. Annual turnover in the coastal protection industry in Europe is estimated to be between EUR 1 billion and EUR 5 billion. Given changes such as sea-level rise and increased coastal storms, it is expected that the industry will see considerable growth in the coming years (Ecorys et al., 2012). Protection measures mostly aim to protect against erosion or floods. However, man-made structures are increasingly being built to protect natural marine habitats in Europe.

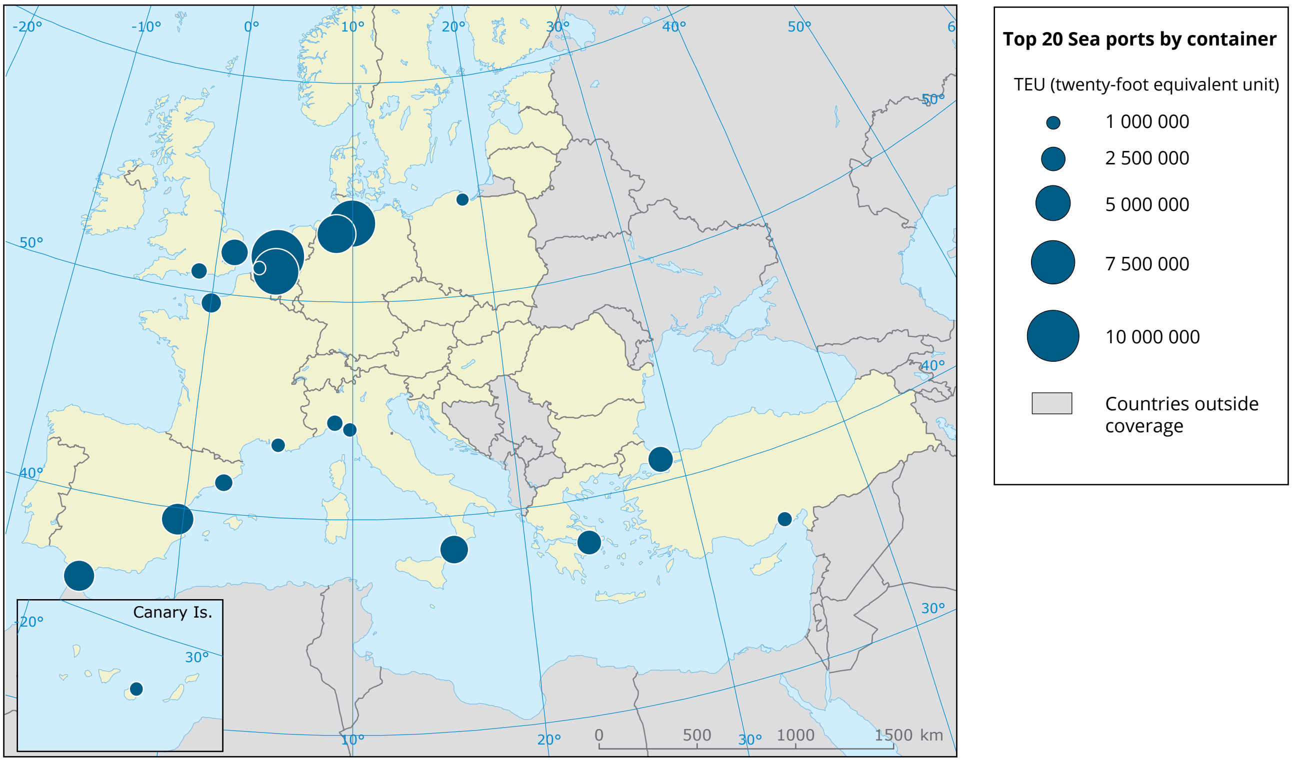
Artificial reefs have been built for many years in the Mediterranean Sea and along the Atlantic coast in an effort to enhance fish stocks. There are currently no binding regulations on the placement of artificial reefs, although some guidelines and protocols have been drawn up in different European regions. The lack of regulatory oversight and use of unsuitable materials for reefs has led to concerns regarding the possible negative impacts of reefs (Fabi et al., 2011).

It is difficult to estimate the amount of activities associated with port operations. This is because these are not stand-alone activities but clusters of independent activities operating together. Estimates suggest that the port sector represents about 1.5 million Full Time Equivalent jobs (FTEs) in direct employment (ESPO, 2013). Major European ports experienced overall growth in gross weight handled ([14]) between 1997 and 2008, before falling in 2009 due to the global financial crisis. However, gross weight handled began to rise again in most ports in 2011, although activities have not surpassed 2008 levels. Growth in 2011 was mainly due to increased volumes of inward movement of goods (Lund, 2013). The largest European ports, namely Rotterdam, Antwerp, and Hamburg are all connected to the North-east Atlantic coast in northern Europe (Figure 5.10). Both Antwerp and Hamburg are located somewhat inland along rivers.

The waters that surround Europe contain a range of pipelines and cables, which transport electricity, oil, gas, and telecommunications. Although difficult to segment into countries or regions and estimates are likely to be low, the European value of the pipeline and cable industry is estimated at EUR 185 million in annual revenues, which includes capital expenditure on the manufacture, supply, and installation of underwater telecommunication cables (Douglas-Westwood Limited, 2005). Oil and gas pipelines are significant in the North East Atlantic, including the North Sea. As the oil industry shifts its focus to the Arctic, new pipelines will be necessary to extend to the newly developed offshore operations. Offshore energy grids (i.e. submerged electricity cables) are also expected to grow in the future to transfer electricity from offshore wind farms.

([14]) Gross weight handled is a measure that includes container freight, dry bulk freight (coal, iron ore etc), and liquid fuels (refined or unrefined).

Figure 5.10 Top 20 sea ports by container in TEU



Source: Eurostat, 2014c (mar_mg_am_pvh).

In addition, canals and locks are also used along European coasts to support shipping traffic. These usually function as the point between inland waterways and marine waters. They are often located at river mouths. Some examples include the North Sea Canal (which connects Amsterdam with the North Sea); the Kiel Canal in northern Germany (which links the North Sea and Baltic Sea); and the Suez Canal (which links the Mediterranean Sea to the Red Sea).

Pressures from construction and operation

Man-made structures can lead to pressures on the marine environment both during the construction phase and the operation phase (Koss et al., 2011). Coastal protection measures, artificial reefs, beach replenishment, and the creation of lagoons for canals or channels can lead to several pressures on the environment. The construction phase of such activities can lead to physical damage to habitats through sealing of the sea bed, changes in siltation, interaction with the sea floor, increased turbidity, habitat loss due to smothering, and increased levels of underwater noise. During operation of these structures, the main pressures and impacts they cause are interference on hydrological processes through thermal regime changes or through changes in water-flow rates. Artificial reefs may also lead to changes in visual cues to local species, as reefs provide reference points for species when foraging. In addition, artificial reefs can cause alterations in wave exposure. Creating lagoons may also interfere with the chemical composition of water, caused by changes in salinity. Pipelines and cables cause similar pressures to coastal protection measures, while cables cause the additional pressure of localised electro-magnetic changes during their operation (Koss et al., 2011).

Port and marina construction also creates various pressures on the marine environment. These include physical loss and physical damage to ecosystems caused by interaction with the seafloor from anchoring; physical damage to the seafloor such as changes in siltation and abrasion; marine litter; and other physical disturbances such as underwater noise. Pressures also include interference with the chemical composition of water (salinity regime changes), and interference with hydrological processes (both through thermal regime changes, and through changes to water flow rates) (Koss et al., 2011). During operation, pressures are caused by contaminants such as anti-fouling paints (used to keep artificial surfaces free of algae); contamination by hazardous substances; and biological disturbances (introduction of microbial pathogens, introduction of non-indigenous species and translocations).

5.9 Energy production — offshore renewables

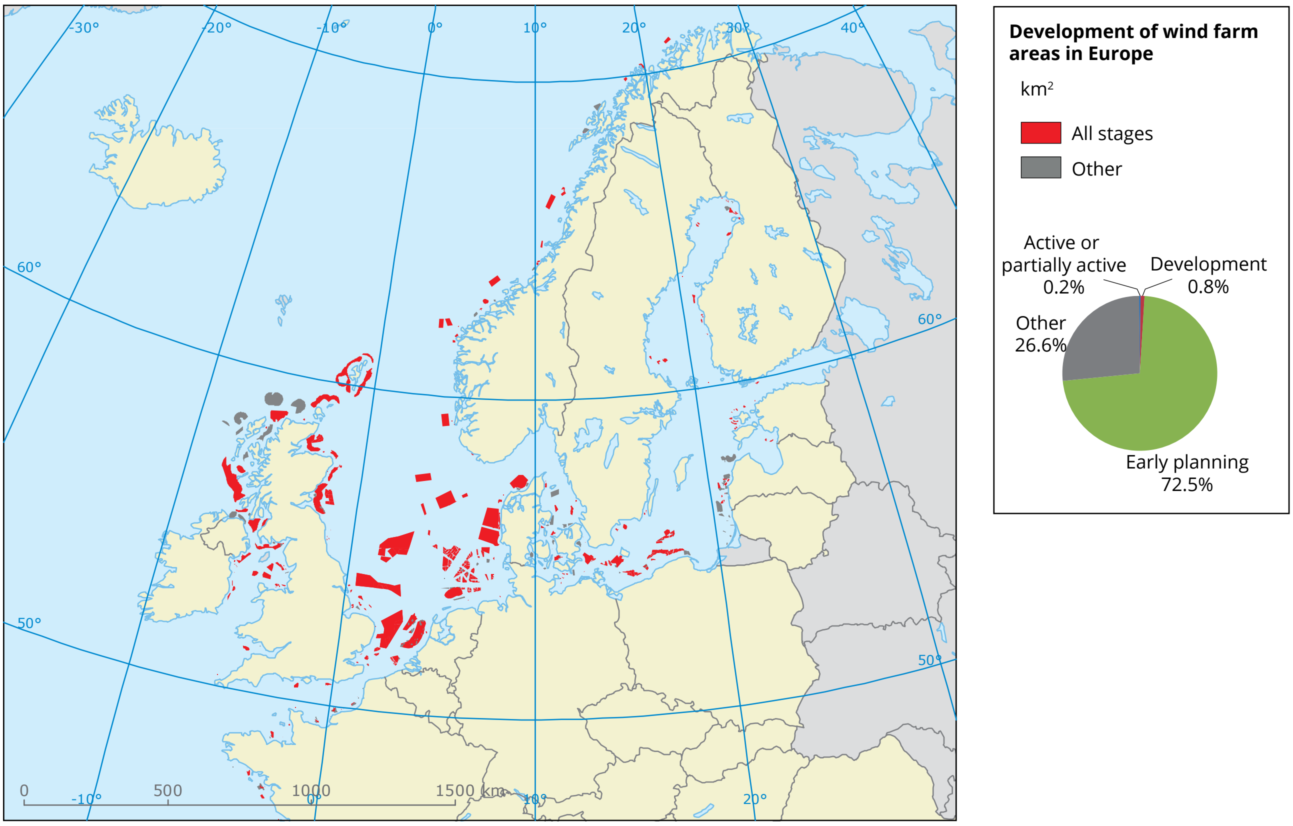
Messages on energy production offshore renewables

- Offshore wind power installations in Europe have greatly increased in number in the past decade. Installations are concentrated almost exclusively in northern Europe. Although offshore wind power is predicted to continue to grow in the future, it is expected that its growth rate will somewhat decrease due to high investment costs and a lack of political commitment.
- Wind farms can disrupt biological and hydrological processes in the sea, but can also provide new habitats for marine species.
- Wave and tidal power are considered to be a large untapped source of clean power, and are predicted to increase in importance in the next few years. These installations are known to interfere with hydrological processes, in addition to causing other environmental pressures.

The growth of offshore renewable energy

Offshore wind energy is by far the largest type of renewable energy generation in the European marine economy in terms of production. Offshore wind farms produce 10% of total wind energy in Europe (EWEA, 2013). The majority of offshore wind farms are located in the North-east Atlantic Ocean, particularly the North Sea (Figure 5.11). The Mediterranean Sea is less suitable for this activity as it is too deep for currently-used models of wind turbines. Offshore wind energy accounts for a GVA of EUR 2.4 billion and employment of 35 000 (FTE).

Figure 5.11 Development of wind farm areas in Europe (km²), 2013



Note: 'Active or partially active' describes wind farms that are 'generating power' or 'partial generation/under construction'. 'Development' includes those wind farms that are considered to 'have authorised consent' or be 'under construction'. 'Early development' includes those described as 'concept, early planning', 'consent application submitted', and 'development zone'. 'Other' includes 'cancelled', 'decommissioned', 'dormant', and 'failed proposal'.

Source: 4c offshore.

Wind energy was the fastest growing European marine activity in the period 2003–2008, with its energy output increasing by 21.7% over the period (Ecorys et al., 2012).

Other types of renewable energy are being developed, such as wave and tidal power. Most of these are still in an experimental phase and still represent a very small share of marine economic activities. In combination with thermal conversion and biofuel, their GVA is less than EUR 250 million and they account for employment of around 1 000 (FTE) (Ecorys et al., 2012b; Ecorys et al., 2012a). Nonetheless, wave and tidal power are considered to be a large untapped source that could ultimately provide up to 15% of the energy used in Europe, based on recent estimates.

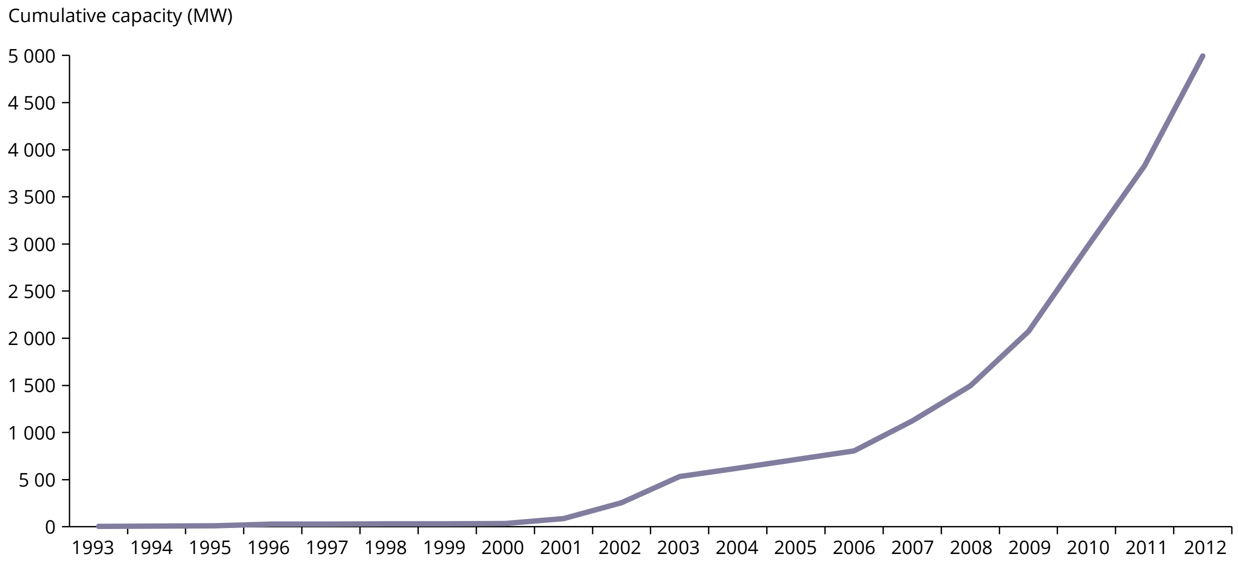
Slowing progress

After substantial growth, the significant increase in offshore wind farms over recent decades (Figure 5.12) is showing signs of slowing in 2014. While growth is still expected in the future, it is being impeded by environmental issues and by high costs related to technical challenges. In part, this is because projects are moving further out to sea and further away from the coasts, but it is also because developers are becoming more experienced and have a better understanding of the associated costs (Helsinki Times, 2014; EWEA, 2014).

Offshore wind farms are associated with a range of environmental pressures throughout their life cycle. Pressures come from site selection, construction, operation, decommissioning, and removal. These pressures can include underwater noise, which has effects on marine mammals and fish. Other pressures include disturbance and loss of habitats, collision with birds, and hydrological impacts (OSPAR, 2010b).

In addition to environmental pressures, offshore wind farms may also provide benefits to marine ecosystems. Wind farms may act as artificial reefs, providing habitats and protection to some marine species, enabling them to move to new areas where habitats were previously not available. But for this reason, wind farms may also contribute to the spread of invasive alien species (Adams et al., 2014).

Figure 5.12 Offshore wind installations in Europe (MW)



Source: EWEA, 2013.

5.10 Energy production — oil and gas

Messages on energy production — oil and gas

- Marine hydrocarbon extraction is declining in Europe but is still an important part of the maritime economy.
- In addition to being a non-renewable energy, the different phases of hydrocarbon extraction generate many negative environmental impacts. These impacts include the loss of seabed substrate and the death or injury of marine animals because of collision with installations.

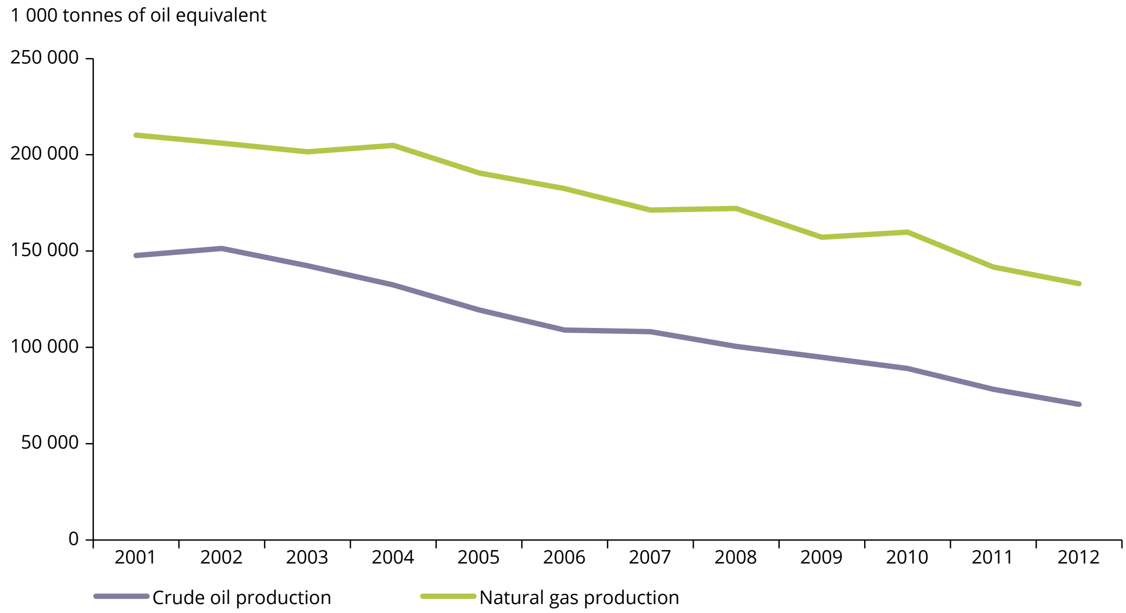
Oil and gas

The EU is still heavily dependent on fossil fuels, and more than half of its supply comes from countries outside the EU, with a large proportion of this supply coming from Russia (Eurostat, 2012a). Marine hydrocarbon (oil and gas) extraction remains a significant activity in the marine energy sector, in 2011 it was estimated to have a GVA between EUR 107 billion and EUR 133 billion, and employment of 25 000 to 50 000 (Ecorys, 2012). However, marine hydrocarbon production in Europe is starting to decline (Figure 5.13). Between 2001 and 2012, natural gas production declined by 37% and crude oil production declined by 52% (Eurostat, 2013c; Eurostat, 2013a). GVA and employment in the European oil and gas industry decreased by 4.8% in the period 2003–2008 (Ecorys, 2012) The oil and gas industry claims that vast oil and gas resources are still recoverable around the world, especially when non-conventional means for recovery are included (International Association of Oil and Gas Producers (OGP), n.d.).

In the EU and Norway, over 90% of oil and over 60% of gas is produced from offshore operations, mostly in the North Sea and the Norwegian Sea (EC, 2010a). The United Kingdom and Norway, focusing on the North Sea, account for the majority of offshore oil and gas production in the European Economic Area, while the remainder is divided between Denmark, the Netherlands, Italy, Romania, and Ireland. It is estimated that the North-East Atlantic has some 1 340 offshore installations, of which 1 170 are operational (EC, 2010a, citing OSPAR Commission).

The total amount of oil and gas produced in the OSPAR region decreased by 14% between 2001 and 2007 to 442 million tonnes of oil equivalent, whereas the number of offshore installations increased. This indicates a trend toward the exploitation of smaller

Figure 5.13 Key trends: crude oil and natural gas production in the EU-28



Source: Eurostat, 2013a and 2013c.

fields. A network of pipelines connects the offshore installations with onshore distribution networks. The OSPAR region has an estimated 50 000 km of pipelines transporting oil and gas products onshore. As offshore oil and gas production declines in the North Sea, the oil industry is shifting efforts to other areas such as the Arctic or Mediterranean (OSPAR, 2010a).

In 2010, a report by the United States Geological Survey revealed that the eastern Mediterranean region contains significant untapped resources, and has 1.7 billion barrels of oil and 122 trillion cubic feet of gas (USGS, 2010). New sources of energy will also require new means to transfer oil and gas to shore (Box 5.7).

Oil and gas extraction detrimentally affects the environment during the exploration, construction, operational, and decommissioning phases. Certain detrimental impacts only occur during one or two phases. For example, the operational phase is the only phase where the input of organic matter and the introduction of microbial pathogens occur, while seabed substrate loss is a threat during the exploration and construction phases. Conversely, smothering of sea floor habitats, changes in siltation, underwater noise, and death or injury of marine animals caused by collision with equipment can happen during all four phases (Koss et al., 2011). The decommissioning phase will be particularly relevant in the upcoming years, as extraction activity slowly declines and platforms stop operating.

Box 5.7 A new energy corridor in the Mediterranean Sea?

Surveys have confirmed the presence of hydrocarbon reserves in the eastern Mediterranean Sea (USGS, 2010), and the countries in the area all wish to develop their oil and gas industry (Günaydin, 2013). With the discovery of natural gas in the Mediterranean it can be expected that other activities to support hydrocarbon extraction will also be developed. Some proposals have already been made for pipelines to be built in the eastern Mediterranean. For example, Greece requested a study on the feasibility of a pipeline to carry gas from Israel and Cyprus (Reuters, 2010). Pipelines generate negative environmental effects both during their construction and their operation. These effects include changes in siltation, smothering, and in hydrological processes (Koss et al., 2011). Beyond the political conflicts in the region, serious environmental considerations should also be taken into account (USGS 2010; Koss et al. 2011; Reuters 2014; Günaydin 2014).

Source: © Dag Myrestrand, Statoil

5.11 Research and surveys

Messages on research and surveys

- Marine research and survey activities are expected to grow significantly in the future due to an increasing focus on 'Blue Growth' in the EU, environmental awareness, and climate change. Security threats and concerns about illegal activities at sea will also help to promote research and survey activities.
- Research and survey activities involve offshore surveillance installations, underwater noise (sonar), or the extraction of marine flora and fauna.
- Environmental pressures and impacts from these activities include physical damage, noise, and litter.

Understanding the marine environment

Marine environmental research focuses on the changes in the physical, biological, and chemical state of the seas and ocean. Increased awareness of climate change, combined with growing concerns about the state of the marine environment, suggest that marine observation and research will continue to grow in the future. The sector is highly dependent upon public policy and funding for research. It is estimated that spending on marine research will double in the coming decade (an annual growth rate of 7%).

Employment in the sector is therefore also likely to grow (Ecorys, 2012). According to the Eurofleets European Vessels Database, there are 268 research vessels in Europe (Eurofleets, 2014). This is a clear indicator of the interest that the EU and its Member States have in understanding Europe's marine waters.

In addition to investments in research to achieve environmental or policy goals, private companies also invest in research in an effort to identify and exploit available resources. However, little information on such activities is available.

'Survey and monitoring' refers to observing sea activities for security (e.g. terrorist activities or piracy) or environmental (e.g. illegal dumping or fisheries control) reasons, in order to contribute to assessments for policy and conservation goals.

Security concerns are a major source of spending on marine research and surveys. Many security related activities fall under shipping and port activities such as the International Ship and Port Facility Security (ISPS) code of the International Maritime Organisation (IMO), which are measures to enhance the security of ships and ports. The sector is very broad and includes a number of different functions. It is estimated that the European maritime security market is worth around EUR 1.8–2.3 billion in annual revenues, excluding its indirect effects on the economy. The sector has been growing at between 30% and 40% annually over the last few years, and is expected to continue growing at an annual rate of around 15–25% in the coming years (Ecorys, 2012).

Marine research — essential knowledge for science and policy

Significant resources and effort are invested into understanding marine and coastal environments in order to improve science and policy. The EU included the 'sustainable management of marine environments' as one of the research themes in its Seventh Framework Programme for research. The EU has also included 'Blue Growth: unlocking the potential of Seas and Oceans' as a research theme in its Horizon 2020 programme. This research focuses on improving the understanding of the impacts of human activities on the ocean and marine resources. It also seeks to promote the sustainable exploitation of resources, the preservation of marine ecosystems, and a better understanding of the effects of climate change on ecosystems. In addition to research conducted or funded by the EU, regional and national mechanisms are also used to support research within specific geographic areas, such as the BONUS programme in the Baltic Sea region.

5.12 Military

Messages on the military

- The increase in maritime activities in European waters makes it an urgent priority to clean-up and remove underwater dumped munitions. Adequate planning measures should also be developed, to ensure that human contact with munitions is avoided.
- Military training activities and dumped munitions can have negative effects on the environment. For example, the use of underwater sonar during training exercises can have negative effects on marine life functioning, while underwater dumped munitions can lead to harmful chemical leaks.

Operations at sea

Military activities in marine spaces include defence operations, training operations, and the dumping of munitions. Military zones in marine areas are defined by governments in order to provide zones for adequate training and security.

Military activities in the marine environment largely involve training such as submarine manoeuvres, shooting practise and aerial exercises. They also involve surveillance, monitoring, and transport. For security reasons, it is difficult to obtain information on military activities undertaken in European marine waters.

In total, the EU's Member States have over 600 commissioned warships, not including auxiliary, survey, or support ships. EU defence projects can be considerable in terms of their cost and the people they employ. For example, the United Kingdom is constructing two new aircraft carriers, the Queen Elizabeth and the Prince of Wales. The project is valued at EUR 5.8 billion and is providing jobs to over 10 000 workers (Summers, 2011). Military zones can take up substantial space in Member State exclusive economic zones (EEZ, the area of sea within 200 nautical miles of a country's shoreline or equidistant to neighbour state). For example, military zones account for about 7% of the EEZ of the Netherlands and about 50% of the EEZ of Germany. However, military zones can also be used for additional purposes, such as sand extraction or nature protection (Veum et al., 2012).

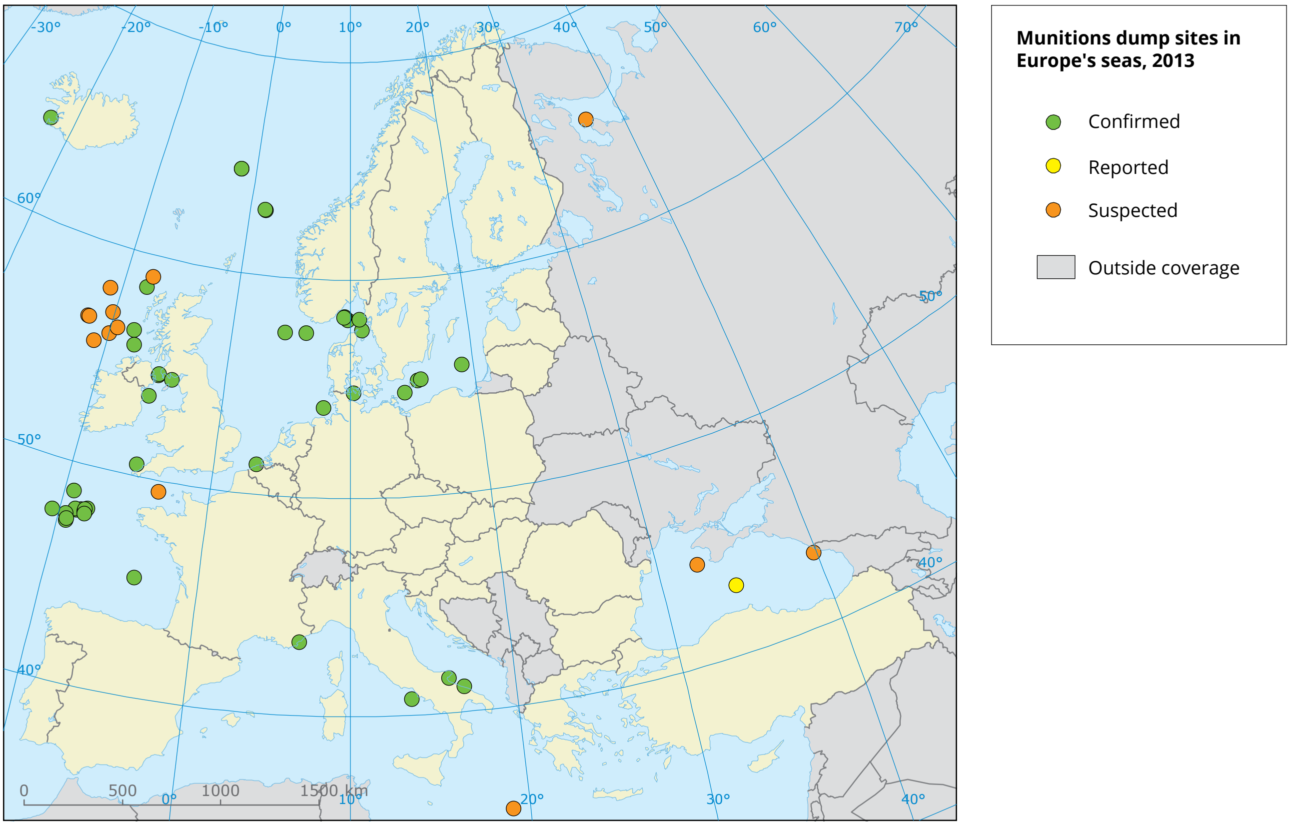
Most dumping of munitions at sea started after the First World War, and continued throughout the Second World War and the Cold War. An estimated

Source: Stock photo © Dovapi

300 000 tonnes of munitions, including conventional munitions (such as torpedoes and mines) and chemical munitions (containing mustard gas) have been dumped into the seas since 1918. Other estimates suggest that far more munitions were dumped at sea during this time. There exist 148 individual dumpsites spread from Iceland to Gibraltar. The practice of dumping munitions at sea continued up to the 1970s, when governments began to understand the impact the dumps had on the environment (KIMO, 2013). It can be assumed that the number of dumped munitions has been decreasing since the 1970s, due to their natural disintegration or to clean-up and removal efforts (Figure 5.14).

Dumped chemical munitions can interfere with the marine environment, humans, and other activities (such as fishing). For example, fish caught near chemical munitions dumped at sea have been shown to have cellular damage (Baršiene et al., 2014). And tourists to the Baltic island of Usedom in Germany regularly collect the light-coloured rocks that wash ashore, believing them to be amber. They are actually phosphorous, which can easily catch fire and cause serious injury. In the past 40 years, about 100 people have been seriously burned this way (Schlacht, 2014). Dumped munitions also cause serious issues for offshore wind farms, especially in the North Sea for countries like Germany. The munitions pose serious risks, and impede progress when building wind turbines and laying the cables that are needed to transport energy. The solution preferred by countries for dealing with this problem is the controlled detonation of the munitions. Yet it is also common policy to leave known munitions sites undisturbed if they do not conflict with human activities. When detonated, underwater explosions can impact marine species such as grey seals and common seals. Explosions can be especially harmful at certain times of the year, such as during the rearing phases of seals, when they can cause mother animals to flee and abandon their young (Bohne, 2012).

Figure 5.14 Munitions dump sites in Europe's seas, 2013



Source: CNS, 2014.

5.13 Are our seas productive?

In summary, Europe's seas provide a vast amount of valuable resources. It is estimated that maritime activities contribute around EUR 467 billion in annual GVA and 6.1 million jobs to the economy. Moreover, projections indicate that Europe's seas will deliver increasing value in the future across most activities (Table 5.1).

It remains a major challenge to categorise — and therefore determine values for — maritime activities. This is because in many instances it is difficult to classify what should be included in an activity, or what should be considered as 'marine' or 'coastal'. For example, some estimates of coastal tourism include aspects such as accommodation and restaurants, but not local transportation (e.g. taxis), which also benefits from tourism. It is also not possible to determine that tourists visit a city or area to be near the sea or coast, as opposed to other attractions such as local heritage, culture, or urban characteristics. In most cases, it is likely that they visit for a combination of these reasons. Countries may also vary in the methodologies they use for categorising activities and estimating their value. Thus, Table 5.1 provides a rough estimate based on best available resources, but should be considered with caution given the significant uncertainties about the data.

Of the 32 sub-activities assessed, 50% (16) are projected to increase, while 12% (4) are expected to decrease, and 9% (3) are expected to remain unchanged. Projections for 28% (9) of activities are unknown. Growth is expected from some of the traditional activities, such as shipping, as well as from new activities, such as offshore renewable energy and the harvesting of bio-genetic resources. Thus, there will be increasing competition for space and other resources within Europe's seas. It should also be noted that there are several links between the growing maritime activities. For example, growth in shipping and transport leads to growth in shipbuilding and port activities.

Most maritime activities are dependent on marine natural capital, while they at the same time cause a variety of pressures (e.g. habitat destruction, pollution, introduction of non-indigenous species, etc.) on this natural capital (Table 5.1). Indeed, two of the ten activities are dependent on biotic resources (e.g. living resources), six are dependent on abiotic resources (e.g. minerals) and two activities are dependent on both. In regard to pressures on natural capital, all of the maritime activities discussed in this chapter place pressure on biotic capital and four place pressure on abiotic resources.

It should be noted that several activities that do not rely on natural capital nevertheless place pressure on it (e.g. man-made structures and shipping). These activities do not have a direct economic incentive in maintaining and preserving these resources for future use. Yet, these resources are essential for other activities to remain productive, in particular those activities that are dependent on healthy seas (i.e. tourism, recreation, and the extraction and production of living resources).

This complexity is also reflected in EU policy objectives. The Blue Growth Strategy aims at increasing sustainable economic outcomes from maritime activities. The MSFD seeks to ensure that the marine environment remains clean, healthy, undisturbed, and productive. Thus, it is essential to integrate these objectives into the broader European aim of smart, sustainable, and inclusive growth under the Europe 2020 Strategy.

This chapter set out to answer whether Europe's seas can be considered productive today and where they might be in the future. While there is no easy and clear answer to this question, it is possible to identify trends that indicate the direction human activities are going. A general increase in maritime activities has occurred over the last decade or more and more than half of the sub-activities are expected to grow in the future. In this respect, it can be said that Europe's seas are currently productive (Table 5.1). However, it remains unclear whether future productivity can be maintained given the dependency and pressures on marine natural capital.

Given the state of Europe's seas (Chapter 3) and the pressures on them (Chapter 4), it is necessary to explore what the identified growth in activities could mean for the sea's potential to generate marine ecosystem services, which is determined by the condition of marine ecosystems. These services are crucial to meeting people's basic needs, and to supporting our well-being and livelihoods (and the economy more broadly) (Chapter 7).

6 The EU policy response

Key messages on the EU policy response

- EU policies on the marine environment are already being implemented. These policies deal with problems such as eutrophication and overfishing. They are leading to improvements in the marine environment.
- In spite of the improvements they have brought, these policies are not achieving their full potential. A number of refinements could be made to make them even more effective.
- Public policy is increasingly complex, because there are many different EU and national policies that directly affect the marine environment. It is important that these policies on the marine environment be implemented in an integrated way.
- The ecosystem-based approach would be an effective way to achieve this integration between policies, but adopting this approach requires changes to traditional policy and management procedures.

6.1 Setting the scene

This chapter seeks to investigate the EU's policy response to the problems facing Europe's seas. The chapter begins with an introduction to the policy framework addressing Europe's marine areas (Section 6.2). It then looks at three specific policy areas where EU legislation affects marine areas: eutrophication (Section 6.3), nature conservation (Section 6.4), and fisheries (Section 6.5). It then discusses the conclusions that can be drawn from Europe's experience in these three policy areas (Section 6.6). In the final section (Section 6.7), the chapter examines a possible way to improve the implementation of EU marine-related policies: ecosystem-based management. Ecosystem-based management is a way of managing human activities in the sea that focuses on ecosystem health.

A growing awareness of the connection between humans and their environment

The 21st century has seen a growing understanding of the interactions between human societies and environmental change in natural systems. Two insights about humans and the environment, key for such understanding, emerged in the scientific community about 20 years ago. The first insight was that the Earth acts as a single self-regulated system, where its individual components of oceans, land, and the atmosphere are closely linked. The biosphere is an active and essential component of this Earth system (Petit et al., 1999; Siegenthaler et al., 2005; Barbante et al., 2006). The second insight is that anthropogenic drivers of environmental change are now so pervasive and extensive in their consequences that they threaten the very environmental conditions upon which humans depend (Steffen et al., 2004).

These insights allowed for further science-based analyses to propose that the Earth has a number of planetary boundaries (Rockström et al., 2009; Steffen et al., 2015). The planetary boundaries are based on critical processes that regulate the Earth system functioning and include processes such as climate change, biodiversity loss, alterations to biogeochemical flows and ocean acidification. This research also indicates that these boundaries should not be transgressed if the relatively stable environmental conditions that have allowed humans to prosper over the past 11 700-year long Holocene epoch are to be maintained. Overstepping these boundaries puts the global societal development outside a 'safe operating space', which could have detrimental consequences for large parts of the world. At the same, time it is clear that a great acceleration of human consumption has happened since the 1950s along with a rapid increase in ecological degradation (Steffen et al., 2004; Steffen et al., 2015).

Can the policy response deal with complexity and system-level problems?

Over the past 20 years, the growing awareness and understanding of the connections between human systems and the Earth system, together with the enhanced understanding of the systemic nature of many of our environmental challenges (such as biodiversity loss and climate change), led to important shifts in the international and EU policy response. One of the major turning points in the policy response was the Earth Summit in Rio de Janeiro in 1992, where the Convention on Biological Diversity and the Framework Convention on Climate Change were opened for signature by national governments. Signatories to these Conventions made several commitments to promote sustainable development, and these commitments were expanded upon at the Earth Summits in Johannesburg in 2002 and in Rio de Janeiro in 2012.

The European Union has also formulated its own policy response within this changing context. For the past 40 years it has produced ambitious policies that cover different aspects of Europe's environment, including the marine environment. With the 7th Environment Action Programme, the EU has also started to offer a coherent framework for environmental policies to address the more complex environmental challenges, uniting the short, medium and long-term (see Chapter 1). This body of EU environmental law has delivered a range of environmental, economic and social benefits but the depletion of natural capital continues to jeopardise ecosystem health and resilience. This depletion is often due to insufficient implementation of agreed policies (EEA, 2015h). In the next three sections, we will look at this gap between policy targets and policy implementation in three different areas affecting marine ecosystems, which have been the subject of long-term EU policies: eutrophication, marine conservation (through marine protected areas) and fishing.

6.2 Eutrophication — breaking the trends

Nitrogen and phosphorus inputs to Europe's transitional, coastal, and marine waters have decreased over the past 20 years. However, excessive nutrient levels continue to cause eutrophication and to affect the quality of water in these areas. Although policies addressing eutrophication are in place, and reductions have occurred, the target of achieving good ecological status in transitional and coastal water bodies or good environmental status with respect to eutrophication is still not being met. EEA has shown that 50% of coastal and 67% of transitional waters fail to achieve the target of good ecological potential or status (EEA, 2012) under the Water Framework Directive. Regional Sea assessments have also documented massive eutrophication problems in most of the Baltic Sea and along the east coast of the North Sea (Box 4.6), anticipating that 'good environmental status' will not be met in these areas.

This problem is primarily caused by modern agricultural practices, which make intense use of fertilisers and manure. This leads to high nutrient surpluses on land, which are washed into the sea by the rain. They then end up causing widespread problems of nutrient enrichment in transitional, coastal, and marine waters. As shown in Section 47.5 more progress is needed on reducing the diffuse nitrogen emissions from agriculture.

In order to address the problem of eutrophication, the EU has adopted several directives aimed at reducing nutrient inputs: the Nitrates Directive, the Urban Waste Water Treatment Directive, and the Water Framework Directive (91/676/EEC, 91/271/EEC, and 2000/60/EEC). In addition, the EU adopted the Clean Air Policy Package in 2013 (aimed at reducing nitrogen emissions to the atmosphere) (COM/2013/0918). These directives individually address different sources of nutrient pollution across Europe. The MSFD objective of minimising eutrophication in marine waters will be achieved by the implementation of these directives (and additional measures by Member States).

The implementation of these directives is the responsibility of the Member States, primarily through the Programmes of Measures that they create under the Water Framework Directive. These programmes of measures will document the many initiatives in place to reduce nutrient inputs, but as this information has not yet been reported, a European overview is currently not in place. Reducing nutrient inputs will require addressing agricultural practices. Hence, it is important that the Common Agricultural Policy (CAP), has provisions that can lead to nutrient reductions. Recent reforms of the CAP have resulted in a 'decoupling' of agricultural subsidies from production, and it is anticipated that it will reduce the use of fertilisers on farms. The reforms have also led to the implementation of a cross-compliance mechanism, whereby farmers must comply with a set of statutory management requirements, including those that relate to the environment. A range of other measures for the improvement of water quality have also been suggested in the recent CAP reforms. The measures include the improvement of manure storage, the use of cover crops, the creation of riparian buffer strips, and the restoration of wetlands.

Due to this very large number of policies and policy instruments, the 7th EAP has expressed the need to address the nutrient cycle as part of a more holistic approach. In the coming years, the EU will focus more on integrating existing policies that play a role in tackling eutrophication.

In addition to EU legislation, many international agreements and national policies are in place to reduce nutrient inputs. The four Regional Sea Conventions

(HELCOM in the Baltic, OSPAR in the North Sea, the Barcelona Convention in the Mediterranean, and the Bucharest Convention in the Black Sea) have all worked to map the impacts of eutrophication and to establish coordinated actions and targets for nutrient reductions. The most prominent such policy is the Baltic Sea Action Plan, where countries around the Baltic Sea have agreed specific targets for nutrient loads at national level (HELCOM, 2007).

International River Conventions also play a role in reducing eutrophication of marine waters. The International Commission for the Protection of the Rhine and the International Commission for the Protection of the Danube River both have objectives of reducing nutrient loads. These objectives are implemented via the Water Framework Directive's River Basin Management Plans, and the Programmes of Measures contained in these plans.

6.3 Marine protected areas — an example of successful EU policy?

Human activities continue to place pressure upon the marine environment, causing harm to its constituent species and habitats. One of the ways to address pressures with a large spatial footprint, such as those coming from fisheries, is by using 'spatial protection measures'. These measures can include the prohibition of a given activity (such as fishing or hydrocarbon extraction) in a specific area, or restricting the use of certain types of fishing gear in an area. The strictest type of spatial protection measure is a type of marine protected area (MPAs) called reserves, where almost all human activities are prohibited.

Spatial protection measures are the only measures that are specifically mentioned by name in the MSFD. Europe are thus working on establishing a network of marine protected areas in its regional seas.

Protected areas should cover 10% of our seas

The year 1992 was a turning point for global biodiversity protection, because it was the year that the UN Convention on Biological Diversity was opened for signature. The Convention has since provided an important basis for further biodiversity protection.

In 2002, at the Johannesburg World Summit, policymakers focused on marine biodiversity. The summit led to the goal of creating a representative, global network of MPAs by 2012. In Nagoya in 2010, the date for achieving this target was postponed to 2020. However, the Nagoya summit also saw the addition for the first time of a quantitative target attached to this date, namely that 10% of coastal and marine areas should be 'conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures'. The 'area-based conservation measures' mentioned in the Nagoya text appear similar to the 'spatial protection measures' mentioned in the MSFD. However, neither the Nagoya text nor the MSFD defined what these measures mean. There is no EU database of 'spatial protection measures' except for those related to marine protected sites.

Marine habitats are also protected by the EU's Habitats Directive, which was adopted in 1992. The Habitats Directive aims to protect natural habitats and wild fauna and flora. A key measure of the directive is the establishment of the Natura 2000 network of protected areas, a type of spatial protection measure. The Natura 2000 network includes both terrestrial protected areas and marine protected areas. The first marine habitat sites were designated as Natura 2000 sites in 1995. In 2012, the marine Natura 2000 network accounted for 229 000 km^2, or 4% of the EU's marine areas (EEA, 2014b).

Natura 2000 has been a key driver for the protection of vulnerable marine species and habitats, especially in coastal waters. The marine network of Natura 2000 now covers 24 EU Member States (4 EU Member States do not have marine territory), making it a major success for the EU.

In addition, the marine Natura 2000 network is supplemented by marine protected areas that were designated under national legislation. Including

Box 6.1 Marine protected areas

- Marine protected areas (MPAs) are geographically distinct zones for which protection objectives are set.
- They often aim at striking a balance between ecological constraints and economic activity, so that the seas may continue to deliver the ecosystem services and associated benefits supporting peoples lives.
- Marine reserves are MPAs where human impacts are kept at a minimum (e.g. no extraction of fish, minerals or hydrocarbons are allowed).

these nationally designated sites, the MPA network in European seas in 2012 covered more than 338 000 km^2, or 5.9% of the EU marine area within 200 nautical miles (nm) of the coast (Figure 6.1).

However, despite these successes, Europe's network of marine protected areas cannot yet be considered to be fully coherent nor representative, especially in offshore areas (HELCOM, 2009a; (OSPAR, 2010c)). Significant differences remain between the regional seas in terms of their coverage by MPAs (EEA, 2014c). And there are also differences in terms of the coverage of different types of marine area. For example, Europe is doing well in coverage of coastal waters, with more than 16% of coastal marine areas now inside an MPA. However, beyond 12 nm from the shore, only 3% of the EU's seas are protected inside an MPA. This shows that the MPA network is not representative, because the EU's offshore seas cover 4.7 million km^2 (or 80% of the EU's total sea area, excluding overseas territories).

The EU thus still faces a large challenge if it is to meet its policy targets. In less than seven years, EU Member States have to designate the same amount of MPAs in terms of area as has been designated under the marine Natura 2000 network over the last 20 years. But even if the EU achieves this, there is no guarantee that the 10% coverage will in itself create a coherent and representative network of MPAs.

It should be noted that since 2012, several countries, such as Spain and the United Kingdom, have designated even more marine protected areas. This has moved the EU as a whole closer to the 10% Nagoya target. Portugal is also expected to designate very large MPAs in the near future.

Well-managed MPA networks

Besides reaching the targets mentioned above, there is a need to ensure that the MPA networks meet the Nagoya goal of being 'effectively and equitably managed'. This means ensuring that management efforts within the already established sites are actually effective in protecting marine biodiversity and preserving aquatic resources.

It has been shown that the ecological effects of well-managed marine reserves deliver significant improvements in key biological variables such as density of species, biomass, body size, and species richness (Fenberg et al., 2012). It has been estimated that more than 1% of the European MPAs (looking at 16 countries) can be considered as being marine reserves with a high level of protection (Fenberg et al., 2012).

'Well-managed' thus often means having high levels of protection. For example, it has been documented that the conservation benefits of an MPA increase exponentially if it has five key features: it is a 'no-take' zone (i.e. no fishing, mining, or hydrocarbon extraction); conservation measures are well enforced; the MPA is more than 10 years old; the MPA is greater in size than 100 km^2; and the MPA is isolated by deep water or sand. In studies, MPAs with only one or two of these key features were not distinguishable from areas without MPA designation (Edgar et al., 2014; Halpern, 2014).

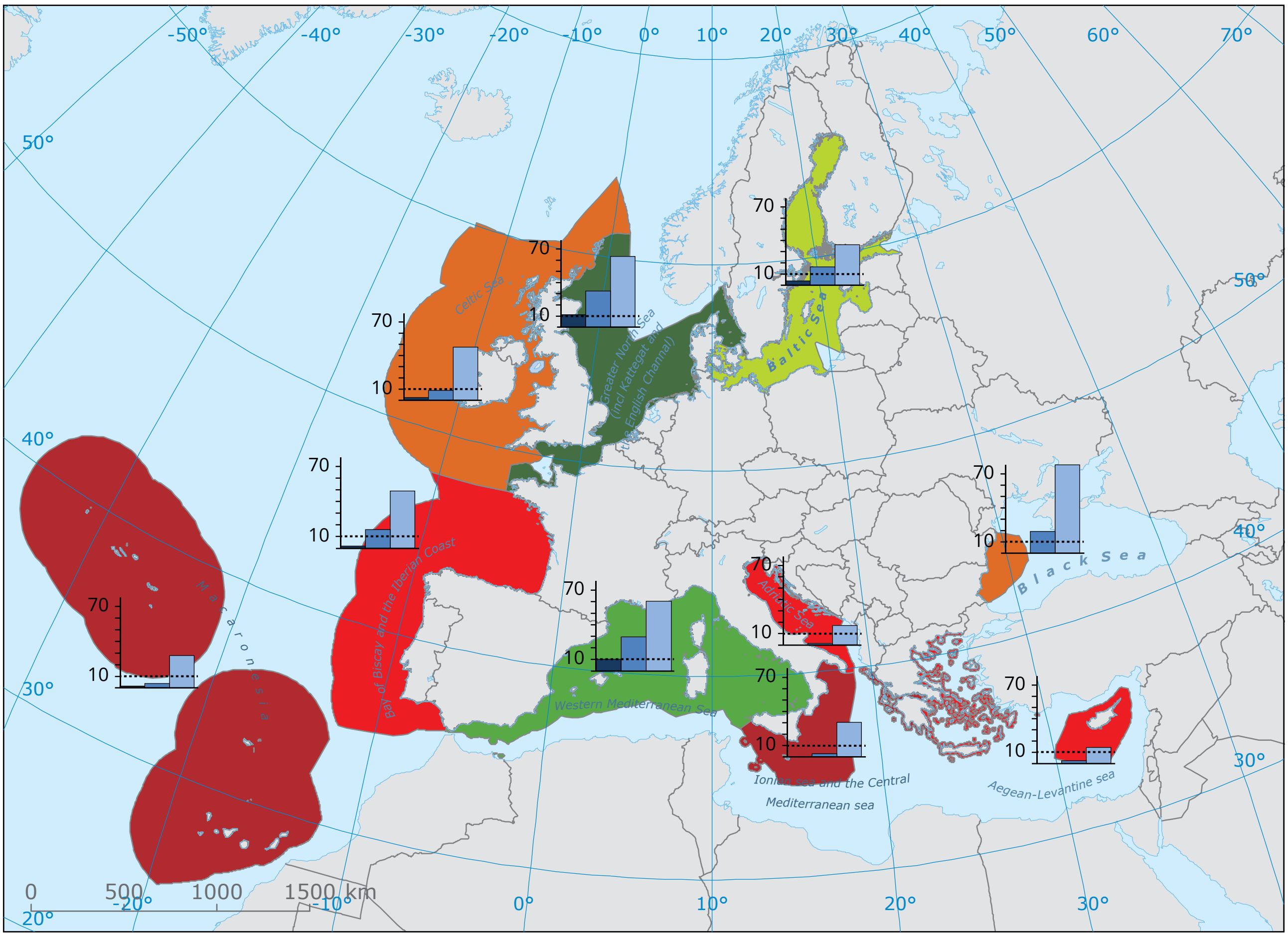
Improving Europe's MPA networks

The low number of assessments of species and habitats in 'favourable conservation status' as well as the low percentage of fish stocks with 'good environmental status' (see Chapter 3) indicates that the current management of Europe's MPAs is not yet as effective as it could be (and needs to be strengthened, perhaps by ensuring that they are managed with all five of the features mentioned above). So far, no coherent overview exists of the management effectiveness of Europe's MPA networks.

The EU already has the policy tools it needs to establish an ecologically coherent and representative MPA network. However, more efforts are needed to reach the 10% target in 7 out of 10 regional seas by 2020. In addition, significant efforts are needed to assess whether the network is effectively contributing to achieving 'favourable conservation status' for individual species and habitats and to the 'good environmental status' of the seas as a whole. Enforcement and survey data would help in making such assessments.

The MSFD does not specifically promote the establishment of more well-managed marine reserves (the strictest type of MPA with all five key features mentioned above) as part of the existing MPA network. However, this is an example of a spatial protection measure that could potentially help to achieve 'good environmental status' for Europe's seas.

Figure 6.1 **Percentage cover of marine protected area networks in European regional seas, including sites designated under Natura 2000, Regional Sea Conventions, and national legislation**



Distance to Aichi target 11 of 10% coverage

% of MPA coverage per EEA assessment area

- 0–2
- 2–4
- 4–6
- 6–8
- 8–10
- 10–12
- 12–14
- 14–16
- 16–18

Difference to 10% target in near shore, coastal and offshore distance

- 0–1 nautical miles
- 1–12 nautical miles
- 12 nautical miles to END

Disclaimer: For the Mediterranean Sea the boundaries are indicative only and do not imply any legal status.

Note: END is the end of the MPA assessment zone i.e. 12 nautical miles (NM) to END. This can be 200 NM or the equidistance to non-EU countries.

6.4 The long-term challenge of achieving sustainable fisheries in the EU

Fishing is one of the oldest maritime activities known to man, but it now has an uncertain future. The overexploitation of fisheries, together with inefficient fishing practices and the widespread use of high-impact fishing gear, have made fisheries one of the main drivers of ecosystem change in Europe's seas but also worldwide (Jackson et al., 2001a). The key role of fisheries in driving ecosystem change has not been helped by the EU's ineffective Common Fisheries Policy (CFP), whose shortcomings have been recognised (EC, 2007b; EC, 2009). Also, historically the CFP has not been implemented in a systemic way, which makes its long-term goal of achieving sustainable fisheries a challenge.

However, in recent years there have been important changes in fishing practices and in the CFP implementation. These changes have sought to better safeguard fish stocks and protect marine ecosystems, and have led to noteworthy improvements after decades of overfishing. This section discusses these changes in the new policy context relevant for fisheries management, set in particular by the MSFD. It also highlights some the main challenges ahead in securing a long-term transition to sustainable fisheries and the opportunity offered by ecosystem-based management.

A new policy context and objectives for fisheries management in the EU

EU fisheries are regulated by the Common Fisheries Policy (CFP). The CFP was first implemented in 1983 to ensure the conservation and sustainable exploitation of fisheries resources. It brought under one system the management of fisheries by EU Member States. It also defined a common approach to the structural development of national fishing fleets and to the organisation of domestic markets in fish and fish products (Symes, 1997). Since then, it has evolved incrementally, undergoing reforms every ten years. In spite of these reforms, the CFP failed to deliver on its policy objectives. By the time the third reform process began in 2009, there was a broad acknowledgement of the key failings of the CFP (EC, 2009). This led to a major revision of the CFP that came into force in January 2014 (EC, 2013d; Box 6.2).

The main objective of the revised CFP is *to ensure that fishing and aquaculture activities are environmentally sustainable in the long-term and are managed in a way that is consistent with the objectives of achieving economic, social, and employment benefits, and of contributing to the availability of food supplies*.

The environmental sustainability requirement of the new CFP has two key elements, one applying to fish stocks and the other to the ecosystem impacts of fisheries.

With regard to fish stocks, the new CFP requires populations of fish stocks to be progressively restored and maintained above biomass levels. This means applying the precautionary approach and not fishing beyond Maximum Sustainable Yield (MSY). This sustainable biomass objective has been further translated into an operational management target, which is to ensure that all fish stocks are exploited at MSY rates by 2015 where possible and by 2020 at the latest.

With regard to ecosystem impacts, the CFP also determines the implementation of the ecosystem-based approach to fisheries management (Box 1.2). This requires a fundamental shift in the priorities of fisheries management and the knowledge underpinning it, where the aim is no longer to maximise the catch of single fish stocks but to minimise the impacts of fishing activities (including aquaculture) on the marine ecosystem.

The new CFP is part of a shift in the broader environmental policy context, which can also be seen in the 2008 Marine Strategy Framework Directive

Box 6.2 CFP structural failures and major reforms in the new CFP

The structural failures of the CFP are recognised to have been mainly due to fleet overcapacity, an absence of clear objectives, continuous disregard of scientific advice and early warnings, lack of political will to ensure compliance, a decision-making system geared towards short-term gains, and insufficient responsibility given to the industry (EC, 2009).

The new CFP sought to address these failings and incorporated fundamental changes. It introduced changes to overcome the earlier failings, namely: clearer objectives with a Maximum Sustainable Yield target for fishing pressure, measures for conservation and sustainable use (e.g. multi-annual plans, fish stock recovery areas), introduction of a landing obligation, technical measures to protect marine biodiversity, adjustment of fishing capacity, and the introduction of more power for the regions (EC, 2013d).

(EC, 2008). The MSFD also adopts the ecosystem approach, and has the main objective of reaching 'good environmental status' (GES) of the EU's seas by 2020. The state of commercial fish stocks and the pressure and impacts of fisheries in the wider ecosystem are recognised as key components of GES. In particular for fish stocks, the MSFD describes GES as a level of exploitation that is at or below MSY, with full reproductive capacity (meaning reproductive capacity is equal or greater than MSY), and a population age and size distribution indicative of a healthy stock. It is therefore clear that the MSFD objective of reaching GES by 2020 is intimately linked with the CFP objectives. For this reason, it is critical to ensure that these two policies are implemented in an integrated way.

The MSFD also creates the obligation to implement ecosystem-based management in all human activities that affect the EU's seas. This means fisheries management will have to be integrated with other maritime activities so that their cumulative pressure and impacts do not affect GES. This integration is also at the core of the Maritime Spatial Planning Directive, adopted in 2014, which determines the application of an ecosystem-based approach to the spatial planning of all maritime activities (EC, 2014b).

Progress to reaching long-standing targets visible but efforts need to be stepped up

The new policy context for fisheries management sets 2020 as the deadline for the policy objective of fishing all stocks at MSY. This objective is to be achieved by following the precautionary principle and implementing an ecosystem approach. However, these objectives are not new. Similar commitments have been made before in the past by the EU and its Member States to relative little effect given the time span since their agreement (EEA, 2001; Proelss and Houghton, 2012; Salomon et al., 2014). Fishing at MSY has been the main goal for the management of fish stocks since as early as 1982, with its reference in the United Nations Convention on the Law of the Sea (UNCLOS). And at the 2002 World Summit on Sustainable Development (WSSD), the EU and other world nations committed themselves to maintaining or restoring fish stocks to a level that can produce MSY no later than 2015, while encouraging the adoption of the ecosystem approach to fisheries management by 2010. These commitments have been further reinforced in 2012 at the Rio+20 United Nations Conference on Sustainable Development (see the 'Future we want' resolution — UN, 2012).

The fact that the objective of fishing at sustainable levels, in line with the precautionary principle and following an ecosystem approach is enshrined in recent EU legislation (with the new CFP, MSFD, and other policies — see Table 1.2) shows this is a persistent and complex challenge. Although progress towards reaching these long-standing commitments has been slow, there have been significant improvements during the last 10 years. For example, there were significant achievements made in conservation during the late 2000s in the North-east Atlantic Ocean and the Baltic Sea. The situation in these seas changed from a state where nearly all assessed stocks where overfished in 2007 to one where currently around 40% of stocks are fished above MSY rates (EC, 2014a). This in turn has led to important signs of recovery in the reproductive capacity of certain stocks (Figure 4.4). The economic performance of the EU fishing fleets has also been improving in recent years, although this differs from fleet to fleet and from country to country (Cardinale et al., 2013, STEFC 2013).

In spite of these improvements, the current level of exploitation in European seas is still far too high for many fish stocks (Figure 3.6). As discussed in Chapter 3, most of the assessed commercial fish stocks in European seas (58%) are not at 'good environmental status' (GES). This means that neither the level of fishing pressure nor the reproductive capacity of fish stocks are fulfilling the MSY objectives. In addition, GES cannot be assessed for 40% of EU catches, making it impossible to assess if their status has indeed improved (Figure 3.7). There are also significant disparities between regional seas. For example, the status of the assessed fish stocks and availability of fish stock information is particularly poor for the Mediterranean and Black Seas.

The challenge ahead: implementing ecosystem-based management in fisheries

Historically, the aim of fisheries management has been to achieve a sustainable exploitation of the target species. This resulted in a European fisheries policy mostly geared towards the management of single species based on annual stock assessments. Stock assessments are important management tools to analyse status and compare status against reference points for sustainability or precautionary levels. However, to truly diagnose the impact of fishing, the full footprint of fisheries on ecosystem structure and functioning and its effects on ecosystem resilience should also be accounted for (Rice, 2011; Travis et al., 2014). Ecosystem indicators are important tools to facilitate such information. Unfortunately, ecosystem indicators are still not operationable or routinely calculated, and the analysis of the impacts of EU fisheries on ecosystems therefore remains incomplete (Gascuel et al., 2014; Probst and Stelzenmüller, 2015).

This hampers the adequate implementation of ecosystem-based management to fisheries.

In addition to considering ecosystem structure and functioning, ecosystem-based management also requires the consideration of human objectives. This means defining clear social and economic objectives for our use of the seas (Rice, 2011). As shown in this report, human development can compete with and degrade ecosystem health if these two systems are not analysed within a holistic approach. Although the significance of social issues in fisheries policy is acknowledged, its translation into explicit objectives and operational practices is a challenge (Symes and Phillipson, 2009). Competing objectives must therefore be considered by decision-makers to make adequate trade-offs between conservation objectives and use/exploitation objectives. Ecosystem-based management offers a platform for doing so in an adaptive way.

Implementing ecosystem based-management in Europe's fisheries has long been recognised as key to adequately manage fisheries resources and secure a long-term future to the activity. However its operationalisation remains a challenge that is equally acknowledged (Kempf, 2010; Rice, 2011). Bridging this gap is crucial and ever so more as the interest for the sea's natural capital increases. The recent advances in the development of integrated ecosystem approaches in the North-east Atlantic Ocean and Baltic Sea offer a promising opportunity to start bridging this implementation gap in Europe's seas (Dickey-Collas, 2014; Walther and Möllmann, 2014). Learning from these advances can also show promises for the subsequent development of ecosystem based management across Europe.

Strict implementation of ecosystem-based management therefore offers an opportunity to ensure fishing and other human activities can develop according to the limits of the ecosystem, and following the precautionary approach for where our knowledge is still lacking. With the new CFP and MSFD, the opportunity to do this is within the EU's grasp.

6.5 EU's marine knowledge

Messages on the EU's marine knowledge

- The current information-base available for the marine environment is fragmented and of poor quality. The information reported under by EU Member States under the 2012 Initial Assessment is not a comprehensive representation of the marine information-base in Europe. Indicators and other assessments already exist (and more are being developed) that could play a role in improving the information-base.
- One way that Europe is working to improve its knowledge base is by developing indicators. WISE-Marine is a pan-European project to improve marine indicators. Regional Seas Conventions are also developing their own indicators. In order to create EU-level assessments, it will be critical to improve the methodologies used to create indicators, as well as the underlying data used to populate them.
- Regional and national-level assessments of marine ecosystems can play an important role in assessing the quality of marine ecosystems. These types of assessment are all designed differently and they often do not originate in EU legislation. As a result, the outcomes they produce are not really comparable across Europe.

The information-base on Europe's marine ecosystems is fragmented and contains many gaps. This suggests the need for a more harmonised approach across Europe. This section looks at ways to bridge these gaps. It begins by looking at attempts by the EU and Regional Sea Conventions to improve indicators across Europe. Indicators are useful tools for assessment and management of marine areas, but much work remains to be done on improving the methodologies and data they use, especially if they are to provide the basis of an EU-level overview. The section then turns to regional and national-level studies of marine areas. Many of these studies use different methods so the results they produce are not comparable across Europe. However, they provide important insights for the development of EU-level overviews.

Marine knowledge — a complex European challenge

Implementing an ecosystem-based approach to the marine environment requires knowledge about the state of ecosystems, the pressures acting upon them, and the human activities that are responsible for these pressures. The EU's 'Blue Growth' strategy seeks to stimulate growth in the marine economy. However, because of our inadequate understanding of the status of the marine environment, there is a risk that the expansion of the marine economy is unsustainable. It is therefore critical that we work to improve our knowledge of Europe's seas.

The Marine Strategy Framework Directive (MSFD) seeks to establish the necessary knowledge-base on Europe's seas. The MSFD provides a common framework for national assessments to address the status of the 11 descriptors of 'good environmental status'. This common framework provides an opportunity to develop more consistent and coherent approaches to marine knowledge and marine assessment. These coherent approaches will be of great value not only in assessing the status of our seas, but also, when it comes to implementing other aspects of marine policy. However, although it provides a useful framework, there have been many shortcomings in the MSFD's Initial Assessments, which were compiled by Member States in 2012.

The European Commission has launched a number of initiatives to address the lack of knowledge and to support the development of the knowledge base on the marine environment. These initiatives are aimed at providing new technologies that can support Member States and Regional Sea Conventions in their work to better assess the marine environment.

Improving indicators to support ecosystem-based management

For the upcoming cycle of the MSFD initial assessments, significant effort is being made by MS and Regional Sea Conventions to close some of the gaps in our knowledge of Europe's seas. The MSFD requires that assessments are made against environmental indicators that reflect the development towards good environmental status, but for many themes of the MSFD, indicators still need to be developed. Indicators are often used as a tool to synthesise progress towards environmental targets, implying that regular updates to document development over time is an essential perspective. For many themes of the MSFD conceptual understanding of environmental indicators is in place and particular attention is being paid to the role that regional cooperation in the context of Regional Sea Conventions can play in closing these gaps. Indicator approaches often differ among Member States within the same region, and it is a major undertaking to achieve a higher degree of commonality. Also, the regular observations that document progress at the scale of marine (sub)regions are in many cases only beginning to be put in place.

Those efforts are, however, essential as documenting the progress towards good environmental status will require indicators that are relevant at a regional scale and show progress against regional targets. The knowledge base on the marine environment can thus be enhanced by increasing cooperation on indicators between the EU and the Regional Sea Conventions. To document these developments, WISE-Marine will be developed between all major actors that are producing marine information (Box 6.3).

The four Regional Sea Conventions are working to support the MSFD process with indicators, but there are considerable challenges to develop regional indicators for all 11 descriptors of the MSFD. Within the Baltic (HELCOM) and North-east Atlantic Ocean (OSPAR) regions, regional indicators have already been developed that cover eutrophication and contaminants. HELCOM also has operational indicators on marine mammals. Apart from these examples, the predominant situation is that regional-level indicators are either under development by the RSCs or do not yet exist. The greatest challenges lie with UNEP/MAP (Mediterranean) and the Black Sea Commission where all indicators are in the early stages of development. It must be borne in mind that even this brief overview does not reveal any information about the adequacy of the proposed indicators, or about the sometimes large regional differences in approaches.

The indicators needed for the MSFD will depend critically on consistent data being available. In the case of the underlying data, in some cases, the underlying data are transferred (flow) to a central repository from where analysis can take place. In other cases, experts in different locations perform analyses based on their access to observations and agreed methodology. In either case, it is critical to have identified the relevant observations and to ensure that Member States have monitoring programmes in place that allow changes to be tracked over time. These requirements make it necessary to establish extensive regional collaboration and coordination, a requirement that has become even stronger with the MSFD, and this will be integrated into the development of WISE-Marine. WISE-Marine is well-suited to assist in this coordination. It is being developed as a state-of-the-environment portal. Over time, WISE-Marine will provide access to these indicators.

The European Marine Observation and Data Network (EMODnet) is helping this process. It is a network of marine organisations that provide a single entry point for free and open-access retrieval of marine data from organisations throughout the EU. By facilitating access to data from multiple sources, and by harmonising this data, EMODnet can greatly reduce the effort needed to establish regional indicators. An additional benefit of EMODnet is that the free and open access to data improves transparency and quality.

Box 6.3 WISE-Marine

WISE-Marine will become the marine component of the Water Information System for Europe (WISE). It will be developed as a web-based portal for sharing information to the marine community on the marine environment. Through the topics selected to characterise the state of the marine environment, it will also provide a European perspective on the ecosystem-based approach. The information will be supported by data and indicators emanating from national, RSC, and European processes that support MSFD implementation. The target audience for information in WISE-Marine is the 'wider' MSFD community (experts and policymakers not necessarily directly engaged in the MSFD process itself). In addition, WISE-Marine will connect to the JRC's MSFD Competence Centre, which gathers information from research projects (such as FP7 and Horizon 2020) to help support the implementation of the MSFD.

6.6 What we have learned from EU marine policy implementation

Several conclusions can be drawn from the examples in Sections 6.2, 6.3 and 6.4.

First of all, these examples show the value of having an information-base covering the entirety of Europe's seas, and not only assessments from the waters of individual Member States. Marine ecosystems and the environmental pressures and impacts acting upon them are transboundary in nature. Therefore, the information-base to identify these pressures must cover all of the ecosystems in question rather than parts of it.

Secondly, the examples show that one of the biggest challenges remains the full and timely implementation of existing policy. For example, sustainability has been a core objective of the CFP since its creation, but there is still some distance to cover before all stocks are fished at MSY and before impacts upon the marine ecosystem are reduced to healthy levels (Table 6.1). Similarly, while significant progress has been made with the Natura 2000 network, Europe must still designate the same amount of protected sites in seven years as was done over the last 20 years if it is to reach agreed policy targets on coverage of MPA networks in Europe's seas.

Thirdly, looking at the policy framework for establishing MPA networks, there is considerable overlap and complexity. For example, countries like Denmark and Sweden have to designate MPAs under OSPAR, HELCOM, the Birds Directive, the Habitats Directive, and national law — all for the same sea area (the Kattegat). This makes it more complicated than necessary to implement policy and to measure progress against targets.

Lastly, individual policy goals are not always well coordinated. For example, it is necessary to better coordinate actions that support fisheries targets with actions that aim to complete the network of MPAs. It is also necessary to coordinate implementation of the Common Fisheries Policy and Habitats Directive with other activities such as aggregate extraction or offshore wind farms.

For all of these issues, the ecosystem-based approach to management introduced by policies such as the MSFD and CFP (and supported by maritime spatial planning) can help to bridge the gaps between these increasingly complex challenges by 2020.

So how great are these gaps? And how far has Europe progressed when it comes to implementing an ecosystem-based approach to the management of human activities in its seas?

Table 6.1 Summary of progress towards selected policy objectives and targets for achieving healthy, clean and productive Europe's seas, 2010–2020

Objective	Sources for target	Target	What is happening?
Healthy seas			
Halt the loss of biodiversity	EU Biodiversity Strategy to 2020	Compared to 2008 assessments, 50% more species assessments should show favourable conservation status in 2020.	3% of marine species assessments were favourable in 2008.
Halt the loss of biodiversity	EU Biodiversity Strategy to 2020	Compared to 2008 assessments, 100% more habitat assessments should show favourable conservation status in 2020.	7% of marine habitat assessments were favourable in 2008.
Clean and undisturbed seas			
Combating invasive alien species (IAS)	EU Biodiversity Strategy to 2020	By 2020, IAS and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS.	320 new marine non-indigenous species (NIS) observed since 2000. Impacts unknown for most of 1 400 recorded NIS. Aquaculture mediations appear controlled.
Reach Good Ecological Status of water bodies	Water Framework Directive	All European surface waters in 'good ecological status' by 2015.	By 2015, 52% of water bodies are expected to reach good status, compared with 42% in 2009
Fishing at Maximum Sustainable Yield (MSY)	Common Fisheries Policy (CFP)	All fish stocks should be fished at MSY rates by 2020 at the latest.	In 2014, 41% of assessed fish stocks in EU Atlantic and Baltic waters were fished at MSY rates compared to 6% in 2005.
Productive seas			
Develop further the offshore wind energy industry	EWEA 2013	Member States indicate that they will deploy 43.3 giga watt (GW) of offshore wind capacity to meet the EU's commitments to achieve 20% of its energy consumption through renewable energy by 2020.	Despite significant growth across Europe, only 6 GW had been installed by June 2013, compared to the expected 9 GW.
Marine knowledge			
Establishing a sustainable process ensuring that marine data is easily accessible, interoperable and free of restrictions of use.	Marine Knowledge 2020	Develop a multi-resolution map of the entire seabed and overlying water column of European waters by 2020, as a flagship initiative.	A new digital map of Europe's seabed topography was released in 2015 with a higher resolution than had previously been publicly available.
Member States shall cooperate on marine strategies	Directive 2008/56/EC (6-year cycle)	The different elements of marine strategies should be coherent and coordinated across marine regions and subregions.	In 2012, more than 70% of the reported maritime boundaries between EU Member States had either overlaps or gaps.
Reporting of conservation status of species and habitats	Directive 92/43/EEC (6-year cycle)	In order to monitor progress towards favourable conservation status, assessments of status are necessary.	70% of the marine species assessments and 40% of the marine habitat assessments were considered unknown in 2008.
Management measures			
Establish an ecologically coherent network of marine protected areas	CBD 2004	10% of European waters should be covered by networks of marine protected areas by 2012.	In 2012, 5.9% of European waters were covered by marine protected area networks. 3 out of 10 regions had achieved the target on coverage.

Source: Adapted from EEA, 2014b.

6.7 Finding long-term sustainable solutions — ecosystem-based management?

The Marine Strategy Framework Directive (MSFD), the Maritime spatial Planning Directive (MSPD) and the Common Fisheries Policy (CFP) are three of the main EU policies that adopt the ecosystem-based management (EBM) framework to human activities in the marine environment (see Chapter 1). These three instruments will play a central part in addressing the sustainability challenges faced by EU marine ecosystems. Ecosystem-based management is not a new concept, but making it a practical reality remains a challenge in Europe. It is therefore crucial to understand how far the EU has progressed in implementing ecosystem-based management for its seas today. It is also crucial to understand what challenges might prevent the EU from delivering on its policy objectives.

To answer these questions we compare the key elements of ecosystem-based management (EBM) with the findings in this report from across Europe's seas. Here we keep in mind that ecosystem-based management addresses the sum of ecosystem services and benefits we want to achieve from the marine environment rather than focusing on a single service or activity. The elements of ecosystem-based management we look at here are: recognising the spatial dimension; assessing cumulative impacts; acknowledging connections; and handling multiple objectives (EEA, 2014b).

Recognising the spatial dimension of EBM

Any number of activities can occur at a single location, whether it is an offshore wind farm, a fishery, or a leisure activity. Often these locations are also home to a large variety of species and habitats. For this reason, it makes sense to use a spatial approach that provides such an overview when managing human activities at sea. However, there are a number of obstacles to implementing a spatial approach as part of ecosystem-based management in Europe's seas.

One obstacle is the issue of geographical boundaries. A basic requirement of the success of environmental legislation is a clear definition of which geographic area it covers. But so far, there is no commonly accepted European reference map that delineates the sea areas where EU marine and maritime policies apply. Disputes, gaps, or overlaps on the position of maritime boundaries between countries exist for more than 70% of maritime boundaries within the EU, and cover some 200 000 km^2 (this includes minor and major disputes) (ETC/ICM, 2014). External boundaries towards non-EU Member States are also often disputed. Hence, for parts of Europe's seas it remains unclear who is responsible for implementing EU legislation. The European Environment Agency aim to publish a map of the European marine regions illustrating the current-state of affairs on boundaries between regional seas as recognised by Regional Sea Conventions and EU legislation.

A second obstacle is the lack of agreement between Member States on what should be the basic spatial unit of analysis. There are significant differences in how Member States have approached spatial assessment units in their initial reporting under the MSFD. In total, Member States have reported 280 assessment units — all of different sizes — across the approximately 5.7 million km^2 of sea area under the jurisdiction of EU Member States. One Member State is responsible for 132 units alone. The assessment units reported range in size from 162 km^2 to 488 763 km^2, and many of these units overlap with each other. Moreover, these units only covered 66% of the area where the MSFD applies (estimated as no formal map exists; ETC/ICM, 2014). For this reason, implementing ecosystem-based management will require Member States and the EU to overcome existing administrative barriers.

A third obstacle is that there is no 'correct' spatial scale at which an ecosystem-based approach should be implemented. The appropriate management scale should be determined by the connections within the ecosystem and its ecological features, as well as between these features and human activities. The marine regional and subregional scale is a pragmatic 'upper scale boundary' for implementation of the MSFD, and therefore for EU policy implementation. Defining these assessment scales consistently across Europe is an imperative for any ecosystem-based approach to management as well as for assessing 'good environmental states.

These challenges make it difficult to establish a quantitative, spatially explicit baseline covering all of the marine regions for almost any ecosystem component or human activity. This difficulty is evident for almost every parameter reported on under the MSFD Initial Assessment. Without a spatial baseline or even common terminology it will remain difficult to measure progress, establish new measures, and properly inform future policy actions.

Assessing cumulative impacts on a regional scale

A core component of an ecosystem-based approach is to analyse cumulative pressures and impacts rather than looking at individual pressures and impacts separately. It also means making this analysis across an entire regional sea rather than parts of it (such as national Exclusive Economic Zones).

It is a significant challenge to properly account for cumulative pressures and impacts. But not accounting for these cumulative pressures and impacts poses tremendous risks to adequately assessing ecosystem health and safeguarding ecosystem services essential to human well-being. As discussed in Chapter 4, HELCOM, the Regional Sea Convention in the Baltic Sea, has shown that it is possible to develop an integrated assessment on a regional scale. HELCOM did this by harmonising and combining maps of ecosystem features with maps of pressures resulting from human activities in a combined spatial analysis. This allowed for a spatial description of the relative impacts of human activities across the Baltic Sea (HELCOM, 2010).

Such spatial approaches could be further developed by EU Member States as part of their future marine assessments. However, very few harmonised data sets describing ecosystem features or human activities have been reported by any Member State so far (ETC/ICM, 2014). These spatial data sets are key to implement approaches across the marine regions to assess cumulative impacts and pressures. Therefore, Member States have to consider pooling their efforts to deliver this information and support ecosystem-based management. This pooling work has already begun in the context of the Regional Sea Conventions. A joint approach of this nature at EU level would help to develop common methodologies and reach a common understanding of how EU address 'cumulative pressures and impacts'. It would also help to identify, share, and harmonise the relevant national data sets within and across marine regions.

By working together to identify and assess cumulative pressures and impacts, we can finally begin an informed discussion of the trade-offs within and between sectors. This collaboration will make it easier to find integrated management solutions and measures that cover entire marine regions and subregions. Initiatives such as the EU Marine Knowledge 2020 initiative or the recent EU Directive on Maritime Spatial Planning could potentially provide strong support at all levels, ranging from data collection and exchange, to management and planning solutions.

Acknowledging connections

Ecosystem-based management means acknowledging connections. This includes connections within marine ecosystems, connections within the associated social systems, and connections between ecosystems and social systems. The most basic connection that needs to be acknowledged is the one between Member States sharing a marine region or subregion. Improved cooperation between countries sharing a marine region is urgently needed. For example, while Member States have in general defined what 'good environmental status' means for most of the MSFD descriptors, none have defined it in the same way or even similarly (EC, 2014e).

When we turn to EU policies and international organisations, the need to acknowledge connections becomes even more acute. Even very basic issues such as harmonising between geographic areas and terminology are a challenge. For example, the MSFD operates with four 'marine regions' but the Habitats Directive has five marine 'biogeographic regions'. This discrepancy makes a one-to-one translation of data more complicated than necessary. Another example is that until recently the International Council for Exploration of the Sea (ICES), which operated with different boundaries and regions (ICES ecoregions) than EU environmental legislation, making it a challenge to compare or use data (especially fisheries data) together with other reporting streams. Similarly, the Regional Sea Conventions use yet another set of boundaries and terminology to the EU and ICES. And these complexities are solely at the level of basic administrative boundaries. Assessing status or harmonising environmental or economic data is even more difficult, although it would be more cost-efficient to once-and-for-all agree to identical methodology and terminology for collecting and sharing information. Efforts addressing these issues are currently going on at EEA, ICES and the Regional Sea Conventions.

The situation becomes even more complicated when it comes to acknowledging the linkages between marine ecosystems and social systems. How will we actually connect our information on individual human activities and their pressures with ecosystem features? How will this information translate into knowledge about ecosystem health and resilience? How will we embed the MSFD implementation within our human systems of production and consumption? Such questions have not been addressed adequately within or across the marine regions. There is therefore a pressing need to further develop and discuss what 'acknowledging connections' actually means for EU policies and for the ecosystem-based approach to management of human activities.

Handling multiple objectives

Perhaps one of the more important emerging challenges is how to integrate the multiple policy objectives existing for Europe's seas into a coherent whole. We need to better understand how different policy targets relate to each other, from a science, policy, and management point of view. We also need to understand how these targets relate to maritime activities and to the ambitions of other stakeholders to make greater use of the sea. For example, the European Commission has shown that Member States often do not take into account even their existing obligations (e.g. under other EU Directives) when they outline the path by which they intend to reach 'good environmental status'. Here too, there is a lack of coherence, both across the EU, and between countries that share the same marine region or subregion (EC, 2014e).

Another way in which we need to handle multiple objectives is by better understanding the interactions between different policy objectives, such as the relation between 'good environmental status' (MSFD), 'good ecological status' (Water Framework Directive), 'favourable conservation status' (Habitats Directive), and fishing at Maximum Sustainable Yield. Meeting one target might not automatically deliver the others.

At the same time, a number of other sectoral objectives exist that are not always mutually compatible with environmental objectives, but nor are they always mutually exclusive. Finding the appropriate, balance between exploitation/use of the sea and sustainability will be a key challenge for EU policies in the near future. Ecosystem-based management could provide a platform for finding this balance. But in order to do so, ecosystem-based management has to be explicit about the trade-offs between multiple objectives.

The traditional way of making these trade-offs was to do so on a local and sectoral basis. For example, the installation of offshore wind power might be accepted in one location at sea in return for the expansion of a marine protected area elsewhere. However, these trade-offs are at too small a scale to protect ecosystems. In order for trade-offs to be ecologically coherent they must be integrated and managed across entire seas, and across the countries, communities, and governance structures sharing those seas. With the MSFD, Europe already has a legal framework and shared desire to ensure that its seas remain healthy while allowing for its sustainable use. If properly used, the MSFD could provide part of the solution to how we maintain a balance between short-term gains and long-term sustainability. However, for doing so, its implementation has to be coordinated and integrated with the wider legislative and policy frameworks that apply to Europe's seas.

These legislative and policy frameworks are becoming increasingly complex. Successfully implementing these policies — and the systemic challenges they aim to address — thus requires governance structures that are capable of grasping the 'big picture' and maintaining it at the different levels of governance (national, regional, European, etc.). For this reason, governance structures need to better understand how to balance multiple objectives while simultaneously promoting sustainability. It also means that governance structures need to be better at recognising the connections between policies and at recognising the full range of factors that influence the issues they target. Shaping governance structures to accomplish these aims will require new approaches that are flexible and adaptive, more collaborative and inclusive, and more integrated than traditional administrative structures. Ecosystem-based management offers an opportunity to shape governance structures in this new way.

Conclusion: towards 2020 and healthy seas

Let us return to the question: how far has Europe implemented ecosystem-based management for its seas? The examples presented for each key component above indicates that ecosystem-based management of human activities in the marine environment is still poorly understood in Europe. Nevertheless, in some seas, individual Member States and some Regional Sea Conventions have made progress.

Despite this overall failure to implement ecosystem-based management more widely, the EU and its Member States have taken an important step towards the ecosystem-based management of our seas with the current implementation of the MSFD, the Habitats Directive, and the Common Fisheries Policy. The process of producing the Initial Assessments under the MSFD is itself of tremendous value. It has shown that Member States have a huge depository of data and knowledge, but that it remains largely untapped for applying ecosystem based-management.

At a core of this discrepancy lie inadequate governance structures and information exchange mechanisms capable of handling and integrating multiple objectives at a regional level. To overcome this situation, the dialogue has been intense through the MSFD Common Implementation Strategy, in the Regional Sea Conventions and between individual Member States sharing the marine regions. As a result, several processes are now in place to enhance stakeholder collaboration and improve the streamlining of the implementation of different EU policies and regional commitments. For example, the Regional Sea Conventions are making important changes to their processes of data exchange and assessment provision to ensure more coherent assessments of the marine environment at the regional level. The European Commission has also started several processes to better integrate across policy objectives, such as the WFD, the nature directives and CFP with the MSFD.

Innovative methodologies such as the use of area-based assessment tools are also appearing. These methodologies and associated tools allow a better understanding of where and how human use impacts ecosystems and drives change (Andersen et al., 2013; Andersen et al., 2015). Acknowledging these connections is key to assess trade-offs and prioritise objectives in a context of multiple use of the seas.

As a final reflection, the need for new environmental policies for Europe's seas appears small because existing policies are starting to show results. Instead of new policies, Europe must focus on two challenges: 1) the timely and adequate implementation of existing policies and legislation, and 2) how to focus its future efforts in terms of creating agreed spatial boundaries, assessing cumulative impacts, improving 'connections', and handling multiple objectives covering entire regional seas.

Whatever solutions Europe will choose, they will depend on sound information and a strong knowledge-base. Our seas are facing unprecedented change, and knowledge is fast becoming our most precious resource. It is only with access to coherent, accurate, and unbiased information that Europe can formulate effective solutions to our environmental problems. The next chapter will discuss the state of the current information base available for Europe's seas, and will give an overview of the direction that Europe is taking in order to improve that knowledge base to ensure that it can inform the 2020 policy objectives.

7 Assessing marine ecosystem services to better manage our use of the sea's natural capital

Summary of main points in this chapter

- The way we use the natural capital of Europe's seas does not appear to be sustainable, i.e. we may be mismanaging this use. Thus, the self-renewal of marine ecosystem capital, its biotic constituent, may be at risk because of the significant degradation and loss of marine ecosystems and biodiversity reported across Europe's seas.
- To a certain extent, degradation and loss of marine ecosystems and biodiversity is caused by direct pressures from human activities using marine ecosystem capital itself. However, a greater range of pressures, both in terms of numbers and type, are exerted on marine ecosystems and biodiversity indirectly by human activities using/sourcing marine abiotic natural capital.
- The main pressures on marine ecosystem capital are physical damage and loss as well as biological disturbance. These pressures can be exerted by fisheries, aquaculture, dredge disposal and construction at sea, mineral and aggregate mining, dredging, and marine and coastal tourism. Many of these human activities, but not fisheries, are on the increase.
- The possible risk to the self-renewal of marine ecosystem capital from human activities would be difficult to manage due to the substantial lack of knowledge on the state of marine ecosystems and biodiversity overall reported across Europe's seas (in addition to their degradation). For example, 80% of marine biodiversity assessments and 100% of ecosystem assessments under the Marine Stratgey Framework Directive's Initial Assessment show that their 'overall status' is 'unknown'.
- The possible mismanagement of our use of the natural capital of Europe's seas has worrisome implications for meeting the basic needs and supporting the well-being and livelihoods of Europeans (as well as for the European economy more broadly) since we all depend on it. Marine ecosystem capital is the part of the sea's natural capital that most directly supports our daily lives because of the potential of marine ecosystems to deliver ecosystem services. These are the final outputs or products from marine ecosystems that are directly consumed, used (actively or passively) or enjoyed by people.
- Marine ecosystem services include provisioning services (such as food from fish); regulation and maintenance services (such as the sea's ability to absorb greenhouse gases, thus regulating the climate); and cultural services (such as the availability of charismatic marine species to observe or to research). We get many benefits from these services such as nutrition, reductions in anthropogenic CO_2, and recreation.
- All the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat, i.e. their delivery may not be sustained/continued over time.
- There are possibilities for better EU-level assessment of the potential of marine ecosystems to supply services than the one provided in this chapter, and even for full marine ecosystem service assessments. However, these possibilities have not completely materialised as yet.
- The ecosystem services concept is still not a 'common language' across the EU with which to communicate about all the benefits people get from marine ecosystems in an EU-policy and management context. Having such a common perspective should help us to better manage all human activities using the natural capital of Europe's seas in order to prevent its misuse.

As explained earlier in this report, people depend on the sea's natural capital to meet their basic needs, and to support our well-being and livelihoods (and the economy more broadly). Of the two constituents of the sea's natural capital, marine ecosystem capital (the biotic constituent) is the one that most directly supports our daily lives. This is because of the capacity of marine ecosystems to generate ecosystem services, which are the final outputs or products from ecosystems directly consumed, used (actively or passively) or enjoyed by people. These ecosystem services cannot be replaced by the abiotic constituent of the sea's natural capital. The availability of marine ecosystem capital is therefore critical for people.

In principle, a lot of marine ecosystem capital is renewable. However, it can be degraded or lost when the use of the sea's natural capital overall is mismanaged. Degradation and loss of marine ecosystem capital stem from human use of both marine ecosystem capital itself and marine abiotic natural capital, as human activities using/sourcing marine abiotic outputs can also damage ecosystems indirectly. Maintaining marine ecosystem capital requires that such use is sustainable, i.e. within the ecosystem's carrying capacity. Knowing about the state of marine ecosystem capital can therefore orient policy and management towards ensuring the sustainable use of the marine environment as a whole (i.e. of the sea's natural capital), leading to 'healthy' seas and meeting people's needs and supporting our well-being over time.

7.1 About this chapter

The main aim of this chapter is to assess the state of marine ecosystem capital, and conclude on whether the use of the natural capital of Europe's sea is sustainable, or leads to the degradation and loss of marine ecosystems and their services.

In this chapter, we discuss different ways of assessing marine ecosystem capital, in particular ecosystem services. Marine ecosystems comprise many different components that can deliver ecosystem services. It is therefore a complex task to consider these components in a comprehensive and meaningful way. In spite of these difficulties, the chapter includes an assessment of Europe's marine ecosystems and establishes how their condition is affecting the delivery of ecosystem services. Other assessments also exist. All these assessments show significant degradation of Europe's marine ecosystems and, additionally, a substantial lack of knowledge on the condition of marine ecosystems. This evidence has led us to conclude that all the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat.

We begin in Section 7.2 by defining and classifying marine ecosystem services. Then, Section 7.3 assesses marine ecosystem services at the EU level on the basis of the 'supply-side' approach for the assessment of ecosystem services. This approach focuses on the ecosystem's capacity to deliver services, and assumes that the condition of a particular ecosystem is a good indication of that capacity. In this section, we look at the premises for this assessment, where the assessment information comes from, the methodology used to process the information, the assessment outcomes, and the conclusions that can be drawn from this assessment.

In Section 7.4, we focus on the ways in which the assessment of marine ecosystem services can be improved at the EU level. In this section, we refer to EU-level initiatives supporting this improvement, and we also reflect on the challenges that these initiatives need to overcome in order to be successful.

In Section 7.5, we look at existing knowledge on marine ecosystem service assessment across the EU. There are national, regional and other assessment approaches that have not been sufficiently reflected in EU-level initiatives supporting marine ecosystem service assessment. Our view is that these approaches could be used to overcome some of the challenges faced by EU-level assessments.

In Section 7.6, we look at a the 'demand-side' approach for assessing (marine) ecosystem services, which focuses on how much marine ecosystem flows are actually consumed, used or enjoyed by people and become services, and on the economic valuation of the benefits obtained from these services. Placing an economic value on the benefits of ecosystem services is challenging, and raises many political/ethical and methodological problems. In spite of these difficulties, these economic valuations are already part of policy-related assessments. Nevertheless, economic valuations are subject to high degrees of uncertainty and need to be used with caution.

In Section 7.7, we look at how Member States have used the 'ecosystem services' concept in the socio-economic analyses under the Marine Strategy Framework Directive's Initial Assessments. In this section, we focus on establishing whether Member States have estimated the cost of the degradation associated with their use of marine ecosystems and their services (i.e. marine ecosystem capital).

In Section 7.8, we conclude the chapter with a reflection on what the assessments of marine ecosystem capital show in the context of the overall sustainability of our use of the natural capital of Europe's seas. Our conclusion is that the self-renewal of marine ecosystem capital may be at risk and that such a risk would be difficult to manage. Therefore, the way we use the natural capital of Europe's seas does not appear to be sustainable, a conclusion which has worrisome implications for meeting the basic needs and supporting the well-being and livelihoods of Europeans (as well as for the European economy more broadly) since we all depend on it.

7.2 Framing marine ecosystem services

Summary of main points in this section

- Socio-technical systems require continuous flows of both abiotic resources and ecosystem services to operate. The relationships between socio-technical systems and ecosystems are very complex. The concept of ecosystem services offers a 'common language' to structure our thinking on these relationships. It can allow people to better understand and relate to all the benefits provided by marine ecosystem capital. This common language can therefore help in the formulation of policy and in decision-making, including in the identification of trade-offs and the resolution of conflicts between the different uses of the seas' natural capital.
- Ecosystem services are the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people. The Common International Classification of Ecosystem Services (CICES) is the 'EU reference' typology for all ecosystem services. CICES considers that the generation of ecosystem services must involve living organisms; therefore, abiotic environmental outputs (e.g. sea salt) are not services under this typology.
- CICES separates ecosystem services (e.g. fish biomass) from the benefits they can provide to people (e.g. the nutritional value of the fish biomass). Marine ecosystem services include provisioning services (such as food from fish); regulation and maintenance services (such as the sea's ability to absorb greenhouse gases, thus regulating the climate); and cultural services (such as the availability of charismatic marine species to observe or to research). We get many benefits from these services such as nutrition, reductions in anthropogenic CO_2, and recreation.
- There has been EU-level work delineating and verifying the marine ecosystem services from within the broad typology established by CICES. We have built on this work and developed an improved marine ecosystem services typology for EU-level use. However, there is still a need for some 'marine optimisation' of CICES.

The ecosystem services concept as a 'common language' to reach policy and management decisions

The concept of ecosystem services is anthropocentric in nature, given that ecosystems have the potential to deliver ecosystem services (service 'supply') regardless of whether those services are utilised by people (service 'demand') or not. Ecosystem characteristics, i.e. their structures, processes and functions (including the interactions between them), only become services if there are people who directly consume, use, or enjoy them, and thus benefit from them (Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al, 2013). Service use is defined as an 'active or passive human demand', i.e. a want or need (Haines-Young and Potschin, 2013).

In a policy or management context, the ecosystem services concept can be used as a 'common language' to structure our thinking on the complex relationships between ecosystems and socio-technical systems. Socio-technical systems require continuous flows of both abiotic resources and ecosystem services to operate, and therefore act as 'drivers of change' on the sea's natural capital, and on marine ecosystems in particular (Figures I.1 and 2.1). The ecosystem services concept can allow people to better understand and relate to all the benefits from marine ecosystem capital. It could thus lead to having a common perspective to structure thought processes, base negotiations, and improve transparency and communication (Granek et al., 2010). This 'common language' can therefore help in the formulation of policy and in decision-making, including in the identification of trade-offs and the resolution of conflicts between the different uses of the sea's natural capital. An example of trade-off identification: the total social benefits from carbon capture and storage by the high seas, a global climate regulation service, amount to USD 148 billion a year; whilst the food provisioning service from the high seas is USD 16 billion a year (Rogers et al., 2014). This has led to suggesting that high-seas fisheries should be stopped because they damage the ecosystems upon which the more beneficial (ecologically, economically and socially) global climate regulation service depends (Rogers et al., 2014).

Defining and classifying ecosystem services

A consistent definition of ecosystem services is vital in order to achieve such a 'common language'. Ecosystem services, including those that come from marine ecosystems, were defined by the Millennium Ecosystem Assessment ([15]) as 'the benefits people obtain from

([15]) The Millennium Ecosystem Assessment was the first global assessment of the condition and trends in ecosystems and the services they provide.

ecosystems' (MA, 2005). The Economics of Ecosystems and Biodiversity international initiative refined this definition and considers that services are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2009, 2010).

The 2013 Common International Classification of Ecosystem Services (CICES ([16])) is the third international ecosystem services definition and classification system. It was developed to support both ecosystem assessment and ecosystem accounting (Section 7.6). CICES is the classification used as a reference at the EU level (Maes et al., 2013) (Table 7.1, Section 7.4).

One of the main differences between CICES, the MA and TEEB is their definition of ecosystem services (see Box 7.1 for differences in service classification). Under CICES, ecosystem services are considered the direct contributions that ecosystems make to human well-being. Thus, ecosystem services are the link between ecosystems and things that people benefit from (e.g. fish biomass), and are not the benefits themselves (e.g. the nutritional value of the fish biomass) (as per Fisher et al., 2009, and clarified in Atkins et al., 2013). This is because getting the benefit requires human input/action (e.g. processing of the fish biomass for marketing). In a CICES context, therefore, services are the 'final' outputs or products from ecosystems, i.e. the things that are directly consumed, used (actively or passively) or enjoyed by people ([17]) (Haines-Young and Potschin, 2013; Maes et al., 2013).

Marine abiotic outputs and CICES

Given that CICES defines ecosystems in terms of the interaction between living organisms (biota) and their abiotic environment, it then argues that the generation of an ecosystem service must involve biota (and thus depends on biodiversity). Indeed, under CICES, ecosystem services are seen as arising from biota and/or the interaction of biotic and abiotic processes at the ecosystem level. Therefore, a fundamental characteristic of ecosystem services is that they retain a connection to the underlying ecosystem structures, processes and functions that generate them (Haines-Young and Potschin, 2013) (Chapter 2). According to this strict definition, marine abiotic environmental outputs, such as salt, sand, oil or gravel, are not included in the CICES main system as provisioning services, and neither is seawater volume (although potable freshwater volume is considered as a provisioning service) (Haines-Young and Potschin, 2013; Maes et al, 2013). Nevertheless, abiotic environmental outputs have been outlined in a separate 'complementary classification' under the CICES approach (Table 7.2).

Identifying marine ecosystem services and marine abiotic outputs

As was the case with the generalised model for marine ecosystem service generation (Chapter 2), the criteria underpinning CICES originated in the terrestrial

Box 7.1 Classifying ecosystem services

Both the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity international initiative provide for a similar classification of ecosystem services in four categories depending on the role of the services in human well-being. In the case of the MA, these four categories are: provisioning services (e.g. fish as food), regulating services (e.g. marine climate regulation), cultural services (e.g. recreation such as snorkelling), and supporting services (e.g. marine nutrient cycling) (MA, 2005).

CICES differs from the MA and TEEB services classifications in that it recognises only three categories (called 'sections') of 'final' ecosystem outputs: provisioning services, regulation and maintenance services, and cultural services (Table 7.1). CICES does not include the so-called 'supporting' services, which is a category first defined in the MA and also used under TEEB (although in TEEB this category includes the 'habitats for species' and 'maintenance of genetic diversity' services, which makes it different from the MA's (TEEB, 2009)). CICES excludes 'supporting' services because it considers that these are part of the processes and functions that characterise ecosystems (Chapter 2) and thus they may simultaneously facilitate many 'final' ecosystem outputs. These 'supporting' services are therefore only consumed or used by people indirectly rather than directly, which is the CICES criterion defining services (see the correlation between MA, TEEB and CICES service typologies in Maes et al., 2013).

Source: Adapted from Haines-Young and Potschin, 2013; and Maes et al., 2013.

([16]) Common International Classification of Ecosystem Services (http://cices.eu).
([17]) In this context, Haines-Young and Potschin (2013) further specify that services are ecosystem outputs directly consumed, used (actively or passively) or enjoyed by a *beneficiary*.

domain, although it includes services from marine ecosystems. A first attempt at delineating and verifying the marine ecosystem services from within the broad typology established by CICES was carried out by Maes et al. (2014). This attempt showed that several of the CICES ecosystem services classes are not relevant for marine ecosystems, while some other classes lead to difficulties in proper interpretation in a marine context (Maes et al., 2014).

An example of the lack of relevance for marine ecosystems is the 'energy provisioning' services class, where the 'animal-based mechanical energy' service (such as horsepower for pulling farm equipment) has no known marine equivalent.

An example of the difficulties in interpreting what a specific service would be in a marine context is the 'regulation and maintenance' services linked to the 'mediation of mass flows'. Thus, the service classes on 'mass flow stabilisation and control of erosion rates' (erosion prevention) and 'buffering and attenuation of mass flows' (sediment retention) both involve the accumulation and stabilisation of marine sediments, as well as the attenuation of wave energy, in order to prevent erosion and to buffer the movement of sediments (Culhane et al., unpublished) (Table 7.1). Given that the individual benefits from each of these service classes are not clear, it might be helpful to aggregate the two classes into one (Culhane et al., unpublished).

Maes et al. (2014) therefore concluded that some 'marine optimisation' (further development) of the current version of CICES (v4.3) was needed. Table 7.1 aims at improving on the work by Maes et al. (2014) with regard to extracting the marine ecosystem services from CICES (v4.3). This improvement also builds on other work, including a study commissioned by the EEA (Culhane et al., unpublished).

Table 7.1 excludes services not relevant to marine ecosystems. It also excludes possible services where the contribution from marine biota is deemed to be negligible compared to that of abiotic processes within marine ecosystems. Therefore, it excludes cases where the generation of the services does not involve marine biota in a significant manner.

For example, even if marine 'ecosystem dilution' is a way to mediate waste and toxicants, where bioturbator and filter feeding biota may facilitate dilution of substances/particles, it has not been included under the 'regulation and maintenance services' category in Table 7.1. This is because the bulk of waste and toxicant dilution in marine ecosystems would be a physical process and rely on seawater volume and movement. For example, in the North-east Atlantic Ocean this possible service would be mostly delivered by abiotic processes, such as wind-driven mixing, global currents, and tidal movement in the seawater column (Culhane et al., unpublished).

Another example of the negligible role of marine biorta versus that of abiotic processes would be the possible 'hydrological cycle and water flow maintenance' service, also under the 'regulation and maintenance services' category. Biota-mediated contributions to this service would be localised coastal influences by the dimethylsulphide produced by phytoplankton, and localised flow changes from macrophytes/macroalgae. However, the major forces driving the hydrological cycle are physical process such as evaporation, condensation, and precipitation, and so these biota-mediated local contributions are not considered, and the possible service is also dismissed from Table 7.1 (Culhane et al., unpublished).

Service identification in Table 7.1 is based on evidence of the actual use of the services in the EU, and so it excludes experimental use, such as laboratory-produced algal (e.g. from phytoplankton) and marine invertebrate (e.g. from tunicates) biofuels for energy provisioning. In fact, the table excludes the whole 'biomass-based energy' provisioning service group from CICES. This is due to lack of current evidence in the literature of the gathering of wild marine plants, algae and animals, and their outputs, for burning and thus of the use of this provisioning service in the EU (Culhane et al., unpublished).

Service identification also takes into account EU and global regulation for the protection of certain species of birds, mammals (e.g. whales), and reptiles (e.g. turtles) by excluding certain services linked to them (e.g. nutrition provisioning from whale biomass, or raw material provision from turtle shell to make combs). However, this regulation may be subject to national derogations under certain conditions and, in those instances, the relevant services have been included in the table (e.g. nutrition provisioning from waterfowl (birds) biomass) (Culhane et al., unpublished).

Table 7.1 includes services where the marine ecosystem contribution is marginal compared to that of freshwater and terrestrial ecosystems. For example, under 'regulation and maintenance' services, salt marsh plants (species of grasses, shrubs and herbs that can tolerate the salty conditions of these marshes) could deliver the CICES 'micro and regional climate regulation' service. Thus, these plants could cause small scale changes in temperature, humidity, wind patterns, and precipitation, which is what this service is about. However, this contribution from salt marsh plants would be at a much smaller scale than the contribution delivered by other ecosystem stocks, e.g. forests (Culhane et al., unpublished). Such 'marginal' marine services are included in the table to be faithful to the role of marine ecosystems and their biota in service generation in the EU. However, these services may eventually be excluded from a EU-level ecosystem service assessment covering all ecosystems (and services).

The table also includes some services where there are still question marks over their marine interpretation. For example, under the 'regulation and maintenance' category, the services linked to the 'mediation of waste, toxicants and other nuisances' via filtration/sequestration/storage/accumulation have been split up on the basis of whether they are provided by biota or by ecosystems (i.e. biota and ecosystem working in tandem). This separation appears to be artificial in a marine context (Culhane et al., unpublished). Further interpreting these services to ensure adequate delineation in a marine context may require structural changes to CICES (v4.3), which would only be possible through a wider discussion in a full CICES context. Therefore, these 'unclear' services have been kept on the table until such a discussion takes place and a final decision on whether or not they should be removed can be made.

Culhane et al. (unpublished) investigated the application of the classification in Table 7.1. Despite coming across issues supporting the need for some 'marine optimisation' of CICES (v4.3), such as those highlighted above, their findings show that this classification has improved on the work of Maes et al. (2014). The overview and classification of marine ecosystem services in Table 7.1 is therefore the most adequate for EU-level use at present.

Table 7.1 Overview of the natural capital of Europe's seas: broad themes and classes of marine ecosystem services

<table>
<tr><th colspan="3">Marine ecosystem services</th></tr>
<tr><th>CICES Section</th><th>CICES Division</th><th>Summarised from CICES Group and Class</th></tr>
<tr><td rowspan="2">Provisioning
All materials and biota constituting tangible outputs from marine ecosystems. They can be exchanged or traded, as well as consumed or used by people in manufacturing.</td><td>Nutrition => All marine ecosystem outputs that are used as foodstuffs (seafood).</td><td>Biomass from marine plants, algae and animals, and their outputs
• Wild capture seafood
• In situ aquaculture seafood</td></tr>
<tr><td>Materials => Marine biotic materials that are used in the manufacture of goods.</td><td>Raw materials from marine plants, algae and animals, and their outputs
• Fibres and other materials for direct use or processing
• Materials for agricultural and aquaculture use
• Genetic materials for biochemical, industrial and pharmaceutical processes</td></tr>
<tr><td rowspan="2">Regulation and maintenance
All the ways in which marine biota and ecosystems control or modify the biotic or 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.</td><td rowspan="2">Mediation of waste, toxicants and other nuisances => Marine biota or ecosystems can mediate (neutralise or remove) waste and toxic substances that result from human activities. This mediation has the effect of detoxifying the marine environment.</td><td>Mediation by marine biota (micro-organisms, plants, algae, and animals)
• Bio-remediation
• Filtration/sequestration/storage/accumulation</td></tr>
<tr><td>Mediation by marine ecosystems
• Filtration/sequestration/storage/accumulation
• Mediation of smells/noise/visual impacts</td></tr>
</table>

Table 7.1 Overview of the natural capital of Europe's seas: broad themes and classes of marine ecosystem services (cont.)

Marine ecosystem services		
CICES Section	**CICES Division**	**Summarised from CICES Group and Class**
Regulation and maintenance (cont.) All the ways in which marine biota and ecosystems control or modify the biotic or 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.	*Mediation of flows* => Marine biota/ecosystem contribution to maintaining coastal landmasses and currents, reducing the intensity of floods, and keeping a favourable ambient climate.	*Mass flows* • Mass stabilisation and control of erosion rates • Buffering and attenuation of mass flows
		Liquid flows • Flood protection
		Gaseous/air flows • Ventilation and transpiration
	Maintenance of physical, chemical and biological conditions => Marine biota/ecosystem contribution to the provision of sustainable human living conditions.	*Life-cycle maintenance, habitat and gene-pool protection* • Seed and gamete dispersal • Maintaining nursery populations and habitats • Gene-pool protection
		Pest and disease control • Pest control • Disease control
		Soil formation and composition • Weathering processes • Marine sediment decomposition and fixing processes
		Water conditions • Chemical condition of salt waters
		Atmospheric composition and climate regulation • Global climate regulation by reduction of greenhouse gas concentrations • Micro- and regional climate regulation
Cultural Includes all non-material marine ecosystem outputs that have physical, experiential, intellectual, representational, spiritual, emblematic, or other cultural significance.	*Physical and intellectual interactions with marine plants, algae, animals, ecosystems, and seascapes* => Marine biota/ecosystem provision of opportunities for recreation and leisure as well as intellectual, emotional, and artistic development that can depend on a particular state of marine/coastal ecosystems (or where this can enhance it).	*Physical and experiential interactions* • Experiential use of marine biota (e.g. whale watching, snorkelling) • Physical use of marine ecosystems and seascapes (more sports-type activities such as sailing and leisure angling)
		Intellectual and representational interactions • Scientific • Heritage • Educational • Entertainment • Aesthetic
	Spiritual, symbolic and other interactions with marine plants, algae, animals, ecosystems, and seascapes.	*Spiritual and/or emblematic interactions* • Symbolic • Sacred and/or religious
		Other cultural interactions ([18]) • Existence • Bequest

Note: Service section and division titles come directly from CICES (v4.3 http://cices.eu). Group and class names are summaries of those used in CICES. The original CICES table includes examples of each class in order to help service delineation. Marine ecosystem service identification is based on evidence of actual (not experimental) use of the services in the EU. It also takes into account EU and global regulation for the protection of certain species of birds, mammals, and reptiles, and so excludes certain services linked to them (although these may be subject to national derogations under certain conditions and some of these have been included). It also excludes possible services where the contribution from biota is deemed to be negligible compared to that of abiotic processes (e.g. a possible marine 'hydrological cycle and water flow maintenance' service, where phytoplankton and macrophytes/macroalgae have a very small and localised role compared to the physical process driving the hydrological cycle such as evaporation, condensation, and precipitation. In this case, the role of phytoplankton and macrophytes/macroalgae and, therefore the possible service, is dismissed).

Source: Adapted from Fletcher et al., 2012; Salomidi et al., 2012; Boehnke-Henrichs et al., 2013; CICES, v4.3, 2013; Maes et al., 2013; Maes et al., 2014; and Culhane et al., unpublished.

([18]) Existence: Relates to people placing value on simply knowing that something exists, even if they will never see it or use it.
Bequest: Relates to people placing a value on knowing that future generations will have the option to enjoy something.

The CICES system excludes abiotic environmental outputs, as they are not ecosystem services. However, CICES outlines these abiotic outputs separately, because that also helps to understand what are or are not ecosystem services. Further work is needed to improve the definition and classification of these abiotic outputs. Nevertheless, given that one of the aims of this report is to show all the benefits people can get from the sea, we have included the current classification of abiotic environmental outputs under CICES and adapted it to the marine environment as in Table 7.2 here. This table therefore complements Table 7.1, which had shown the equivalent for marine ecosystem services.

Table 7.2 Overview of the natural capital of Europe's seas: broad marine abiotic output themes, classes and non-exhaustive examples

Marine abiotic outputs		
CICES Section	**CICES Division**	**CICES Group and some examples**
Abiotic provisioning	*Nutritional abiotic substances*	*Mineral*, e.g. salt
	Abiotic substances and materials	*Metallic,* e.g. metal ores *Non-metallic*, e.g. minerals, aggregates (sand/gravel), pigments, building materials (mud/clay), seawater
	Energy	*Renewable abiotic energy sources*, e.g. wind, wave, tides *Non-renewable energy source*s, e.g. oil, gas
Regulation and maintenance by natural physical structures and processes	*Mediation of waste, toxicants and other nuisances*	*By natural chemical and physical processes* e.g. adsorption and sequestration of contaminated water in marine sediments
	Mediation of flows by natural abiotic structures	*By solid (mass) flows*, e.g. protection by sand and mud flats
	Maintenance of physical, chemical, and abiotic conditions	*By natural chemical and physical processes*, e.g. sea breeze
Cultural settings dependent on abiotic structures	*Physical and intellectual interactions with seascapes [physical settings]*	*By physical and experiential interactions or intellectual and representational interactions*, e.g. coastal and sea caves
	Spiritual, symbolic and other interactions with seascapes [physical settings]	*By type*, e.g. sacred rocks or other physical structures or spaces in the coast and sea

Source: Adapted from the table showing broad abiotic output themes, classes, and non-exhaustive examples for all natural systems produced in the context of CICES, 2013.

7.3 An EU-level assessment of marine ecosystem potential to deliver services

Summary of main points in this section

- EU policy-relevant information available at the EU level only allows a 'top-down' assessment of the potential 'supply' of marine ecosystem services. 'Supply-based' assessments are assessments that look at the capacity of ecosystems to deliver services, and infer that an ecosystem in good condition would have maximum potential for service delivery. Full marine ecosystem service assessments would also consider the service 'demand', and thus estimate the actual use of the services by people and the value of the benefits resulting from this use.

- The EU-level reporting stream from the Marine Strategy Framework Directive (MSFD) Initial Assessment has not provided an EU-level assessment of the actual state of marine ecosystem services. It does not include a single, common pan-European metric to assess the potential supply of marine ecosystem services on the basis of the 'overall status' of marine ecosystems either. As a result, such potential at the EU level has to be assessed using the 'overall status' of marine biodiversity from the MSFD reporting stream as a proxy for ecosystems.

- 80% of marine biodiversity assessments under the MSFD Initial Assessment across the EU show that its 'overall status' is 'unknown'. Information from other EU, regional and national sources, as well as the scientific literature, has been used here to try to close this knowledge gap when assessing the potential supply of marine ecosystem services at the EU level.

- All EU policy-relevant and other information on the condition of marine biodiversity and ecosystems across this report has been pulled together using expert judgment, and indicates that:

  - All the eight main marine ecosystems/biodiversity components in Europe's seas are either currently degraded (for seabed habitats, reptiles, and marine mammals), or their degradation is a possibility (for water column habitats, invertebrates, fish, and water birds/seabirds as well as ecosystem processes and functions).

  - If marine ecosystems/biodiversity components are not degraded now, they would be so in the next 5–10 years (with the exception of fish and water birds/seabirds where that is only a possibility).

  - There are no instances where the condition of marine ecosystem/biodiversity components is currently good, nor where improving trends in this condition dominate.

  - 'Sufficient' (but not 'good') information exists to assess the condition of less than half these components. The information is 'bad' for the remainder of these components.

- Our conclusion, based on this common pool of information, is that all the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat, i.e. their delivery may not be sustained/continued over time.

- A key tool to reverse the reported degradation of marine ecosystems and biodiversity is the MSFD 2015 Programme of Measures (PoM), which Member States have to make operational by 2016 in order to maintain or achieve 'good environmental status' by 2020. Whether the 2015 PoMs will be successful in reversing the reported degradation in the short time available is unclear.

- It is extremely unlikely that the gaps in the knowledge-base regarding the condition of marine ecosystems and biodiversity can be filled, and any potential degradation reversed, by the MSFD 2020 deadline using the 2015 PoMs. 2020 is also the deadline for achieving the headline target on halting biodiversity loss and the degradation of ecosystem services under the EU Biodiversity Strategy to 2020.

- The missing knowledge on the condition of marine ecosystems and biodiversity risks undermining the effectiveness of the MSFD (and thus of ecosystem-based management) to manage all human activities using the natural capital of Europe's seas. It is therefore crucial to apply the EU's 'precautionary' and 'polluter pays' principles to the management of these activities until this knowledge can be gathered.

One of the aims of this report is to support the implementation of EU marine policy (and associated management). This requires using EU policy-relevant information as input for the assessments included in the report in as much as possible, so the outputs can be used directly to support the evaluation of the effectiveness of policy implementation at the EU level. In doing so, we mostly use information made directly available at the EU level from the Member State assessment and reporting requirements under this policy ([19]).

At present, reported information is insufficient to carry out a full assessment of the actual state of marine ecosystem services at the EU level. Such an assessment would require looking at these services from their beginning, i.e. at how marine ecosystem condition influences their delivery ('supply-side' approach), to their end, i.e. at how much they are used by people and at the value of their benefits for people ('demand-side' approach) (Figure I.1). However, even if not perfect, there is policy-relevant information at the EU level to assess marine ecosystem condition, and this is the key information to ascertain whether marine ecosystem capital is being degraded or lost. This section therefore puts forward an assessment of marine ecosystem services at the EU level following the 'supply-side' approach, and thus focusing on the capacity of marine ecosystems to deliver services, and assuming that ecosystems in good condition would have maximum potential for service delivery.

The input information for the assessment in this section is the condition of marine ecosystems, and the outcome will relate to whether their potential to deliver services can be sustained over time, i.e. to the sustainability of the sea's potential for service delivery.

Information used in assessing marine ecosystem potential to deliver services at the EU level

In earlier chapters, this report assessed the state of Europe's marine environment and considered the pressures and drivers acting upon it. Those chapters included information from the reporting conducted by Member States as part of the implementation of the Marine Strategy Framework Directive (MSFD). Member State reporting on the MSFD Initial Assessment is currently the widest-ranging common information pool on the marine environment at the EU level. However, this information is still not appropriate to fully characterise the state of Europe's seas (EC, 2014a; EC, 2014f; Palialexis et al., 2014). The information from the MSFD reporting stream was therefore supplemented with other information where needed, including from other EU, regional, and national sources, and the scientific literature.

In terms of assessing the state of ecosystems — and judging from the associated reporting ([20]) — one shortcoming of the MSFD Initial Assessment is that Member States focused on certain ecosystem attributes (such as ecosystem abundance and proportion, or the condition of specific habitats and species), rather than looking at ecosystems as whole entities and considering their overall structure and functioning (Article 8.1.a reporting, ETC/ICM, 2014). Thus, no Member State assessed the 'overall status' (overall condition) of ecosystems under the MSFD Initial Assessment ([21]). The 'overall status' would be the current condition of these ecosystems estimated against 'good environmental status', which is the MSFD 2020 target. Furthermore, very few Member States have considered ecosystem services when carrying out the socio-economic analyses under the MSFD Initial Assessment (Article 8.1.c, ETC/ICM, 2014, Section 7.7).

In contrast — and judging from the associated reporting ([22]) — the assessment of the state of marine biodiversity under the MSFD Initial Assessment is relatively better than the assessment of marine ecosystems and their services (Article 8.1.a reporting, ETC/ICM, 2014). One of the reasons for this is that it includes an assessment of the 'overall status' of marine biodiversity components against 'good environmental status' (ETC/ICM, 2014). Because of the better information on marine biodiversity, and because biodiversity plays a key role in the generation of ecosystem services, this section (Table 7.3) will use MSFD information on the state of marine biodiversity as a proxy for ecosystems to assess ecosystem condition, and to provide an indication of the sustainability of marine ecosystem potential for service delivery.

Notwithstanding, there are many shortcomings in the reported information on the Member State assessments of marine biodiversity under the MSFD Initial Assessment. For example, there is a limited amount of available information in a complete, coherent and comparable manner across the EU (ETC/ICM, 2014). Despite these shortcomings, this reporting stream is the

([19]) This approach is considerably simpler than undertaking the endless task of considering the information that may be available at the national level in a systematic and comparable manner for each Member State. The primary source of information for the assessments in this report are actually the MSFD Initial Assessment reporting sheets that were generated under the MSFD Article 12 process, rather than the full Member States reports on the Initial Assessment. This is because these sheets are in English, rather than in native languages, and were designed to allow comparability of national assessment outcomes, even if this aim has not been fully fulfilled. However, as shown throughout the report, national (and regional) information has also been used as examples and case studies, and — at times — this information comes from the full Member States reports on the Initial Assessment.

([20]) Specifically the MSFD Initial Assessment reporting sheets on the 'Biodiversity' Descriptor generated under the MSFD Article 12 process.

([21]) The 'overall status' of ecosystems has been reported as a 100% 'unknown' across the EU (ETC/ICM, 2014).

([22]) Specifically the MSFD Initial Assessment reporting sheets on the 'Biodiversity' Descriptor generated under the MSFD Article 12 process.

most comprehensive common source of information on the state of marine biodiversity that is available at the EU level.

Member States also report on the state of marine biodiversity as part of the implementation of the Habitats Directive. However, this Directive only covers a limited number of marine habitats and species (the most vulnerable or characteristic habitats and species at the EU level). For this reason, the reporting under the Habitats Directive is not used to perform the assessment of ecosystem condition in this section (as it cannot be directly integrated with the MSFD information stream used in Table 7.3). However, the outcomes from the latest European assessment under Article 17 of this directive (2007–2012 period) will be used to support, contextualise and conclude on the outcomes from the assessment in this section. Similarly, the scope of other information on marine biodiversity (and ecosystem) condition provided in other chapters of this report tends to be narrower than the MSFD's; although there are exceptions (such as EEA marine indicators). Nonetheless, its use will also be limited to support, contextualise and conclude on the outcomes from the assessment here.

The assessment of ecosystem condition in this section has covered seven marine biodiversity components: seabed habitats, water column habitats, invertebrates, fish, birds, reptiles and mammals ([23]). These components originate in the different habitat ([24]) types and biological features defining the MSFD's 'Biodiversity' Descriptor (also known as Descriptor 1). They are actually based in the MSFD 'predominant habitat types' (at the ecological-zone level, e.g. seabed habitats), 'functional groups' of highly mobile species (at the species group level, e.g. marine mammals, but with the exception of the MSFD cephalopods species group) and 'individual species' (for the invertebrates component, which also includes the MSFD cephalopods species group) (EC , 2011d).

Member States were required to report on the state of these marine biodiversity components using many different criteria that varied per component (as specified in EC, 2010c), with the exception of their 'overall status' against 'good environmental status', which was common to all the components (ETC/ICM, 2014). Because the 'overall status' of these marine biodiversity components was the only information that Member States had to systematically report on, **it provides the single common and comprehensive pan-European metric to establish the state of marine biodiversity, and thus to assess ecosystem condition, and to provide an indication of the sustainability of marine ecosystem potential for service delivery, in this section (Table 7.3).**

Methodological aspects of the assessment

Marine ecosystem functioning is complex, and there are gaps in our knowledge of it. These gaps are in particular with regard to some of the particularities of how ecosystem functioning leads to the delivery of ecosystem services, and the role of marine biodiversity in this (Chapter 2). Nevertheless, EU FP7 projects, such as ODEMM ([25]) and MESMA ([26]), have shown that it is possible to establish a set of prioritised qualitative linkages (i.e. causal relationships/interactions) between marine ecosystem/biodiversity components and the services that these can potentially deliver, as well as the pressures and drivers acting upon them.

The linkages between the MSFD-based marine biodiversity components used here and the services they could deliver have been established and are shown in Table 7.3. These linkages build on research and the literature (Fletcher et al., 2012; Salomidi et al., 2012; Boehnke-Henrichs, et al., 2013; White et al., 2013b; Maes et al., 2014; and Culhane et al., unpublished). The ecosystem services in the table come from adapting the CICES ([27]) ecosystem services typology to marine ecosystems (Table 7.1, Section 7.2). Regarding the marine biodiversity components, the table also shows whether these are in 'good environmental status' or not (from ETC/ICM, 2014).

Following from the 'supply-side' approach, looking at each component, its status and its linkages to certain services will tell us something about the capacity of the component to keep on delivering the services, i.e. about the sustainability of the sea's potential for service delivery at th e EU level. A marine biodiversity component not in 'good environmental status' is considered degraded. As a general rule, when this occurs, the components' potential to deliver the relevant services (those linked to it) is considered to be under threat, i.e. service delivery may not be sustained/ continued over time. It is implicit in this assumption that, if the degradation of the biodiversity component can be reversed and 'good environmental status' can be

([23]) These are the same marine biodiversity components used in Chapter 3.
([24]) Under the MSFD, the term 'habitat' addresses both the habitat's abiotic characteristics and the associated biological community, treating both elements together in the sense of the term 'biotope' (EC, 2010c; EC, 2011d).
([25]) Options for Delivering Ecosystem-Based Marine Management http://www.liv.ac.uk/odemm.
([26]) Monitoring and Evaluation of Spatially Managed Areas http://www.mesma.org/default.asp?ZNT=S0T1O474.
([27]) Common International Classification of Ecosystem Services (version4.3) http://cices.eu.

achieved, then the threat to the component's sustained potential to deliver services would be removed.

Assessment outcomes

The assessment outcomes for the condition of MSFD-based marine biodiversity components are not very encouraging. When considering the overall EU picture (i.e. all the seven biodiversity components and the four EU marine regions together), 80% of the assessments of the 'overall status' of these components are categorised as 'unknown' and only 4% are at 'good environmental status'. Of the remainder, 2% are 'not at good environmental status' and 14% are classified as 'other' ([28]), which basically means that they may or not be at a 'good environmental status' (ETC/ICM, 2014). Table 7.3 shows the breakdown of this assessment per component based on the percentage of Member State assessments that fall into each of the categories (in relation to the total number of 'overall status' assessments per Member State and category).

In terms of the degradation of marine biodiversity, Table 7.3 shows degradation when components are 'not at good environmental status', and there could also be degraded components within the 'other' category, i.e. those in a 'negative' status, although the percentage can currently not be estimated (see definition of 'other'). Evidence of marine biodiversity degradation in relation to component falling under the MSFD 'Biodiversity' Descriptor's scope but using non-MSFD-based (outside MSFD reporting) information has been provided in Chapter 3 of this report. Degradation in relation to other MSFD Descriptors using both MSFD-based and non-MSFD-based information has also been shown in Chapters 3, 4 and 5. These other descriptors include aspects of ecological quality/integrity to a large extent, and are: 'Invasive alien species' (Descriptor 2), 'Commercial fish stocks' (Descriptor 3), 'Food webs' (Descriptor 4), and 'Seafloor integrity' (Descriptor 6).

Evidence of degradation can also be seen in the updated (2007–2012 period) European biogeographic assessments under Article 17 of the Habitats Directive for the most vulnerable or characteristic marine habitats and species. These show that 66% of the assessments of the relevant marine habitats and almost 27% of the assessments of the relevant marine species are in 'unfavourable conservation status'. Thus, these habitats and species fail to meet the Directive's 'favourable conservation status' objective and are therefore considered to be degraded here (following the approach above for the MSFD marine biodiversity components not in 'good environmental status'). The status of the rest of the Habitats Directive's marine habitats and species tends to be 'unknown' (Chapter 3). The lower number of habitats and species groups that are not in 'good' status and the higher numbers of 'unknowns' in Table 7.3 when compared to the assessment under the Habitats Directive is consistent with the fact that the scope of marine biodiversity under the MSFD (i.e. Descriptor 1) is much wider than under the Habitats Directive. It is also because the Habitats Directive has been implemented for longer time than the MSFD, as this is the second European biogeographic assessments under its Article 17 (where it is the first Initial Assessment under the MSFD Article 8).

All the information above and other information across the report has been synthesised in Table 8.1. Under the 'healthy seas' heading, Table 8.1 includes the seven marine biodiversity components that have been assessed here in Table 7.3. For each component, Table 8.1 provides a qualitative, indicative assessment of their current status (condition) and of the 5–10 year trend on the basis of all the information available across the report (including the MSFD-based marine biodiversity assessment in Table 7.3), which has been combined using expert judgment. The table also rates the availability and quality of this information.

Table 8.1 shows that the current status of three (seabed habitats, reptiles, and marine mammals) out of these seven components is not good (i.e. they are degraded). For the other four (water column habitats, invertebrates, fish, and water birds/seabirds) the status shows a mixed picture, which includes degradation. The situation worsens over time (5–10 years), where for five (seabed habitats, water column habitats, invertebrates, reptiles, and marine mammals) out of the seven components the deteriorating trends dominate. And for the other two (fish, and water birds/seabirds) the trends show a mixed picture, which includes deterioration.

Table 8.1 also includes information on ecosystem processes and functions, which could not be included in Table 7.3 due to the lack of information on the 'overall status' of ecosystems under the MSFD Initial Assessment. The current status of ecosystem processes and functions shows a mixed picture, which includes degradation, and the 5–10 year trend is dominated by deterioration. There are no instances where the status of marine biodiversity components/ecosystems is currently good, nor where improving trends in this status dominate in Table 8.1.

([28]) 'Other' means that the status is classified using an alternative terminology to 'good environmental status' (GES). In the 'other' category, a variety of terms have been used by Member States, along with detailed descriptions of the status. It is not possible to summarise this information to produce a comparable and EU-wide assessment due to its very descriptive nature, often being in native languages, and the need for additional interpretation as to whether the descriptive status provided is 'positive' and equivalent to GES, or not ('negative' status) (ETC/ICM, 2014).

Table 7.3 Marine ecosystem condition and potential for marine ecosystem service delivery threatened by failure to achieve 'good environmental status' (GES)

MFSD assessment of marine biodiversity component	Main MSFD pressures upon marine biodiversity component	Potential for marine ecosystem service delivery threatened by failure to achieve 'good environmental status'		
		Provisioning services	Regulation and maintenance services	Cultural services
Seabed habitats 702 'overall status' assessments 4.6% 'at GES' 0.7% 'not at GES' 18.4% 'other' 76.4% 'unknown'	• Physical damage • Physical loss • Biological disturbance	• Seafood (wild capture and related outputs). • Fibres and other materials for direct use or processing. • Materials for agricultural and aquaculture use. • Genetic materials for biochemical, industrial, and pharmaceutical processes.	• Bio-remediation of wastes and toxicants by biota. • Filtration/sequestration/storage/accumulation of wastes and toxicants by biota and by ecosystems. • Mediation of smell/noise/visual impacts. • Mass stabilisation and control of erosion rates, buffering, and attenuation of mass flows and flood protection. • Ventilation and transpiration. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Weathering processes. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gas concentrations. • Micro- and regional climate regulation.	• Experiential use of marine plants, algae, and animals. • Physical use of marine ecosystems and seascapes (including leisure fishing). • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, existence, and bequest interactions.
Water column habitats 75 'overall status' assessments 1.3% 'at GES' 0% 'not at GES' 5.3% 'other' 93.3% 'unknown'	• Nutrient and organic matter enrichment • Physical loss • Biological disturbance	• Seafood (wild capture, in situ aquaculture and related outputs). • Genetic materials for biochemical, industrial, and pharmaceutical processes.	• Bio-remediation of wastes and toxicants by biota. • Filtration/sequestration/storage/accumulation of wastes and toxicants by biota and by ecosystems. • Mediation of smell/noise/visual impacts. • Ventilation and transpiration. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gas concentrations. • Micro- and regional climate regulation.	• Experiential use of marine plants, algae, and animals. • Physical use of marine ecosystems and seascapes (including leisure fishing). • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, existence, and bequest interactions.
Invertebrates 30 'overall status' assessments 0% 'at GES' 0% 'not at GES' 0% 'other' 100% 'unknown'	• Biological disturbance • Physical loss • Interference with hydrological processes	• Seafood (wild capture, in situ aquaculture and related outputs). • Fibres and other materials for direct use or processing. • Materials for agricultural and aquaculture use. • Genetic materials for biochemical, industrial, and pharmaceutical processes.	• Bio-remediation of wastes and toxicants by biota. • Filtration/sequestration/storage/accumulation of wastes and toxicants by biota. • Mediation of smell/noise/visual impacts. • Mass stabilisation and control of erosion rates, buffering, and attenuation of mass flows and flood protection. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gas concentrations.	• Experiential use of marine plants, algae, and animals. • Physical use of marine ecosystems and seascapes (including leisure fishing). • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, existence, and bequest interactions.
Fish 351 'overall status' assessments 3.4% 'at GES' 4.6% 'not at GES' 6.3% 'other' 83.8% 'unknown'	• Biological disturbance • Physical loss	• Seafood (wild capture, and related outputs). • Fibres and other materials for direct use or processing. • Materials for agricultural and aquaculture use. • Genetic materials for biochemical, industrial, and pharmaceutical processes.	• Filtration/sequestration/storage/accumulation of wastes and toxicants by biota. • Seed and gamete dispersal. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gas concentrations.	• Experiential use of marine plants, algae, and animals. • Physical use of marine ecosystems and seascapes (including leisure fishing). • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, existence, and bequest interactions.

Table 7.3 Marine ecosystem condition and potential for marine ecosystem service delivery threatened by failure to achieve 'good environmental status' (GES) (cont.)

MFSD assessment of marine biodiversity component	Main MSFD pressures upon marine biodiversity component	Potential for marine ecosystem service delivery threatened by failure to achieve 'good environmental status'		
		Provisioning services	Regulation and maintenance services	Cultural services
Birds 50 'overall status' assessments 4% 'at GES' 10% 'not at GES' 16% 'other' 70% 'unknown'	• Biological disturbance • Physical loss • Contamination by hazardous substances	• Food (wild capture and related outputs). • Fibres and other materials for direct use or processing. • Genetic materials for biochemical, industrial, and pharmaceutical processes.	• Filtration/sequestration/storage/accumulation of wastes and toxicants by biota. • Mediation of smell/noise/visual impacts. • Seed and gamete dispersal. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gas concentrations.	• Experiential use of marine plants, algae and animals. • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, aesthetic, existence, and bequest interactions.
Reptiles 25 'overall status' assessments 8% 'at GES' 0% 'not at GES' 12% 'other' 80% 'unknown'	• Biological disturbance • Physical disturbance	—	• Filtration/sequestration/storage/accumulation of wastes and toxicants by biota. • Seed and gamete dispersal. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gases.	• Experiential use of marine plants, algae and animals. • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, aesthetic, existence, and bequest interactions.
Mammals 56 'overall status' assessments 1.8% 'at GES' 3.6% 'not at GES' 16.1% 'other' 78.6% 'unknown'	• Biological disturbance • Physical disturbance • Contamination by hazardous substances	• Fibres and other materials for direct use or processing.	• Filtration/sequestration/storage/accumulation of wastes and toxicants by biota. • Maintaining nursery populations and habitats. • Gene pool protection. • Disease control and Pest control. • Decomposition and fixing processes. • Chemical condition of salt waters. • Global climate regulation by reduction of greenhouse gases.	• Experiential use of marine plants, algae and animals. • Scientific, educational, heritage, entertainment, aesthetic, symbolic, sacred/religious, aesthetic, existence, and bequest interactions.

Notes: EU-level assessment of 'good environmental status' (GES) based on the Member States' MSFD Initial Assessment (circa 2012) reporting on the 'Biodiversity' Descriptor. Marine ecosystem service identification is based on evidence of actual (not experimental) use of the services in the EU. It also takes into account EU and global regulation for the protection of certain species of birds, mammals, and reptiles, and so excludes certain services linked to them (although these may be subject to national derogations under certain conditions and some of these have been included). It also excludes possible services where the contribution from biota is deemed to be negligible compared to that of abiotic processes. The service list is the same as in Table 7.1, but service names have been made more general and some services have been grouped in a single bullet point due to space limitations.

Marine biodiversity components: these originate in the MSFD 'predominant habitat types' (at the ecological-zone level) and 'functional groups' of highly mobile species (at the species-group level but excluding the cephalopods species group). In addition, the 'Invertebrates' group is based on the reporting on MSFD 'individual species' and on the MSFD cephalopods species group. There would be a certain amount of 'double counting' of service linkages between components because some species (e.g. mussels) from a few biotic groups (e.g. 'invertebrates') are also part of the 'habitats' component, as 'habitats' are actually biotopes.

'Overall status assessment' (number and percentage): reported by Member States as the overall assessment against GES for the relevant biodiversity component(s), which could be determined from the associated GES criteria or other information. There were a number of these assessments for every given component both within and across Member States and the outcomes ('overall status') have been expressed against that total number.

'Other': this means that the status is classified using an alternative terminology to 'good environmental status'. In the 'other' category, a variety of terms have been used by Member States, along with detailed descriptions of the status. It is not possible to summarise this information to produce a comparable and EU-wide assessment due to its very descriptive nature, often being in native languages, and the need for additional interpretation as to whether the descriptive status provided is 'positive' and equivalent to GES, or not ('negative' status).

'Fish': all fish species including commercial stocks; 'Birds': both water and seabirds; and 'Reptiles': these are turtles and only occur in the Mediterranean Sea and the North East Atlantic.

Sources: Service list is adapted from Fletcher et al., 2012; Salomidi et al., 2012; Boehnke-Henrichs et al., 2013; CICES (v4.3), 2013; Maes et al., 2013; Maes et al., 2014; and Culhane et al., unpublished; Service linkages to biodiversity components are adapted from Fletcher et al., 2012; Salomidi et al., 2012; Boehnke-Henrichs et al., 2013; White et al., 2013b; Maes et al., 2014; and Culhane et al., unpublished; and Marine biodiversity components are based on the habitat types and biological features defined in EC, 2011d; and the MSFD GES assessment comes from ETC/ICM, 2014.

Table 8.1 also indicates that there is 'sufficient' (but not 'good') information to assess the condition of less than half these components, and that the information is 'bad' for the others. Thus, we have expanded the knowledge-base compared with the assessment of the MSFD's 'Biodiversity' Descriptor (and the high percentages of reported 'unknowns' for marine biodiversity and ecosystems). In closing this knowledge gap a bit, we see more degradation.

What do these outcomes mean?

Throughout this report, and culminating in Table 8.1, we have provided evidence of significant marine biodiversity/ecosystem degradation and, in addition, of a substantial lack of knowledge on the state of marine biodiversity/ecosystems. **This leads us to conclude that all the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat,** i.e. their delivery may not be sustained/continued over time. There are two reasons for this conclusion: the limited time available for the recovery of the degraded marine ecosystems by 2020, and the lack of information to assist in the recovery (or to prevent degradation) of marine ecosystems overall. Let's look at each of these reasons in greater detail.

The limited time available for the recovery of the degraded marine ecosystems by 2020: Marine ecosystem/biodiversity components that are currently not in good condition, i.e. degraded, may not be able to continue delivering ecosystem services over time because degradation undermines their capacity to do so. Marine ecosystem/biodiversity components where the degradation is currently only a possibility, would most probably be degraded over the next 5–10 years, which then increases the risk of the delivery of services not being sustained over time.

In the context of MSFD implementation, a key question would then be whether the degradation of marine ecosystem/biodiversity components can be addressed and reversed by the MSFD 2020 deadline for achieving 'good environmental status'. The tool for addressing degradation would be the MSFD Programme of Measures (PoM), which Member States must draw up in order to tackle the findings of their Initial Assessments (or of other relevant assessments). The PoMs should outline management measures to maintain or achieve 'good environmental status'. The Initial Assessments were carried out circa 2012, and the PoMs are to be completed this year (2015) and implemented in 2016. Therefore, Member States should have had enough time to use the 2015 PoMs as a management tool to reverse the degradation they observed in their Initial Assessments (or elsewhere) by 2020. Whether they can be successful or not to achieve this over 2016–2020 is another issue, given that time is limited and ecosystem change is difficult to reverse (Chapter 2). The year 2020 is also the deadline for achieving most targets under the EU Biodiversity Strategy to 2020, including its headline target on halting biodiversity loss and the degradation of ecosystem services (Box 1.1).

The lack of information on other marine ecosystems may impede efforts to help recovery or to prevent degradation of marine ecosystems overall: The substantial lack of information on the condition of (other) marine ecosystem/biodiversity components (e.g. the high number of 'unknown' status classification for marine biodiversity and ecosystems under the MSFD, reaching an EU total of 80% and 100% respectively) means that we do not know whether this condition is good or bad. In turn, this lack of knowledge prevents the effective management of all human activities that can damage marine ecosystem/biodiversity overall.

In the context of MSFD implementation, not knowing whether certain marine ecosystem/biodiversity components are in good condition or not dates from circa 2012, when the Initial Assessments should have been ready. Unless these Assessments have been recently updated, lack of knowledge on the status of these marine ecosystem/biodiversity components means that taking the necessary action to prevent their degradation (by maintaining 'good environmental status'), or to reverse their degradation (by achieving 'good environmental status') may not be possible in the context of the 2015 PoMs (to be implemented in 2016). Thus, the PoMs cannot tackle what it is not known.

Moreover, not knowing about how so many marine ecosystem/biodiversity components were doing in 2012 would probably mean that the 2015 PoMs would not be adequate to manage human activities on the marine environment in general. Thus, the lack of knowledge of what exactly needs to be done and where is substantial under the MSFD judging by the very high percentage of 'unknowns' (lack of knowledge is also an issue under the Habitats Directive but to a relatively lesser extent with the exception of the 'marine mammals' group, Chapter 4). In addition, the next MSFD (Initial) Assessment is not required until 2018 (although Member States can always update the existing assessments when they wish), and there is no mandatory PoM update before this 2020 deadline. It therefore seems to be an 'assessment gap' in terms of the missing knowledge-base. This assessment gap risks creating a 'management gap' whereby the MSFD cannot be fully implemented, and thus all human activities in the marine environment overall would not be adequately managed, because the necessary knowledge would not be available for some time.

It follows that it is unlikely that many improvements in the condition of marine ecosystems/biodiversity can be seen by the MSFD 2020 deadline to achieve 'good environmental status'. Similarly, achieving the EU Biodiversity Strategy targets for marine ecosystems and their biodiversity by the 2020 deadline looks extremely unlikely. This situation of missing knowledge, which undermines the effectiveness of MSFD implementation (and thus of ecosystem-based management), stresses the importance of applying the EU's 'precautionary' and 'polluter pays' principles when it comes to the management of human activities in the marine environment.

The evidence of degradation of marine ecosystems/biodiversity implies that the self-renewal of marine ecosystem capital may be at risk. Furthermore, the additional lack of knowledge on the state of marine ecosystems/biodiversity means that such a risk would be difficult to manage overall. Therefore, the way we use the natural capital of Europe's seas does not appear to be sustainable, i.e. we may be mismanaging this use.

The pressure on marine ecosystem capital is the result of human activities exploiting the sea's natural capital overall, i.e. both marine ecosystem capital itself and marine abiotic natural capital. In fact, human activities using/sourcing marine abiotic capital can generate a greater range of pressures, both in terms of numbers and type, on marine ecosystems and biodiversity than those activities using marine ecosystem assets and services (Table 5.1). The top three pressures on the marine biodiversity components making up the MSFD's 'Biodiversity' Descriptor are shown in Table 7.3. These pressures ([29]) are: 'physical damage', 'physical loss', and 'biological disturbance' (MSFD, Annex III, Table 2). There are several human activities that can cause these pressures, including fisheries and aquaculture (for 'biological disturbance'); dredge disposal and construction at sea, such as for the deployment of renewable energy (for 'physical loss'); and mineral and aggregate mining, dredging, fisheries, and marine and coastal tourism (for 'physical damage'). With the exception of fishing, most of the activities that can cause 'physical damage' and 'physical loss' are on the increase (Table 5.1).

Final reflection

The outcomes from the assessment of marine biodiversity/ecosystem condition in this section have led us to conclude that the future of all the marine ecosystem services that can potentially be delivered by Europe's seas is in jeopardy. This conclusion is consistent with some national and regional assessments of marine ecosystem services based on ecosystem capacity ('supply-side' approach), which were carried out outside the MSFD implementation process (see examples in Section 7.5). However, in general, those assessments were able to provide a much better characterisation of the threat to the sustainability of the sea's potential for service delivery. Thus, beyond identifying the specific services under threat for each ecosystem type, they also managed to estimate the percentage of services under threat, and/or to the detemine the specific human activities responsible for the threat. This shows that 'lower level' service assessments are better suited to inform the *in situ* management of human activities on the marine environment than those carried out at the EU level.

Nonetheless, an assessment can only be as good as the information and methodology supporting it. The EU-level assessment in this section is based on several methodological assumptions, which have been made in order to overcome the limitations of the information available from the Member States' reporting on the MSFD Initial Assessment. Further, how we have contextualised the outcomes from this assessment and what we have concluded about them has been supported on information on the condition of marine biodiversity/ecosystems from elsewhere in this report, which is of an indicative nature. As a result, our conclusion regarding the current threat to the sustainability of the potential of Europe's seas to deliver all marine ecosystem services should be seen as a rather general and rough EU overview.

([29]) Table 7.3 does not show the information on 'ecosystems' from the reporting on the MSFD Initial Assessment's 'Biodiversity' Descriptor (Article 8.1.a) because there was no information on their 'overall status' (they were all 'unknown'). However, Member States reported on the pressures on 'ecosystems' as part of the pressure assessment under Article 8.1.b. The top three pressures were 'physical damage', 'biological disturbance' and 'nutrient and organic matter enrichment'. The reporting on the uses of marine waters under MSFD Initial Assessments' socio-economic analyses (Article 8.1.c) also included pressures on 'ecosystem services' or on the socio-economic 'themes' selected for those assessments (e.g. fisheries), which, at times, can provide an idea of pressures on ecosystem services. Top pressures were 'physical damage', 'biological disturbance', 'interference with hydrological processes' and 'contamination by hazardous substances'. There are some discrepancies between the pressure ranking on marine biodiversity, ecosystems and ecosystem services (or socio-economic 'themes'). However, given that the reporting on ecosystems and ecosystem services (Section 7.7) was very poor overall, and because marine biodiversity has been used as a proxy of ecosystem capacity for service delivery in Table 7.3, we are using the pressure ranking on marine biodiversity in this chapter.

Nevertheless, the reasons behind the outcomes of our assessment — and the conclusion that can be derived from it — are useful for EU-level policy and management. Thus, we have shown gaps in the MSFD knowledge-base due to both how the Initial Assessments of the state of marine ecosystems and their biodiversity have been carried out, and how they have been reported. We have also shown that these knowledge gaps could be risking the effectiveness of the MSFD 2015 PoMs to achieve the sustainable management of all human activities using the natural capital of Europe's seas. The assessment is therefore offered for reflection towards an improved situation by 2020, the deadline to achieve the MSFD 'good environmental status'.

Photo: 'Seafood provisioning' marine ecosystem service: fishing boat in North Zealand (Denmark).

Source: © Peter Kristensen

7.4 How can we improve EU-level assessment of marine ecosystem services?

Summary of main points in this section

- There are possibilities for better EU-level assessment of the potential of marine ecosystems to supply services than the one provided in this chapter, and even for full marine ecosystem service assessments. However, these possibilities have not completely materialised as yet.
- An EU-level working group was set up in 2012 to assist fulfilling the 2014 goal of Target 2/Action 5 of the EU Biodiversity Strategy to 2020, with regard to the Mapping and Assessment of all Ecosystems and their Services (MAES) by Member States with the assistance of the European Commission. This working group has produced EU-level guidance material for MAES-type assessments. Member States continue to develop and carry out MAES-type assessments in 2015.
- MAES-type assessments should include the assessment of the potential supply of ecosystem services on the basis of 'ecosystem condition' information from EU environmental legislation. The outcomes from national MAES-type marine assessments could thus be used directly (aggregated) at the EU level to provide a 'bottom up' assessment of the potential supply of marine ecosystem services. These national assessments could also be used indirectly to develop a 'top-down' EU level assessment, which would be based on the information underpinning them (rather than on the outcomes from the assessments).
- There are several challenges for an EU level assessment of the potential supply of marine ecosystem services if this is to use 'ecosystem condition' information from EU environmental legislation. These challenges are in particular for a 'top-down' EU-level assessment. Many of these challenges are shared by national MAES-type marine assessments. One crucial challenge for EU-level assessment is the need to ensure comparability of the outcome from national MAES-type marine assessments, or of the information underpinning them. Another challenge is that the marine component of the MAES guidance needs further development, which may mean that the application of this guidance is not promoting as much comparability of MAES-type marine assessments across the EU as it could be.
- There is a lot of action across the EU, and in particular at the EU level, to overcome the challenges for MAES-type marine assessments. This includes facilitating EU level assessments. However, more time is needed to see wide-spread results at all levels.
- A positive sign is that there are more Member States that have carried out or are carrying out national MAES-type marine assessments than there were Member States that chose to assess marine ecosystem services as part of the socio-economic analyses under the MSFD Initial Assessment. However, there is not a full geographical coverage of national assessments to produce an EU overview yet. Further, given the knowledge gaps in the EU-level reporting stream from the MSFD Initial Assessment with regard to the condition of marine ecosystems and biodiversity, we are unsure of where the information for these MAES-type marine assessments comes from.

EU-level support for the assessment of marine ecosystems and their services

The implementation of the EU Biodiversity Strategy to 2020 (Box 1.1) should eventually lead to assessing all ecosystems and their services at the national level. This improvement in national-level knowledge should translate in better knowledge available for EU-level assessment of marine ecosystem services.

The Strategy contains six specific targets, the second of which (Target 2) requires that *By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems*. Action 5 under Target 2 is about improving knowledge of ecosystems and their services in the EU. It requires that *Member States, with the assistance of the Commission, will map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020*.

Target 2/Action 5 could be taken as requiring a full assessment of ecosystem services (in the sense of the definition of a full services assessment in Section 7.3). Thus, the 2014 assessment would consider the service 'supply' (ecosystem capacity) and the 2020 assessment would additionally consider the service 'demand' (service use and benefit value).

An EU-level Working Group on the 'Mapping and Assessment of Ecosystems and their Services' (known as WG MAES) was established in 2012 to help Member States achieve Action 5, in particular its first element, which had to be completed by the end of 2014.

WG MAES is composed of representatives from Member States' Ministries; Environment Agencies or Nature Agencies; European Commission services; the EEA; and EU-level stakeholders (e.g. the European hunters' association, environmental NGOs). It has produced several guidance elements, some of which were inspired by the experience of Member States when they were carrying out national ecosystem assessments as part of their follow-up to the Millennium Ecosystem Assessment (MA, 2005) (Section 7.5). Other guidance elements were inspired by global initiatives such as The Economics of Ecosystems and Biodiversity (TEEB, 2009).

WG MAES guidance includes: a general conceptual model/framework for ecosystem mapping and assessment; a typology of ecosystems; and the ecosystem services classification from CICES (Maes et al., 2013). This guidance supports the premise that assessments relating to the achievement of Target 2 of the EU Biodiversity Strategy should make use of information resulting from the implementation of EU nature, water, and/or marine directives, in particular with regard to information on 'ecosystem condition'. All these directives are relevant to marine ecosystems.

Information on the condition of marine ecosystems from Member State reporting under those directives could, in principle, be combined to assess marine ecosystem services at the EU level following the 'supply-side' approach. This type of 'top-down' EU-level assessment of marine ecosystem potential for service delivery would improve on the assessment provided in Table 7.3, which was limited to MSFD-based information. However, coming up with a systematic way of making use of the combined information from these directives for such a 'top-down' EU-level assessment is rather challenging (see below, in particular Table 7.4).

The original MAES guidance elements mentioned above were tested in several pilot projects (including one on marine ecosystems), which have shown that some aspects of the guidance need further development. The outcomes from the pilot projects have been used to develop an additional MAES guidance element, namely a compilation of the indicators that are available for the assessment of ecosystem services across the EU (Maes et al., 2014). All these MAES guidance elements should be considered the 'EU references' for any ecosystem and service mapping and assessment exercise. They were made available across the EU in April 2013 and February 2014.

Towards an EU overview of national marine ecosystem service assessments ('bottom-up' EU-level assessment following the 'supply-side' approach)

Under the first element of Action 5 of the EU Biodiversity Strategy, Member States had to develop MAES-type assessments (mapping and assessment of ecosystems and their services), where — following the MAES concept — the services assessment should be based on ecosystem capacity and thus assessing the potential for service delivery ('supply-side' approach). Further, following also from the MAES concept, these assessments should use 'ecosystem condition' information from the implementation of EU environmental legislation.

These MAES-type assessments should have been developed for all ecosystems (and their services) by the end of 2014. However, this work will continue towards the 2020 deadline for Action 5 because not all Member States started developing MAES-type assessments at the same time. Several Member States are currently either continuing with or just joining this effort, as the 2014 element of Action 5 is the 'input' information needed to develop its 2020 element anyway.

The outcomes from national assessments of marine ecosystem potential to deliver services developed under the MAES process could be used directly (aggregated) to provide a 'bottom-up' EU level assessment (i.e. an EU overview). Producing this EU overview should be simpler than developing a 'top-down' EU-level assessment of marine ecosystem potential to deliver services by combining the information on marine ecosystem condition available at the EU level from the Member State reporting on several directives.

Two main conditions need to be met in order to produce such an EU overview. These conditions are: having a full geographical coverage of national assessments (all 23 Member States bordering the four EU marine regions should have produced these assessments), and comparability between the assessment outcomes. We have still not looked at these national assessments from an EU-level perspective ([30]) because, as already mentioned, they are still being developed.

Nevertheless, regarding the comparability of national assessments of marine ecosystem potential to deliver services, using the MAES concept and guidance should have allowed a certain degree of convergence between

([30]) The bulk of this report was drafted up to November 2014, with smaller revisions up to May 2015.

Member State procedures. This should therefore facilitate the aggregation of the outcomes from these national assessments into a 'bottom-up' EU-level assessment. However, these national assessments have to overcome similar challenges to those faced by EU-level 'top-down' assessments (see below, in particular Table 7.4).

Despite having the MAES concept and guidance, the way Member States may have overcome these challenges may not be comparable. Between now and 2020, Member State procedures could converge even further if a common, general mapping and assessment methodology was developed at the EU level for all ecosystems, building on the MAES guidance and other information (Section 7.5). This methodology is needed to ensure that the MAES conceptual model is made operational and can deliver an actual assessment of all ecosystems and their services 'on the ground' in a much more similar way across the EU. In any event, having such a methodology does not remove the need for a great deal of expert judgment in this type of assessment. Therefore, some lack of comparability between national assessments may be unavoidable, which may mean that developing a 'bottom-up' EU-level assessment of marine ecosystem potential to deliver services based on national assessment outcomes may still be difficult.

Regarding the geographical coverage of national assessments of marine ecosystem potential to deliver services, we know that about 11 out of the 23 EU Member States bordering the four EU marine regions have carried out or are carrying out these assessments ([31]) at present (although this number does not include two additional 'coastal' ([32]) — rather than fully 'marine' — assessments). Prior to the advent of WG MAES, only three ([33]) Member States had assessed marine ecosystem services. Those assessments were carried out as part of the national follow-up to the Millennium Ecosystem Assessment, and were outside the MSFD implementation process (Section 7.5).

Most of the 'new' national marine assessments under the MAES process appear to be carried out separately from assessments under the MSFD. Thus, under the MSFD Initial Assessment, Member States had the option to carry out the socio-economic analyses of their use and associated degradation of marine waters following the 'ecosystem services' approach (WG ESA, 2010). Very few ([34]) Member States attempted to do this (Section 7.7). However, these socio-economic analyses include valuing the costs of degrading the services in monetary terms. Being able to monetise the cost of service degradation requires knowing the economic value of the service benefits. It also requires establishing the state of the services, which could be done through assessing the potential of marine ecosystems to deliver them (service 'supply'). Economic valuation of service benefits thus adds a further complexity to the assessment of the service 'supply'. However, economic valuation of (the benefits of) ecosystem services is not required under Target 2/ Action 5 of the EU Biodiversity Strategy until 2020.

So it could be concluded that the MAES process and guidance are helping Member States to carry out assessments of marine ecosystem potential to deliver services. Nevertheless, the requirement for a full geographical coverage, as needed to produce an EU overview, is currently not being fulfilled.

National assessments of marine ecosystem potential to deliver services may not have been produced yet because they are rather demanding in terms of the required information-base (see below, in particular Table 7.4). Thus, the MSFD Initial Assessments of the 'Biodiversity' Descriptor showed a very substantial lack of knowledge on the state of marine ecosystems and biodiversity, and this is the information on which the assessment of ecosystem potential to deliver services would be based. Member States cited lack of information and of suitable assessment methods as the reason for returning an 'unknown' for most of their MSFD 'Biodiversity' Descriptor assessments, namely 80% for marine biodiversity and 100% for ecosystems (when considering the overall EU total) (ETC/ICM, 2014). These Initial Assessments were produced circa 2012, only about a year prior to the release of the MAES guidance. Therefore, it is currently not clear which information is being used by those Member States that have developed or are developing MAES-type marine assessments.

Towards an EU-level assessment of marine ecosystem services using 'ecosystem condition' information from EU environmental legislation ('top down' EU-level assessment following the 'supply-side' approach)

The 'supply side' approach for ecosystem service assessment means looking at the capacity of

([31]) In principle, these assessments have or are being produced by Denmark, Finland, France, Germany, Ireland, Italy, Malta, the Netherlands, Portugal, Spain and the United Kingdom. Note also that some countries outside the EU and bordering EU marine regions are carrying out similar assessments, namely Israel and Norway (Boteler, B., pers comm.; Braat, L., pers. comm.; Erhard, M., pers comm; Karasszon. A., pers comm).

([32]) In principle, these assessments are being produced by Estonia and Latvia (Boteler, B., pers comm.; Braat, L., pers. comm.).

([33]) Portugal, Spain and the United Kingdom (see references in Section 7.5).

([34]) Latvia, the United Kingdom and Sweden for the socio-economic use of marine waters; and the United Kingdom for the cost of degradation (ETC/ICM 2014). See footnotes in Section 7.7.

ecosystems to deliver services, and inferring that an ecosystem in good condition would have maximum potential for service delivery. In an EU marine policy context, this approach could be applied by using the information on 'ecosystem condition' from the state assessments required as part of the implementation of EU environmental legislation. This legislation is the Habitats Directive (HD), Birds Directive (BD), Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD). All these directives are relevant to marine ecosystems and thus their scope includes marine ecosystem components (e.g. habitat types, and biotic groups at the individual species and functional group level). Member State reporting on assessment products on the condition of these marine ecosystem components could, in principle, be combined and used to provide a 'top down' assessment of the sea's potential for service delivery at the EU level following the 'supply-side' approach.

Such a 'top-down' assessment would be the only one that can currently be provided at the EU level (improving on the one in Section 7.3). As explained above, it is currently not possible to produce a 'bottom-up' EU-level assessment (EU overview) of marine ecosystem potential to deliver services based on the outcomes from national MAES-type marine assessments.

In theory, using assessment products on 'ecosystem condition' from the above-mentioned directives for a 'top down' EU-level assessment should be possible because:

- There should be a full geographical coverage of these assessment products at the EU level (all 23 EU Member States bordering the four EU marine regions should have produced them).
- These state-assessment products are classified through status classifications, which conclude on whether they are 'good' or 'not good' (whether their status is good or not). The end-products are thus status assessments of the condition of different ecosystem components (rather than unassessed and thus unclassified datasets). Status classifications are needed to infer whether the condition of a particular ecosystem component has a 'positive' or 'negative' impact on service delivery.
- There are EU-wide processes to promote the comparability of these status assessments by, for example, harmonising the way in which they are reported at the EU level for each directive. This comparability should facilitate aggregation of the information within directives (for aggregation across directives, see Box 7.2).
- The definition of ecosystem condition in each directive includes a combination of ecosystem structural (e.g. species composition for the MSFD species assessment) and functional (e.g. population condition for the MSFD species assessment) criteria. The use of both these static and dynamic types of criteria is the best way to assess the ecosystem's capacity for service delivery, because the assessment will show the extent to which the services can be provided sustainably (Palmer and Febria, 2012).

Nevertheless, in reality, several of the premises above are not fulfilled. Thus, the information on 'ecosystem condition' produced under these directives was designed to serve the specific (and different) objectives of the directives, rather than to support EU-level assessment of ecosystems and their services.

A key consequence of the above is that, even when all these sources of information are combined, the resulting common pool of information on 'ecosystem condition' is still not enough to assess the wide diversity of marine ecosystem services that can potentially be delivered by Europe's seas. This means that other EU (e.g. from the CFP), global (e.g. from IUCN), or regional (e.g. from OSPAR) assessment products on 'ecosystem condition' would also be needed. However, these other assessment products may not be classified in terms of their status to the same extent as assessment products from EU environmental legislation.

Another key consequence of the premises above not being fulfilled is that the common pool of information on 'ecosystem condition' that could be provided by EU environmental legislation is not fully available when it is actually needed for an EU-level assessment. Thus, there are some crucial differences between the directives in terms of both their scope and their monitoring and assessment requirements, in particular with respect to space and time. These differences include the fact that the directives operate at different scales and require state assessments at different times. In addition, there are different timetables for reporting on the associated assessment products at the EU level. Furthermore, although the information is supposed to be reported in the same way, often the reported information may be too different, or too aggregated, or too incomplete to be useful. In other cases, the information may simply not exist.

All of the above makes it very difficult to have all the information providing a good snapshot of 'ecosystem condition' available at a particular moment. Thus, very often, only the 'lowest common denominator' of the required information is actually available. Furthermore, it will be even more difficult to have the required information at the places where the marine ecosystem services to be assessed are used (or consumed, or enjoyed) by people (e.g. the land-sea interface, coastal waters, or offshore waters).

For example, the state of whale populations in the Mediterranean Sea could be relevant to assess the 'whale watching' cultural service, and this assessment could potentially draw from information produced under the MSFD and the HD. However, only whales in coastal waters are actually subject to whale watching and can deliver the service. The assessment therefore could focus, for example, on the state of whale species that are advertised in whale-watching trips offered along the Mediterranean Sea coastline, and thus require state information on these individual whale species. The HD would then be the most suitable source of information for this assessment (Culhane et al., unpublished).

Several of these shortcomings are further discussed below (in particular Table 7.4), which also includes other challenges for the type of assessment being discussed here.

Nevertheless, despite shortcomings and challenges, it should still possible to use the information on 'ecosystem condition' reported under EU environmental legislation to provide a 'top-down' assessment of marine ecosystem potential to deliver services at the EU level following the 'supply-side' approach. A study commissioned by the EEA (Culhane et al., unpublished) developed a methodology aiming at making such an assessment possible. The assessment would be based on several large assumptions. It would also require specific methods to aggregate the information across directives (or other sources of information when needed), and would have to be very explicit about the limitations of its outcomes.

The application of this methodology showed the current state and trend of the potential of marine ecosystems to deliver services in three 'test service assessments'. The future change in state and the direction of change in this potential was also shown by the tests. The tests were carried out using assessment products of 'ecosystem condition' and other information (e.g. on pressures) from the reporting under EU environmental legislation; although other EU and global-policy based information was also needed. Because a lot of this information is not sufficiently spatially-referenced, the tests did not include mapping of the marine ecosystem services assessed (Box 7.2).

Photo: Whale watching is a marine ecosystem 'cultural' service.

Source: Stock photo © GlobalP

Box 7.2 A methodological approach to provide an EU-level assessment of marine ecosystem potential to deliver services using 'ecosystem condition' information from EU environmental legislation ('top down' EU-level assessment following the 'supply-side' approach)

A study commissioned by the EEA and carried out in 2014 (Culhane et al., unpublished) developed a methodology to provide a 'top down' EU-level assessment of marine ecosystem potential to deliver services on the basis of ecosystem condition ('supply-side' approach). This methodology was specifically developed to enable an assessment based on 'ecosystem condition' assessment products from the reporting under EU water (Water Framework Directive/WFD), nature (Habitats Directive/HD) and marine (MSFD) directives. These directives are all relevant to marine ecosystems. Thus, their scope includes marine ecosystem components (e.g. habitat types, and biotic groups at the individual species and functional group level). They also provide classified state-assessment products, i.e. status assessments, of these marine ecosystem components. The methodology can also use state-assessment products from other EU and global policies if these are classified (status) to a certain extent. It also requires using information on pressures, which can come from the EU environmental directives or other sources.

The full assessment methodology from this study is too extensive to be described here. However, we do include some methodological steps to show how the directives' assessment products of 'ecosystem condition' can be used to assess the sea's potential for service delivery.

Initial steps involve extracting the marine services from CICES (Section 7.2) and setting up a comprehensive set of marine ecosystem components specific for the study ([35]) (see stage 1 in diagram). The next step is to establish the qualitative linkages between marine ecosystem components and the services they can deliver (Section 7.3) (see stage 2 in diagram). Because the methodology is limited to deliver a service-per-service assessement, a further step is to estimate the contribution of each relevant marine ecosystem component to the delivery of a particular service. The components making the greatest contribution to the delivery of this service are selected as the critical marine ecosystem components, and these would be the only ones assessed. This step is needed, in particular, in cases where there are many marine ecosystem components involved in the delivery of a service (e.g. climate regulation by carbon sequestration, Box 2.2) in order to ensure that the assessment is practicable. The next step is to look at the state-service relationship between the critical ecosystem components and the service (see stage 2 in diagram). This relationship is qualitatively established by developing different scenarios of how the delivery of the service could be affected by the condition of each of the relevant critical marine ecosystem components. The scenarios are based on the literature and expert judgment. Establishing the state-service relationship also involves considering where the service would be used by people (e.g. cultural services tend to be used in the land-sea interface and coastal waters). Once the state-service relationship for the service is established, status assessments from the above-mentioned directives (or other state assessments) can be identitified and used as a source of 'metrics' (or indicators) to assess the condition of the critical ecosystem components involved in that relationship (see stage 2 in diagram). The idea is to use more than one 'metric' to assess each critical ecosystem component along a state-service relationship.

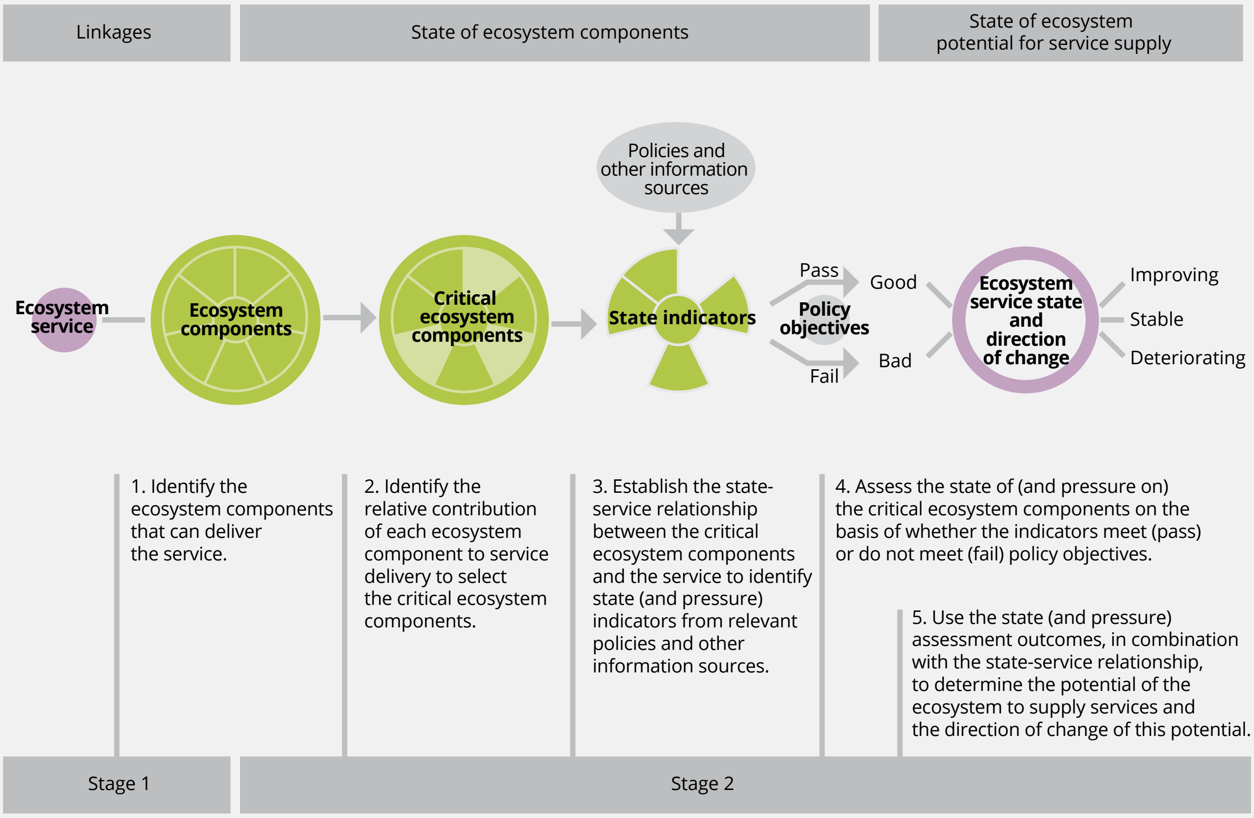
In principle, the condition of the critical ecosystem components in a state-service relationship could be assessed with 'metrics' from more than one directive ([36]). However, the ecosystem condition that needs to be achieved to meet the objectives of a particular directive may not be the condition required for service delivery. The methodology therefore seeks to use several status assessments from different directives together ('joint use') when assessing the same critical marine ecosystem component to provide the best available characterisation of the condition of the component. A key assumption to allow this 'joint use' and avoid 'double counting' is that the criteria defining 'condition' under each directive are different and complementary. Thus, that each directive covers different aspects of 'ecosystem condition' (e.g. for marine species the criteria defining the MSFD's GES are more encompassing than the criteria supporting the HD's 'favourable conservations status'/FSC; EC, 2012c). However, what tends to happen in practice is that this 'joint use' is not possible because the required status assessments are not actually available due to, for example, an absence of reporting or incomplete reporting.

([35]) This comprehensive and specific set of marine ecosystem components was developed by Culhane et al. (unpublished) through a rather complex process building on the MSFD predominant habitat types (biotopes) and all existing marine biotic groups. The process involved distinguishing the sessile (non mobile) biotic groups in these biotopes. It also involved attributing highly mobile groups of species (the MSFD functional groups) to the biotopes. The end-result was that all the marine biota that could be linked to each MSFD predominant habitat type were identified. Each of these pairings (biota-habitat) made up a marine ecosystem component to a total of 230. These components were also classified and divided along the photic zone (the surface layer where light availability is enough for photosynthesis to occur) and the aphotic zone. The study's definition of marine ecosystem components was therefore a bit different from the way the term 'marine ecosystem components' has been used in this chapter and in particular in Box 7.2. The term in this chapter refers specifically to the marine ecosystem components under the scope of EU environmental directives (e.g. habitat types, and biotic groups at the individual species and functional-group level). However, having to express the difference between this definition and that of Culhane et al. (unpublished) would have over-complicated the text in Box 7.2; and calling them the same in the context assessing ecosystem capacity is quite correct anyway.

([36]) For example, the state of marine invertebrates is assessed under the HD, WFD and MSFD, and all these marine-invertebrate status assessments could be used as part of assessing marine ecosystem potential to deliver several marine ecosystem services, such as seafood and raw-material provisioning, or global climate regulation by carbon sequestration (Table 7.3).

Box 7.2 A methodological approach to provide an EU-level assessment of marine ecosystem potential to deliver services using 'ecosystem condition' information from EU environmental legislation ('top down' EU-level assessment following the 'supply-side' approach) (cont.)

What can also happen in practice is that the information available cannot be used for several reasons, such as that the reporting is too aggregated to extract the specific 'metric' of interest for the assessment ([37]). In most cases, there is only one status assessment that can actually be used. As a consequence, state assessments from other sources (e.g. of commercial fish stocks under the CFP, different assessment products from Regional Sea and other International Conventions) need to be brought in. A prerequisite is that their state has to be classified to a certain extent (some sort of status needs to be available). These other assessments are then used together with the available status assessments from EU environmental legislation to assess the condition of each critical marine ecosystem component in the state-service relationship. The combination of status and state assessments for assessing these components is made under the same key assumption mentioned above.



Nevertheless, the information on which the methodology (and ensuing 'test service assessments') was based may have been produced at different times (because the times at which status and/or state assessments were made may not overlap). In addition, this information may not be relevant for the same spatial scales (the units/spatial scales used in the status and/or state assessments tend not to be the same). This possible lack of alignment of the 'source information' is one of the key limitations of the methodology, although it is actually more relevant for the ensuing 'test service assessments'. Another limitation is that the services are considered in isolation when, in reality, many are linked to each other.

The methodology also includes a step for the aggregation of the information used to assess each critical marine ecosystem component along a state-service relationship. However, before aggregation can take place, there is a need to interpret what the status assessments under each directive mean in terms of marine ecosystem potential for service delivery. The status assessments have been used to assess the condition of the critical ecosystem components, and this condition is what determines the potential for service delivery. The methodology makes another key assumption here, which has two aspects and is connected to the assumption above. One aspect is that the level of ambition of all these status classifications is similar across the directives (i.e. that 'good' truly means good).

([37]) For example, whales are part of the MSFD's scope so this directive should be relevant to assess whales. But under the MSFD whales are part of the 'mammals' group, which also includes seals, and the status of whales cannot be disaggregated from them (in the information available at the EU level through reporting sheets). Therefore, MSFD information is not suitable to assess just whales.

Box 7.2 A methodological approach to provide an EU-level assessment of marine ecosystem potential to deliver services using 'ecosystem condition' information from EU environmental legislation ('top down' EU-level assessment following the 'supply-side' approach) (cont.)

The other aspect is that all these status classifications carry the same weight in terms of what they mean for both ecosystem condition and service delivery. Thus, a status classification that meets the directives' objectives (regardless whether it is 'at GES' under the MSFD, or 'at FSC' under the HD, or 'at GEcS' under the WFD) is categorised as a 'pass'. This 'pass' would mean a 'positive' contribution to ecosystem condition and thus towards a 'good' potential for service delivery. Similarly, any deviation from achieving the directives' objectives is categorised as a 'fail', which would mean a 'negative' contribution to ecosystem condition and thus towards a 'bad' potential for service delivery (see stage 2 in diagram). Other state assessments (e.g. of commercial fish stocks under the CFP, IUCN European species red list) that are classified to a certain extent (e.g. endangered/vulnerable/least concern in the case of the IUCN classification) can be transformed in the same way, and this is why they can be used for the assessment. Then all the 'pass' and 'fail' categories are aggregated (following two alternative approaches) into an overall assessment of condition for each critical marine ecosystem component. The further aggregation of these overall assessments is what determines the final assessment outcomes for each service, i.e. 'good' or 'bad' potential for service delivery (see stage 2 in diagram, which expresses this outcome as 'ecosystem service state'). The same process is used for state trend information which then provides the trend in the potential for service delivery. The methodology also allows estimating the future change and the direction of change in this potential, which requires taking into account the state-service relationship. This is often done by using pressure information.

The application of this methodology showed the current state and trend, as well as the future change in state and the direction of change in marine ecosystem potential for service delivery in three semi-quantitative 'test service assessments'. The three services were 'wild capture seafood, 'waste nutrient storage and removal' and 'whale watching' in several EU marine regions. The number of regions varied with each test, but the test 'waste nutrient storage and removal' service assessment covered the four EU marine regions. Each test included the confidence associated with applying every step of the assessment methodology. The outcomes from these tests were consistent with the literature. However, the tests did not include mapping of marine ecosystems and services because the assessment information was either not spatially-referenced or insufficiently so.

Source: Adapted from Culhane et al., unpublished.

Challenges for MAES-type marine assessments across the EU

The conceptual model for mapping and assessing ecosystems and their services and other guidance from WG MAES covers all ecosystems across Europe. But when it comes to applying this guidance to marine ecosystems in particular, certain issues arise that should be discussed in more detail.

The specific MAES guidance for mapping and assessing marine ecosystems and their services (see Maes et al. 2013; Maes et al. 2014) is a very valuable effort. It offers great help to Member States when developing marine MAES-type assessments.

Nevertheless, there are some aspects of this MAES marine guidance that need further development. These aspects (and an idea of how to further develop them) were identified in the MAES guidance documents themselves, namely: extending the scope of current tools available at the EU level for consistent mapping of marine ecosystems (for example, to the pelagic zone); better defining the marine ecosystem typology (for example, to include pelagic habitats and reflect the photic zone ([38])); adjusting the extraction of the marine ecosystem services from CICES; and developing indicators for assessing marine ecosystem services that are relevant for EU marine policy and management ([39]) (Maes et al., 2013; Maes et al. 2014).

A consequence of the need to further develop the marine ecosystem typology and the marine ecosystem services extraction from CICES is that the linkages between marine ecosystems and services established in Maes et al. (2014) also need refining.

([38]) The surface layer where light availability is enough for photosynthesis to occur, and which is fundamental for ecosystem productivity (Box 2.2) and the potential for service delivery.

([39]) The indicators ('metrics') for assessing marine ecosystem services suggested by the MAES marine guidance tend not to use information generated by the implementation of EU environmental legislation relevant to marine ecosystems, namely the WFD and the MSFD in this case. The reason was the lack of EU harmonised data sets from the reporting on these directives (Maes et al., 2014). Instead, other EU environmental legislation (HD) and EU policy-related (CFP) information but mostly global datasets were used to develop these indicators. Therefore, the policy relevance of the MAES marine guidance could be improved by the increased availability of harmonised data sets or, even better, assessment products from EU environmental legislation with which to develop these indicators.

The above-mentioned study by Culhane et al. (unpublished) addressed and provided further insights into all of these issues except mapping (see e.g. Section 7.2, Table 7.1)

Nevertheless, in addition to further developing the MAES marine guidance, there are several challenges that need to be overcome to make the MAES conceptual model operational for the mapping and assessment of marine ecosystems and their services across the EU. These challenges are, in particular, for a 'top-down' EU-level marine ecosystem service assessment using 'ecosystem condition' information from EU environmental legislation following the 'supply-side' approach. However, many of these challenges would also apply if such information and approaches are used to carry out the mapping and assessment of marine ecosystem services at the national level.

Table 7.4 shows the main challenges for developing MAES-type marine assessments (defined here as mapped assessments of marine ecosystem condition on the basis of information from EU environmental legislation, and — following the 'supply-side' approach for assessing marine ecosystem services — expressing this condition in terms of the potential for service delivery). These challenges concern several components of the assessment chain. The table has been compiled by using elements from the preceding sections of this chapter and from Chapter 2 of this report, namely:

- the main knowledge gaps in marine ecosystem service generation outlined in Chapter 2;

- the lack of a common, general mapping and assessment methodology for (marine) ecosystems and their services across the EU;

- the problems with the quality and availability of information on 'ecosystem condition' from the reporting under several EU environmental directives;

- the main difficulties in using information on 'ecosystem condition' from the reporting under several EU environmental directives to provide an assessment of marine ecosystem potential to deliver services at the EU level ('top down') (including from Section 7.3 and Box 7.2);

- and the aspects of the existing MAES marine guidance that have been identified as in need of further development.

Many of the challenges in Table 7.4 reflect the fact that the MAES requirements and guidance (which date from April 2013 and February 2014) have not yet been integrated into the implementation processes of the EU environmental directives that are relevant to marine ecosystems. Therefore, there is scope for future improvement.

But in spite of these challenges, a lot has already been inferred in recent years and still can be inferred now about the state of marine ecosystem services, both at the EU and 'lower' levels. The 'supply side' approach to service assessment is especially useful in helping this work (Section 7.3, Section 7.5). However, we are still not at the stage where the marine ecosystem services concept can be made operational in a way that provides a 'common language' across the EU (Section 7.3). This 'common language' is critical for supporting the implementation of ecosystem-based management in Europe's seas. These issues are further discussed at the end of Section 7.7 on the socio-economic analyses linked to the MSFD's Initial Assessment. That section brings additional information into the discussion from what we have observed on the use of the ecosystem-services approach in these socio-economic analyses.

Table 7.4 Main challenges to overcome for developing EU-level MAES-type marine assessments

<table>
<tr><th colspan="2">Assessment knowledge: key questions</th></tr>
<tr><td>We need to better understand how changes in marine ecosystem condition influence changes in ecosystem service delivery, so we can eventually quantify the link between them. This will mean knowing more about:
The relationship between marine biodiversity change and ecosystem change, in particular what is the sensitivity of ecosystem functioning to changes in marine biodiversity?
The correlation between marine biodiversity and the different service categories (provisioning, regulation and maintenance, and cultural services). We also need to know how to quantify this correlation (this quantification is important for managing the exploitation of marine ecosystems, as trade-offs may have to be made between services).
The capacity for marine ecosystem recovery and resilience, and how these capacities influence the potential of an ecosystem to deliver services (e.g. to know about the possible reversibility of reduced potential for service delivery, due to ecosystem degradation, if the ecosystem recovers).</td><td>Similarly, we also need to better understand how good ecosystem condition relates to the different status classifications (of state assessment products) under the relevant EU environmental legislation (such as 'good environmental status' under the MSFD). To do this, we must be able to answer questions like:
Are the aspects of 'ecosystem condition' covered by each of the relevant pieces of EU legislation (e.g. MSFD, WFD or HD) really different and complementary (so they can all be used together and provide a wide characterisation of ecosystem condition)?
Does 'good' status (under the MSFD or WFD or HD) really mean good ecosystem condition (in terms of the aspects of ecosystem condition covered by each directive)?
Does 'good' status therefore mean good marine ecosystem potential for service delivery?
Does good marine ecosystem potential for service delivery mean that the delivery of services can continue over time?
How does a 'not good' status (under the MSFD or WFD or HD) relate to ecosystem recovery and resilience (and thus to the continued ecosystem potential for service delivery)?</td></tr>
<tr><th colspan="2">Assessment information: poor quality and limited availability of information at the EU level</th></tr>
<tr><td rowspan="3">There are a number of problems with the information (assessment products) on 'ecosystem condition' from EU environmental legislation that could be used for MAES-type marine assessments at the EU level. This information is:
Incomplete/poor and fragmented.
Non-harmonised/too variable.
Mostly qualitative.
Very aggregated, sometimes too much to be able to use it as 'metrics' for the assessment.
Not all reported at the same time, neither regularly, and nor at the same scale (or at a scale that is suitable for assessing the condition of ecosystem components)
Often reported without or with insufficient spatial references (as needed for mapping).
Often insufficiently detailed when it comes to describing ecosystem condition considering both the structural and functional elements of ecosystems.
Not directly targeted to assessing the state of marine ecosystem services (which is why the assessment needs to be based on ecosystem condition).</td><td>At times, the assessment would also need pressure information from which to predict future changes in ecosystem condition. Pressure information from EU environmental legislation available at the EU level is also affected by many of the problems shown for 'ecosystem condition' information.</td></tr>
<tr><td>Some of the problems with the information from EU environmental legislation can be resolved by bringing in additional information available at the EU level, e.g. from other EU (e.g. from the CFP), global (e.g. from IUCN), or regional (e.g. from OSPAR) sources. However, other assessments of 'ecosystem condition' may not be classified (status) to the same extent as assessment products from EU environmental legislation. Status classifications of ecosystem condition are needed to be able to infer a 'positive' or 'negative' impact from this condition on service delivery (which cannot easily be done by any other means).</td></tr>
<tr><td>The MAES-type assessment 'needs' and guidance have not yet been translated into the assessment and reporting requirements of the relevant EU legislation. Therefore, the required assessment information is not readily available at the EU level (even though this information may exist at the Member State (or regional) level).</td></tr>
<tr><th colspan="2">Assessment methodology: problems due to lack of — or incomplete — EU reference methodological elements</th></tr>
<tr><td>The EU reference typologies for both marine ecosystems and marine ecosystem services (in the Maes et al. 2013 guidance document) need further development. This further development should aim at allowing:
Improved correlation with the marine ecosystem typologies (e.g. for habitats) in the relevant EU legislation.</td><td>The EU reference for establishing the linkages between marine ecosystems and ecosystem services needs further development. In addition, these linkages should be prioritised. Further, there is no EU reference for establishing and prioritising the linkages between ecosystems/services and the pressures and drivers acting upon them. Determining this set of causalities (as far as possible in view of existing knowledge gaps) is also a critical requirement for any assessment.</td></tr>
</table>

Table 7.4 Main challenges to overcome for developing EU-level MAES-type marine assessments (cont.)

<table>
<tr><th colspan="2">Assessment methodology: problems due to lack of — or incomplete — EU reference methodological elements (cont.)</th></tr>
<tr><td>• Adequate identification and discrimination of the services provided by marine ecosystems, in particular by pelagic habitats and in the more productive photic zone (40).

These typologies are critical requirements for any assessment.</td><td>There is no EU reference for establishing the state-service relationships between ecosystem components and services. This relationship shows how the condition of each of the ecosystem components linked to the delivery of a particular service (identified using the linkages above) affects the delivery of this service. Determining the state-service relationships (as far as possible in view of existing knowledge gaps) is a further critical requirement for any assessment.</td></tr>
<tr><td colspan="2">There is no common, general methodology for the assessment of marine ecosystems and services across the EU. An EU reference methodology of this type is needed to promote a comparable way of:

• Assessing marine ecosystem condition using both structural and functional elements of ecosystems.

• Assessing cumulative drivers (human activities), pressures, and impacts on both structural and functional elements of ecosystems.

• Identifying which information across all the relevant pieces of EU environmental legislation could be used as 'metrics' to assess marine ecosystem condition and drivers/pressures per service. This identification would be based on the marine ecosystem and marine-ecosystem services typologies, and follow from the linkages and the state-service relationships above.

• Agreeing on which other general sources of information could be used to any fill gaps in the information from EU environmental legislation above.

• Aggregating the 'metrics' that can be used to assess marine ecosystem condition and drivers/pressures across all the relevant pieces of EU environmental legislation from which they have been derived. This implies overcoming a number of specific challenges including: different scales, different assessment units, different parameters assessed, different timing for both assessment and reporting, and understanding the 'overlaps' between the marine ecosystem components across the directives (41). Similarly with the information from other sources.

• Coming up with a way of inferring a positive or negative impact of ecosystem condition on service delivery on the basis of the status classifications (e.g. 'good') of assessment products across the relevant pieces of EU environmental legislation (e.g. MSFD, WFD or HD) (once the related knowledge gaps are clarified). Similarly, a way of transforming whatever status-type classifications are used in assessment products of ecosystem condition from other sources of information into a positive or negative impact on service delivery is also needed. Ideally, these two ways should be the same.

• Classify assessment outcomes of the potential for service delivery and link them back to the status classifications under the relevant EU environmental legislation. This is needed to ensure that these outcomes are policy-relevant, and can provide information on policy effectiveness, as well as allow a policy response.

• Integrate any new information when the knowledge gaps mentioned above are filled.</td></tr>
<tr><th colspan="2">Mapping methodologies: limited consistent EU mapping approaches</th></tr>
<tr><td>There is an urgent need to extend the scope of consistent marine mapping approaches at the EU level. At the moment:

• Consistent EU broad-scale seabed habitat mapping (EUSeaMap) does not fully cover the four EU marine regions. This will only occur in 2016.

• There is no consistent EU mapping of pelagic habitats (and no new initiatives to map these habitats have been envisaged).

• There is no consistent EU mapping of cumulative drivers (human activities) and associated pressures as needed to map their cumulative impacts on marine ecosystems.</td><td>The consistent EU broad-scale seabed habitat mapping (EUSeaMap) approach has some key shortcomings:

• It only looks at physical habitats rather than 'biotopes' or ecosystems.

• It is not sufficiently linked to the habitat typologies under the relevant EU environmental legislation (e.g. it excludes habitats in the littoral zone), nor to the MAES marine ecosystem typology (42) (although the reported information on the condition of these seabed habitats and the pressures and drivers acting upon them tends not to be sufficiently spatially-referenced anyway).</td></tr>
</table>

Note: These challenges are, in particular, for a 'top-down' EU-level assessment of marine ecosystem potential for service delivery on the basis of information on 'ecosystem condition' from EU environmental legislation following the 'supply-side' approach (non-exhaustive list (43)). However, some would also apply to national MAES-type marine assessments.

(40) The surface layer where light availability is enough for photosynthesis to occur.

(41) See, for example, the correspondence between different European marine habitat typologies at: http://biodiversity.europa.eu/maes/crosswalks-between-european-marine-habitat-typologies_10-04-14_v3.pdf.

(42) See footnote (41).

(43) Reflects the situation in November 2014.

Way forward for a better EU-level assessment of marine ecosystem services

More time is clearly needed to tackle the challenges in Table 7.4 at the EU level, including for the further development of some of the new ideas emerging from the MAES process. More time is also needed for these ideas to permeate from the EU level to the national level, and to help raise the number of national MAES-type marine assessments, as well as to increase their comparability across the EU where needed. This would in turn facilitate the assessment of marine ecosystem services at the EU level.

Nevertheless, actions to improve the assessment of marine ecosystems and services have taken place — and are still taking place — throughout the EU. These actions are led by EU bodies, Member State authorities, Regional Sea Conventions, and research and stakeholder organisations. Some of these actions take place under the 'MAES umbrella' and some do not (see also Section 7.5).

At the EU level, WG MAES continues to support the development of the different assessments required from Member States to fulfil Target 2/Action 5 of the EU Biodiversity Strategy to 2020. Also at the EU level, there are recent actions focusing on overcoming some of the challenges above in order to improve the operability of the MAES conceptual model to map and assess marine ecosystems and their services, in particular for a 'top-down' EU-level assessment. One example is the initiative from the EU Nature, Water, and Marine Directors' group to facilitate the use of 'ecosystem condition' information from EU environmental legislation in MAES-type (marine) assessments. This EU Directors' group is promoting the coordinated implementation of the relevant EU environmental legislation (e.g. HD, WFD, MSFD) so that the national assessment and reporting requirements of this legislation can eventually deliver information at the EU level that meets the MAES requirements. The group is assisted in its work by the European Commission services and the EEA. The 'coordinated implementation' process started at the group's first joint meeting in December 2013 in Vilnius, and progress is ongoing.

Another example of action at the EU level is the recent initiative from the European Commission services, with the participation of the EEA, to increase integration between MAES-type marine assessments and MSFD-related assessments. In addition, the EEA is working to make best use of the information and methodologies that are currently available in order to produce MAES-relevant products for all ecosystems in 2015 and 2016.

Nevertheless, it is currently unclear to what extent all these EU-level actions will be able to overcome the challenges for a 'top-down' EU-level assessment of marine ecosystem potential for service delivery on the basis of information on 'ecosystem condition' from EU environmental legislation ('supply-side' approach). It is possible that a few of these challenges may still remain in the future.

7.5 Using knowledge on marine ecosystem service assessment across the EU to support EU-level initiatives

Summary of main points in this section

- A number of national, regional, and other assessments of marine ecosystem services were carried out before and around the time the MAES process was set up and/or started running, and some are thus outside the 'MAES umbrella'. Several of these assessments have addressed some of the challenges faced by MAES-type marine assessments, in particular for a 'top-down' EU-level assessment.
- The approaches used by marine ecosystem service assessments outside the 'MAES umbrella' could serve to overcome some of the methodological and mapping challenges faced by MAES-type marine assessments. However, in general, these approaches have not been sufficiently reflected in EU-level initiatives supporting the MAES process.
- Research-based approaches for marine ecosystem service assessment could provide 'top-down' EU-level assessments of marine ecosystem potential for service supply, and of the actual demand/use of the services by people. However, in general, research approaches tend not to follow the MAES conceptual model closely enough, and/or they tend not to use EU policy-relevant information on ecosystem condition either. This means that it is difficult to use the outcomes from these assessments directly, without some further interpretation, to inform EU marine policy and management.

Existing marine ecosystem service assessment knowledge that could support EU-level initiatives

A number of national, regional, and other marine ecosystem service assessments were carried out before and around the time the MAES process was set up and/or started running. Some of these assessments are thus outside the 'MAES umbrella'. National and regional assessments tend to be based on higher-quality and more comprehensive information than those at the EU level. These 'lower level' assessments can therefore be more sophisticated in terms of what they show about the state of marine ecosystem services than what we have been able to show at the EU level in Section 7.3. As a consequence, these 'lower level' assessments can often be used to support the development of specific management measures to improve the condition of marine ecosystems.

Several of these national, regional, and other marine ecosystem service assessments have addressed some of the methodological and mapping challenges faced by MAES-type marine assessments included in Table 7.4. In some cases, this is because the assessments followed similar conceptual models to the MAES one. Moreover, a few of these methodological approaches have already been used as inspiration for EU-level initiatives. For example, the current approach for consistent EU-level mapping of broad-scale seabed habitats, EUSeaMap, is based on national approaches (UKSeaMap), and on regional approaches for the Baltic (BALANCE ([44]) project) and North (MESH ([45]) project) seas. And, even if full mapping of the four EU marine regions will not be achieved until 2016, EUSeaMap has already succeeded in harmonising the earlier methods and in providing a consistent approach to seabed mapping for the whole of the EU.

In spite of being a possible source of inspiration, the general trend is that the approaches behind these national, regional and other marine ecosystem service assessments have not been sufficiently reflected in EU-level initiatives supporting this type of assessments so far. This is probably not only because most of them precede the MAES process but also because the services may not have always been assessed on the basis of ecosystem condition ('supply-side' approach). In addition, these assessments tend not to use information from the implementation of EU environmental legislation, which is a requirement of the MAES process. Furthermore, not having benefitted from the EU-level guidance produced under the MAES process means that comparability between the methodologies used in these assessments (and thus between the assessment outcomes) may be difficult. Nevertheless, we consider that these assessments are still very valuable to help overcome some of the main challenges for developing MAES-type marine assessments at the EU level (Table 7.4). For example, the methodological approaches used in these assessments could serve to inspire the development of the missing 'EU references' for several methodological and mapping aspects of MAES-type marine assessments shown in Table 7.4, as was the case for EUSeaMap.

([44]) BALANCE: Baltic Sea Management — Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning http://balance-eu.org.
([45]) MESH: Mapping European Seabed Habitats https://www.marine.ie/home/services/surveys/seabed/Mesh.htm.

In Table 7.5 we present an overview of several of these national, regional and other initiatives to assess marine ecosystem services. We also link these initiatives to some of the methodological and mapping challenges for MAES-type marine assessments in Table 7.4 that they could help to overcome. National and regional assessments tend to be research-based or government-led. The latter means that, at times, they may have used information from the implementation of EU environmental legislation. 'Other' assessments are solely from research and include EU-level projects that can cover the four EU marine regions. Regardless of their geographical coverage, research-based initiatives do not normally use information from the implementation of EU environmental legislation.

Looking at Table 7.5 it should be obvious that the initiatives there (and other similar initiatives like them) have a lot to offer in terms of overcoming some of the methodological and mapping challenges for EU-level MAES-type marine assessments (Table 7.4). However, Table 7.5 also indicates that each initiative has tended to resolve the relevant challenges in its own unique way, which could prevent comparability of outcomes. It therefore illustrates the difficulties in using the outcomes from national marine ecosystem service assessments to provide an EU overview ('bottom-up' EU-level assessment) in the absence of the MAES marine guidance, i.e. when there has not been some convergence between Member State assessment procedures as promoted by that guidance.

Table 7.5 Examples of national, regional, and other initiatives relevant to overcome EU-level challenges for the mapping and assessment of marine ecosystems and their services

Example of relevant initiative ([46]) (relevance is in part or in full, list is non-exhaustive)	Example of assessment challenge or issue addressed (list is non-exhaustive)
MESMA EU FP7 • EU-level • Research-based • Methodological elements towards services assessment	• Linkages (causality and some quantification) between marine ecosystems (EUNIS habitats) and services (Salomidi et al., 2012). • Marine ecosystem-services typology (Salomidi et al., 2012).
ODEMM EU FP7 • EU-level (four EU marine regions) • Research-based but used information from the implementation of EU environmental legislation (except from the MSFD) • Methodological elements towards services assessment	• Linkages (causality) between marine ecosystems, services, pressures, and drivers (White et al., 2013a; White et al., 2013b). • Marine ecosystem-services typology (Böhnke-Henrichs et al., 2013).
Natural England marine ecosystem services study • National level: UK marine waters • Government agency-commissioned • Methodological elements towards services assessment	• Linkages (causality) between marine ecosystems (EUNIS habitats) and services (Fletcher et al., 2012). • Marine ecosystem-services typology (Fletcher et al., 2012).
VECTORS EU FP7 • Case study: Dogger Bank • Research-based • Methodological elements towards services assessment	• Marine ecosystem-services typology (Hattam et al., 2015). • Typology of marine indicators for service assessment based on ecosystem condition, ecosystem processes/functions, and service benefits (Hattam et al., 2015).
HELCOM Initial Holistic Assessment (HOLAS) of the Baltic Sea • Regional assessment: Baltic Sea • Commissioned by the member countries of a Regional Sea Convention (HELCOM) • Methodological approach supporting implementation of HELCOM's Baltic Sea Action Plan • Mapped assessment of cumulative impacts on seabed habitats	• Consistent mapping of broad-scale seabed habitats (building on the BALANCE project) (HELCOM, 2010). • Methodology for assessment and mapping of cumulative drivers/activities, pressures, and impacts on seabed habitats (HELCOM, 2010). • Assessment of seabed habitats including maps of cumulative pressure and impact indexes (HELCOM, 2010).

([46]) Reflects the situation in November 2014.

Table 7.5 Examples of national, regional, and other initiatives relevant to overcome EU-level challenges for the mapping and assessment of marine ecosystems and their services (cont.)

Example of relevant initiative [46] (relevance is in part or in full, list is non-exhaustive)	Example of assessment challenge or issue addressed (list is non-exhaustive)
Greater North Sea's HARMONY [47] *project* • Subregional assessment: eastern parts of the Greater North Sea • Led by a Danish government agency • Methodological approach supporting MSFD implementation • Mapped assessment of cumulative impacts on seabed habitats	• Consistent mapping of broad-scale seabed habitats (building on the MESH project) (Andersen and Stock (eds.), 2013). • Methodology for assessment and mapping of cumulative drivers/ activities, pressures, and impacts on seabed habitats (Andersen and Stock (eds.), 2013). • Assessment of seabed habitats including maps of cumulative pressures and impact indexes (Andersen and Stock (eds.), 2013).
Swedish Environmental Protection Agency 'Ecosystem Services provided by the Baltic Sea and Skagerrak' initiative • Regional assessment: Baltic Sea • Led by a Swedish government agency • Marine ecosystem service assessment	• Linkages (causality) between marine ecosystems services, drivers, and impacts (Naturvårdsverket, 2009). • Qualitative assessment of the trend in services (on the basis of the ecosystem potential for their delivery) in relation to 'drivers of change' and their impacts (Naturvårdsverket, 2009).
United Kingdom, Spain, and Portugal National Ecosystem Assessment • National level: follow-up to the Millennium Ecosystem Assessment • Government-led marine ecosystem assessment • Marine ecosystem service assessment	All include semi-quantitative assessments of state and trends for several marine ecosystem services. These are based mainly on the stock (ecosystem potential) as follows: • *United Kingdom*: Several services from the provisioning, regulation, supporting, and cultural categories (Austen and Malcom, 2011). • *Spain*: Most services from the provisioning, regulation and maintenance, and cultural categories (Duarte et al., 2012). • *Portugal*: Food provisioning and cultural (recreation) services (Pereira, Domingos and Vicente (eds.), 2004).
Mapping of Ecosystems and their Services in the EU and its Member States (MESEU) project • Case study: Dutch Wadden Sea • Research-based • MAES-related: National pilot for MAES-type marine assessment • Mapped ecosystem service assessment	Quantitative and spatially resolved assessment of some marine ecosystem services from the provisioning (fish, shellfish), regulating (providing disturbance-free area), habitat (specific species under the Habitats Directive), and cultural services (recreation) (Hendriks et al., in. prep.). • Indicators of flow used for provisioning and cultural services, and of stock for regulation and habitat services (the latter from information generated by the implementation of the Habitats Directive). • Mapping of ecosystems (Habitats Directive's habitats), services, and cumulative pressures upon them.
Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean • Case study: All MSFD subregions in the North-east Atlantic Ocean • Research-based • MAES-related: Marine ecosystem service mapping in the context of a MAES-type marine assessment • Mapping of marine ecosystem services (and a certain degree of assessment)	• Marine ecosystem-services typology (Galparsoro et al., 2014). • Linkages (causality) between marine ecosystems (EUNIS habitats) and services when habitats were not covered in the equivalent work from Salomidi et al. (2012) (Galparsoro et al., 2014). • Maps with spatial distribution of marine ecosystem services (Galparsoro et al., 2014). • The service assessment was not of the state of the services but a verification and quantification of the qualitative linkages between the habitats and the services these could deliver (i.e. assessing the actual relevance of the habitats to specific service delivery) (Galparsoro et al., 2014).

Note: Marine ecosystem services are assessed on the basis of ecosystem condition ('supply-side' approach). These examples could help to overcome some of the challenges for EU-level MAES-type marine assessments highlighted in Table 7.4.

(47) HARMONY: Development and demonstration of MSFD tools for harmonisation of the initial assessment in the eastern parts of the Greater North Sea subregion.

For example, the typology of marine ecosystem services has varied between initiatives. In this instance, however, it should be possible to establish the correspondence between those typologies and CICES, which is the 'EU reference' typology for all ecosystem services. But, at the same time, the extraction of marine ecosystem services from CICES would still need some further development beforehand (Section 7.2, Section 7.4).

Lack of comparability is even more obvious when it comes to the initiatives in Table 7.5 that have actually delivered an assessment of marine ecosystem services. In these initiatives, the lack of comparability stems not only from using different methodological elements (as was the case with the marine ecosystem typology above), but also from the type of assessment that has been carried out.

Some initiatives have quantified and mapped the services (or the ecosystem components with the capacity to deliver them), whilst others have provided qualitative assessments without mapping. Moreover, with very few exceptions, these assessment initiatives have not used information generated from the implementation of EU environmental legislation. This makes it difficult to use them directly in an EU marine-policy context (we explain why below). However, some of the initiatives have used the legislation as a 'framework' (e.g. the HARMONY project used the MSFD as a framework).

As explained in Section 7.4, a new batch of national marine ecosystem service assessments is being produced following from the MAES process supporting the EU-level implementation of Target 2/ Action 5 of the EU Biodiversity Strategy. Because they should have been developed using the MAES concept and guidance, comparability between these assessments should be easier. However, whether this comparability will be enough to provide an EU overview ('bottom-up' EU-level assessment) remains to be seen. This is because several of the challenges put forward in Table 7.4 may still be applicable (e.g. the MAES marine guidance needs further development), and because of the great deal of expert judgment needed for this type of assessment.

As also stated in Section 7.4, further convergence of MAES-type marine assessments between now and 2020, the final deadline for fulfilling Target 2/ Action 5, may be achieved by developing a common, general mapping and assessment methodology for all ecosystems and their services at the EU-level, building on the MAES guidance elements and other approaches such as the ones highlighted in this section.

What can we learn from existing national and regional marine ecosystem service assessment outcomes?

Despite the differences in some of the methodological aspects of the assessment (e.g. use of different marine ecosysten services typologies) and the time elapsed, it may still be worth comparing the 'supply-side' assessment of marine ecosystem services in Section 7.3 with a couple of similar initiatives in Table 7.5. Doing this shows that the conclusion in Section 7.3 with regard to the current threat to the sustainability of the potential of Europe's seas to deliver all marine ecosystem services is consistent with the two examples below, although less precise (as also acknowledged at the end of Section 7.3).

The 2009 initiative from the Swedish Environmental Protection Agency on 'Ecosystem Services provided by the Baltic Sea and Skagerrak' concluded that *most ecosystem services are under threat*. Specifically, it reported that: *Only 10 of the 24 ecosystem services described are operating properly in the Baltic Sea. This conclusion may be drawn even though there are wide gaps in our knowledge of most of the services. Seven are severely threatened, including four of the six supporting services. The four under severe threat are: the food web, biodiversity, habitats and Baltic Sea resilience, i.e. the capacity of the sea to recover. The other three threatened services are food, genetic resources and aesthetic values* (Naturvårdsverket, 2009).

The results from this initiative have been included in HELCOM's 'Ecosystem Health of the Baltic Sea' publication, which contains the results of its Initial Holistic Assessment (HOLAS).

The 2012 marine component of the Spanish National Ecosystem Assessment following the Millennium Ecosystem Assessment concluded: *The use of marine ecosystem services had increased by 80% in the last 50 years and, for this reason, about 40% of the services assessed were in a bad state/degraded or used unsustainably*.

The degraded services above included 'wild food provisioning' (seafood) and 'cultural' services linked to artisanal fisheries (e.g. cultural identity, sense of belonging) due to a high demand combined with overexploitation from industrial fisheries. Also degraded were key 'regulation and maintenance' services linked to mediation of waste and toxics by biota and ecosystems, and mass stabilisation and control of erosion rates. The degradation of these services was caused by the degradation of the underpinning ecosystem/biodiversity components, namely seagrass and other angiosperms, in particular *Posidonia oceanica;* coral and other reefs; seamounds; and top predator fish species such as tuna. This degradation had a proven impact on tourism (Duarte et al., 2012).

Research-based EU-level marine ecosystem service assessments

In spite of the challenges for EU-level assessments (Table 7.4), it may still be possible to produce an EU-level 'top-down' full assessment of the state of marine ecosystem services (combining 'supply-side' and 'demand-side' elements). There are other means to do this than basing the assessment on ecosystem capacity ('supply-side' approach) and using information on 'ecosystem condition' from EU environmental legislation (as was the case of the assessment in Section 7.3 and the type of assessments described in Section 7.4).

One way to do this is to use 'technical' information such as from research (as some of the initiatives in Table 7.5). For example, the JRC used terrestrial and marine datasets (both EU and global) as well as modelled data to assess 'coastal protection' as a marine ecosystem ('regulation and maintenance') service at different spatial-temporal scales for the entire EU coastal zone. The assessment incorporated 14 biophysical and socio-economic variables used to define indicators of coastal protection capacity, coastal exposure, and human demand for protection. In the JRC study, coastal protection benefits for the EU coastline were estimated and classified as 'deficient', 'sufficient', or 'plentiful' for 31%, 27%, and 42% of the coastline respectively (Liquete et al., 2013). The assessment did not value these benefits in monetary terms.

Such a 'technical' assessment obviates the comparability problems for developing a 'bottom up' EU-level assessement (EU overview) of marine ecosystem services using the outcomes from national assessments, and provides a good EU-level 'top-down' picture of the state of these services. Thus, as is the case with the JRC example above, these types of assessments can be coherent, complete, fairly accurate, and fully spatially supported.

Nevertheless, in general, these research-based assessments have a couple of potential drawbacks in an EU marine-policy context. One is that they tend not to follow the MAES conceptual model closely enough (although this is not the case for the JRC example above). Another one is that they tend not to be based on information (assessment products) from EU environmental legislation but datasets, which many times are global datasets and modelled data. For this reason, there is no one-to-one correspondence between the 'metrics' (indicators) they use to assess marine ecosystem services and the aspects of ecosystem condition that are assessed as part of the implementation of this legislation. Therefore, there is no obvious direct link between the outcomes from these research-based service assessments and the legislative assessments of ecosystem condition. These drawbacks make such 'technical' approaches not easy to use directly, without some further interpretation, when evaluating EU policy effectiveness and/or developing EU policy responses.

Research has recently proposed further marine ecosystem service assessment approaches combining 'supply-side' and 'demand-side' elements (e.g. Hattam, 2015). However, these new combined assessment approaches have been designed to detect change and take the appropriate management action 'on the ground' (at a given location). They therefore require quite specific and abundant information. Nonetheless, the possibility of EU-level applicability to suit the more general needs of EU policy and management could be explored. This is, in particular, because some of the indicators proposed (see Hattam, 2015) could be based on information from the implementation of EU environmental legislation, and other EU legislation and policy.

7.6 Valuing marine ecosystem services

Summary of main points in this section

- Economic valuation of the benefits of marine ecosystem services can help to increase recognition of the role of marine ecosystem capital in supporting the economy and human well-being. There is evidence across the EU that this recognition can help to better integrate marine ecosystem capital into decision-making.
- There are many shortcomings attached to the economic valuation of marine ecosystem service benefits, in particular when conducted through the Total Economic Value (TEV) framework. These shortcomings include the high data demand to account for changes in ecosystem service delivery and their impact on people; and the long time it takes to generate original 'non-market' valuation outcomes. As a result, the end-values from economic valuations are quite subjective and very dependent on their context, which means that there is a high degree of uncertainty attached to them and they need to be used with caution.
- Some of the shortcomings from applying the TEV framework to value service benefits could be overcome by using ecosystem accounting. However, where the TEV approach needs a high level of quantitative information, the ecosystem accounting approach also needs this information to be spatially-referenced. These are key challenges in applying such approaches to marine ecosystems and services.
- Much more quantitative and spatially-referenced information needs to be made available for economic valuation of the benefits of marine ecosystem services, and for marine ecosystem accounting in order to achieve the 2020 goal of Target 2/Action 5 of the EU Biodiversity Strategy to 2020. This goal requires Member States to assess the economic value of (marine) ecosystem services, and promote the integration of these values into accounting and reporting systems at EU and national level.

In Chapter 2, and in previous sections of this chapter, we have discussed and used the so-called 'supply-side' approach to assessing marine ecosystem services. However, there is also a 'demand-side' approach to assessing marine ecosystem services, which is used, in particular, in an economic context. In this section and the next section we will look at this approach in more detail. The 'demand-side' approach estimates and values the societal benefits from the **actual realised flow** of ecosystem services. Unlike the 'supply-side' approach, which is focused on estimating **the ecosystem's potential for service delivery**, the 'demand-side' approach seeks to quantify the benefits from the consumption, use (active or passive) or enjoyment of the services by people (i.e. by a given beneficiary or groups of beneficiaries).

The valuation methods used by the 'demand-side' approach can be bio-physical and the value is expressed in physical units, such as tonnes of fish sold by fishermen. But they can also be economic and the value is then expressed in monetary units, such as the profit (in Euro) made by the fishermen from selling the fish. The 'demand-side' approach recognises that not all the benefits that people get from ecosystem services can be easily valued in monetary terms. For example, it is hard to put a price on the aesthetic beauty of a clean beach. Therefore, when carrying out service valuation using the 'demand-side' approach, it is important to include other values as well, such as health, social, or conservation value. Thus, the socio-technical systems that interact with the ecosystem are an integral part of the valuation framework. This is because institutions, stakeholders, and other users of ecosystem services can all affect ecosystems by interacting with them (Figure 2.1).

Some theory on the economic valuation of (marine) ecosystem services

From an economic point of view, the value of ecosystem services results from their utility to people (Brown et al. 2007). Economics therefore classifies ecosystem services according to the type of use they may have. The most accepted conceptual framework for the valuation of the benefits from ecosystem services is the Total Economic Value approach (TEV). The TEV of an ecosystem would be the aggregated value of the benefits from all the ecosystem services provided in a given ecosystem state (TEEB, 2009). According to this approach, the TEV can be divided into 'use' and 'non-use' types of value.

'Use' values include 'direct' use values ([48]) and 'indirect' use values (e.g. from recreational uses). 'Non-use' values include 'existence' and 'option' values. 'Existence' values arise from the knowledge that the service exists and will continue to exist, independently of any actual or prospective use by — and benefits for — the individuals themselves. For example, existence value would be the value people place on improvements to the quality of the bathing water of a remote beach due to some

([48]) 'Direct' use values include both consumptive and non-consumptive values. These are, respectively, the values of resources which are — and are not — diminished by their use.

moral and/or altruistic reason, or for the mere pleasure of knowing that the aesthetic quality of the beach has been enhanced. 'Option' values measure individuals' preferences, and aim at ensuring that the services will be available for their own use in the future, and that their heirs or future generations will also be able to enjoy the services.

Many 'indirect' and 'non-use' types of values from ecosystem service benefits do not have a clear market price. In the absence of market prices, the damages or positive effects that any related economic activity using these services poses to others are not properly (if at all) compensated by the agent responsible for the economic activity. This generates a market externality. Externalities can be negative, such as a polluting activity harming others (e.g. agricultural diffuse pollution reducing bathing water quality and affecting swimmers), or positive, such as the un-valued, indirect positive effects of an activity on others (e.g. when essential public services, such as water and electricity supply, hospitals and schools, are deployed in remote coastal rural areas that are solely dependent of fisheries for their economic development, i.e. would not exist without the fishing activity).

As a result of the lack of clear market prices for many 'indirect' and 'non-use' type of values, the total economic value of the benefits from ecosystem services cannot be easily taken into account in decision-making. This presents difficulties when having to decide between alternative management practices affecting ecosystem services, where information on one type of value is readily available but is not readily available for others. The absence of clear market prices for certain types of values for ecosystem service benefits may ultimately lead to the mismanagement of human activities on ecosystems, as their associated externalities are not compensated. This partly explains why marine problems are still difficult to manage across the EU.

For example, the shipping of goods has a clear monetary value (in terms of the market value of the goods transported), but having healthy populations of marine mammals, fish and invertebrates does not have a clear monetary value. This is because we have not assessed the costs of marine-species loss associated with the negative impacts from marine pollution, such as from the ship's engine noise (which introduces energy into the marine system and is considered a type of pollution). Thus, decisions on the current management and further development of shipping and other human activities may overlook the need to protect marine biodiversity, and the associated ecosystem services and benefits, from engine noise. This omission would generate negative externalities. Knowing the true/full cost of these human activities (for example, by integrating the costs of marine species loss due to engine noise pollution) could act as a driver facilitating decision-making on the sustainable use of the sea.

Nevertheless, even if some of the benefits of ecosystem services do not have a clear market price, very often these benefits must be estimated in monetary terms anyway. One example of this is decision-making on marine policy and management, which often requires a cost-benefit analysis of plans, projects and/or measures. In the case of a specific infrastructure development project, decisions would take into account the benefits of this development for certain economic sectors and other beneficiaries, compared to its construction and running costs. However, decisions should also take into account the current benefits for people from the ecosystem services generated in the development area. Similarly, decisions should consider the benefit loss (costs) resulting from a negative impact of the development on the marine ecosystems delivering these services.

For example, a project to expand an existing harbour over a *Posidonia oceanica* seagrass meadow in the Mediterranean sea should estimate the monetary value of all the benefits from the services provided by the seagrass. This estimation should thus overcome the fact that there are no clear market prices for some of these benefits, such as from certain 'regulation and maintenance' (e.g. mediation of visual impacts), and 'cultural services'. Once all these benefits and their loss (costs) are estimated, the true cost of the harbour will emerge and an informed decision can be made.

In order to assist policymakers take such decisions, economists need to be able to understand and account for policy and management trade-offs, and thus to find ways to estimate the market price of all the benefits people get from ecosystem services. In the absence of existing or alternative market values for some of these benefits, there are methods that can estimate monetary values by establishing hypothetical markets around real-life situations generating these benefits. Once a hypothetical market is established, people can reveal concrete choices in relation to these benefits, and place a monetary value on those choices. These methods then look at peoples' choices, involving their time or the costs borne, to obtain the benefits. Those choices therefore reveal the value that people place on the benefits. Peoples' choices can be observed or elicited via 'stated preference' or 'revealed preference' methods. 'Stated preference methods' use surveys to ask people about their willingness to pay for the benefits, or accept compensation for the benefits lost, from a change in the delivery of the relevant ecosystem services. There are different approaches to carry out these surveys such as 'contingent valuation' and 'choice experiments' (Boxes 7.3, 7.6).

Box 7.3 Valuing the benefits of reduced eutrophication in the Baltic Sea

A study estimated the monetary value of the benefits of reducing eutrophication in the Baltic Sea according to HELCOM's Baltic Sea Action Plan ([49]). The study used the so-called 'contingent valuation' method, which is a survey-based method that directly asks people about their willingness to pay for a well-defined environmental change. For the study here, the change was reducing eutrophication because eutrophication has a negative impact on, e.g. 'cultural' ecosystem services. Therefore, people were willing to pay for this change so they could keep on benefitting from the recreational use of the sea and the existence of a healthy marine environment. 'Contingent valuation' assumes that the willingness to pay represents the benefits from the environmental change on the provision of the service in monetary terms.

The valuation survey was conducted in 2011 in all nine coastal countries of the Baltic Sea. A total of 10 500 responses were collected. In addition to the valuation questions, the survey collected information on respondents' attitudes to the environment, their experiences of eutrophication, their level of knowledge, and their background (e.g. income and age).

In the survey, the effects of Baltic Sea eutrophication were described to respondents on the basis of five ecosystem attributes linked to 'use' and 'non-use' related impacts: Water clarity, blue-green algal blooms, underwater (e.g. seagrass) meadows, fish species, and oxygen conditions in deep sea bottoms. These ecosystem attributes were linked to the benefits obtained from several 'cultural' services for which there is not always a market price (e.g. recreation such as swimming and sunbathing; aesthetic benefits; and existence benefits), and which are dependent on having good water quality and healthy marine habitats (see figure below but note that the ecosystem services definition and typology used in this study is different from CICES, Section 7.2). Changes in eutrophication were presented to respondents with colour maps illustrating the potential improvement in the condition of the Baltic Sea in the year 2050.

The results showed that the majority of respondents attached a great value to improving the state of the Baltic Sea. These results were then up-scaled to all the citizens in the Baltic Sea countries, and this showed a total benefit figure of around EUR 3.8 billion per year as the amount that citizens were willing to pay for reduced eutrophication up to 2050. This figure exceeded the estimated costs of combating eutrophication in the Baltic Sea (EUR 2.8 billion a year) by about EUR 1 billion a year. The findings also indicated that people valued having the entire Baltic Sea in a healthier state, that recreation on Baltic Sea shores and waters was popular in all coastal countries, and that many people were worried about the marine environment.

These estimates are useful in assessing the benefits of reducing eutrophication according to HELCOM's Baltic Sea Action Plan targets and achieving 'good environmental status' under the MSFD's 'Eutrophication' Descriptor. These benefits can be compared with the costs of nutrient abatement to assess the economic efficiency and social desirability of policy responses such as nutrient-abatement programmes.

Source: Adapted from Ahtiainen et al., 2012; Ahtiainen et al., 2013; Ahtiainen and Öhman, 2013; and BalticSTERN Secretariat, 2013.

([49]) See the eutrophication reduction targets, including country allocations, of HELCOM's Baltic Sea Action Plan at: http://helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/targets. Also the reductions achieved so far: http://helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/reductions-achieved and the measure to do so: http://helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/measures.

Evidence of the economic value of marine ecosystem services

There are several initiatives across the EU that have developed frameworks for the economic valuation of the benefits of marine ecosystem services, and also actual service benefit valuations. These initiatives are research-based or based on national or regional policy. Research-based valuation frameworks include the KnowSeas ([50]), SESAME ([51]), VALMER ([52]), and VECTORS ([53]) EU projects, which also conducted service-benefit valuations via case studies. A regional example of service benefit valuation is the first attempt at the economic valuation of the sustainable benefits of marine ecosystems in the Mediterranean Sea, which was undertaken in 2010 under the UNEP-MAP 'Plan Bleu' initiative (Mangos et al., 2010). Another regional example is a 'Stern type' of analysis in the Baltic Sea, which was carried out in 2013 to estimate the benefits and costs of reducing eutrophication according to the HELCOM Baltic Sea Action Plan (BalticSTERN Secretariat, 2013; Box 7.3).

Valuation of ecosystem service benefits can help to increase recognition of the role of marine ecosystem capital in supporting the economy and human well-being (Boxes 7.3, 7.4 and 7.6). The idea behind valuation is that once the importance of marine ecosystem capital is more widely recognised, it can be better integrated into decision-making.

Challenges for economic valuation of (marine) ecosystem service benefits

Despite the fact that monetary valuation of marine ecosystem (and other ecosystem) service benefits is already being conducted, it has many shortcomings. These shortcomings include political and ethical considerations (i.e. whether humans should put a 'price tag on nature' ([54])), the high data demand to account for changes in ecosystem service delivery and their impact on people, and the long time it takes to generate original 'non-market' valuation outcomes. It is important to note that taking into account changes in service delivery is constrained by the availability and quality of the ecological data and knowledge (Hanley et al., 2014). As a result of these shortcomings, the end-values from economic valuations are quite subjective and very dependent on their context (although there are 'benefit transfer' techniques allowing, with limitations, the application of a monetary valuation from one situation to a situation elsewhere). Therefore, economic estimates are subject to high degrees of uncertainty and need to be used with caution.

Box 7.4 The economic value of marine protected areas in the EU

Marine protected areas (MPAs) have become an increasingly popular environmental policy tool to address the challenge of conserving marine biodiversity. MPAs, in particular as part of a wider network of connected areas, can also be effective in protecting related vital services that can be provided by the sea.

In the EU, MPAs include marine Natura 2000 sites, which can deliver a range of ecosystem services and associated benefits. In 2011, a study estimated that the value of the benefits from the services delivered by the marine Natura 2000 network was approximately EUR 1.4–1.5 billion per year. The services were defined for the study and included: raw material provision, food provision, leisure, recreation, nutrient recycling, climate regulation, disturbance prevention, disturbance alleviation, and knowledge-related cultural services such as scientific and educational interactions.

The marine Natura 2000 area was 4.7% of the EU's total marine area in 2011 when the study was carried out. By the end of 2013 (the last available update), it was close to 6%. The study also estimated that the value of the benefits delivered by the marine Natura 2000 network would increase by up to EUR 3.0–3.2 billion per year if 10% of the EU's marine area was protected (as per the CBD Aichi target 11), and by EUR 6.0–6.5 billion per year if the protection reached 20% of the EU's total marine area. These figures should be seen as 'ball park' estimates. Obtaining more robust results would require an improved understanding of how protection will influence habitats, services, and offsite fisheries (relevant for food provision), amongst other issues.

Source: ten Brink et al., 2011.

([50]) Knowledge-based Sustainable Management for Europe's Seas (http://www.knowseas.com).
([51]) Southern European seas: Assessing and modelling ecosystem changes (http://cordis.europa.eu/project/rcn/81284_en.html).
([52]) Valuing ecosystem services in the Western Channel (http://www.valmer.eu).
([53]) Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors (http://www.marine-vectors.eu).
([54]) See for example http://www.theguardian.com/environment/georgemonbiot/2014/jul/24/price-nature-neoliberal-capital-road-ruin.

All these shortcomings also apply when estimating Total Economic Value (TEV). However, an added problem when doing so is the need to aggregate the different 'market'/'non-market' and 'use'/'non-use' types of values for the benefits of different services into a single figure, i.e. the TEV. Amongst other problems, this aggregation may lead to double-counting of the benefits of different ecosystem services and, thus, to an artificially higher benefit value.

Alternatives to standard economic valuation methods

Some of the shortcomings from applying the TEV framework above could be overcome by using ecosystem accounting, which is an approach that aims at measuring ecosystem capital stocks and flows directly. The main global reference for ecosystem accounting is the UN System of Environmental-Economic Accounting, Experimental Ecosystem Accounts, SEEA-EEA ([55]). Ecosystem accounting seeks to physically and monetarily quantify the state of ecosystems (by producing a 'stock' number), and the flows of ecosystem services they can provide to society. This accounting method first attributes bio-physical changes in ecosystem stocks and flows to human use, and establishes whether this use leads to degradation. It then attempts to calculate the costs of avoiding or repairing any degradation.

From a 'demand-side' point of view, this means that ecosystem accounting estimates the service flow that is actually used by people; although it does not directly value the benefits of the services for people. Instead, these benefits are valued indirectly through the costs of the measures to prevent or remediate the observed ecosystem degradation. This way of valuing the benefits of ecosystem services overcomes key drawbacks from the TEV approach.

The idea of ecosystem accounting is to have ecosystem capital asset/stock accounts (for assets such as forests or water ecosystems — roughly analogous to a balance sheet in financial accounting) and also ecosystem flow/service accounts for a growing number of ecosystem services (roughly analogous to a profit-and-loss statement in financial accounting). The ecosystem accounting approach envisages that the accounts would initially use bio-physical quantitative indicators, but that over time, monetary indicators for certain services would be used (depending on the methodological suitability of doing this) (Petersen et al, 2014). It should be stressed that the SEEA-EEA was published in 2013 as methodological guidance rather than as a formal statistical standard (EC et al., 2013).

Although ecosystem accounting is very promising, it still requires a lot of quantitative but also spatially-referenced ecological information. This is currently one of the main challenges in applying this approach to marine ecosystems and services. Overcoming this challenge is key to achieving the 2020 goal of Target 2/Action 5 of the EU Biodiversity Strategy to 2020. This goal requires Member States to: *(...) assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020*.

Recently, a new type of valuation has been proposed as an alternative to standard monetary valuation methods: deliberative valuation. Deliberative valuation still aims at estimating environmental and ecosystem-service benefit values, but it does so by taking a broader perspective on values than conventional monetary approaches. Nevertheless, valuation results can still be expressed in monetary terms. Deliberative valuation involves participatory techniques, such as workshops, where participants have been provided with information about the ecosystem benefits of interest, and their use and management. Participants are then invited to question and deliberate over the information before coming to a more informed conclusion about the individual (or group) value they ascribe to such benefits. This value can be expressed as qualitative descriptions or via some sort of quantitative ranking, including in monetary terms (see review of methods and case studies in Kenter, 2014).

Deliberative valuation methods are obviously time-consuming and have only been used explicitly for valuing ecosystem services in a limited number of cases. However, these methods have been used successfully to evaluate policies and management in other contexts such as improving forestry management. They can be used on their own for conflict resolution because they can consider a broader spectrum of values and concepts of well-being, and thus they may meet with less resistance from the affected parties (Kenter, 2014). They can also be used alongside standard economic methods to provide a more comprehensive valuation, considering not just how much marine ecosystem services are worth but also what they mean to people (Kenter, 2014).

([55]) http://unstats.un.org/unsd/envaccounting/seea.asp.

7.7 The MSFD's 'cost of degradation' analysis

Summary of main points in this section

- Hardly any Member State chose to carry out a full assessment of marine ecosystem services, linking the service 'supply' and 'demand' sides, as part of the socio-economic analyses under the MSFD Initial Assessment. Such an assessment should have ended up estimating the 'cost of degradation' from human use of marine ecosystem services.
- It the few instances where the ecosystem services approach was chosen to carry out the socio-economic analyses under the MSFD Initial Assessment, it has not been generally successful in estimating the cost of degradation in monetary terms. This could be due to the difficulties in performing economic valuation of service benefits. It could also be due to the lack of knowledge on the state of ecosystems and biodiversity reported elsewhere under the MSFD, as this knowledge is what underpins the whole of any marine ecosystem services assessment.
- Other options to estimate the cost of degradation of the use of Europe's seas under the MSFD Initial Assessment were not generally successful either. Therefore, this cost cannot be established as a single number at the EU level yet.
- The first cycle of MSFD implementation has not managed to provide a pan-European baseline on the actual state of marine ecosystem services. However, this gap is being filled by Member State efforts since the completion of the MSFD Initial Assessment. These efforts have been carried out under the 'MAES umbrella' so they are possibly separate from MSFD implementation.
- Increased synergies between the EU-level MSFD and MAES implementation processes are key to improve the socio-economic component of the updated MSFD Initial Assessment in 2018. These synergies are also key to achieve the 2020 goal of Target 2/Action 5 of the EU Biodiversity Strategy with regards to marine ecosystem service valuation and marine ecosystem accounting.
- The ecosystem services concept is not yet a 'common language' across the EU with which to communicate about all the benefits people get from marine ecosystems in an EU-policy and management context. Having such a 'common language' would support the application of ecosystem-based management by, for example, facilitating the identification of general trade-offs between our conflicting uses of the natural capital of Europe's seas.

Defining the 'cost of degradation'

Labour, capital, or energy are needed to obtain the benefits from the sea's natural capital (e.g. investments in vessels and fuel for fish-capture or dredging). These human activities influence marine ecosystem capital by forcing the delivery of certain 'visible' marine ecosystem services (such as seafood provisioning and marine recreation) to meet ever-increasing societal demands. Forcing the delivery of marine ecosystem services often comes at a 'cost' in the form of degradation. The degradation can be of these 'visible' services themselves (e.g. reduced fish provisioning service because less fish biomass is available for capture due to stocks being overfished), or of the 'unseen' services (e.g. reduced climate regulation by carbon sequestration service also due to fish stocks being overfished, Box 2.2). But the degradation can also occur in the general condition of ecosystems (e.g. through pollution, habitat abrasion or other pressures leading to a lowering of biodiversity levels) due to the exploitation of marine abiotic natural capital (Table 5.1), which would also have a negative impact on service generation (Maes et al., 2013).

Degradation of marine ecosystem capital has ecological, economic, and social implications (costs). For example ([56]), achieving the MSFD's 'good environmental status' for commercial fish stocks (Descriptor 3) requires inter alia limiting fishing pressure to the level capable of producing their Maximum Sustainable Yield (MSY) (EC, 2010c). Thus, when the biomass of commercial fish stocks is not capable of producing MSY, these stocks are overfished (degraded). A study from the New Economics Foundation ([57]) showed that having 43 European commercial fish stocks overfished could lead to 3.5 million tonnes less fish landed each year, thus reducing the fish provisioning service. This in turn would imply a loss of EUR 3.2 billion each year from the market value of these extra landings (i.e. money that could have been made), of which EUR 1.8 billion would have gone to EU Member States. It would also imply a loss of 100 000 potential additional jobs in the fishing industry, of which 83 000 would have been in the EU, which would have allowed the EU fishing sector to sustain 31% more jobs (Crilly et al., 2012).

In the context of implementing the MSFD, the 'cost of degradation' is therefore defined as the value of

([56]) See also the *Posidonia oceanica* example in Section 2.3.
([57]) New Economics Foundation (http://www.neweconomics.org/publications/entry/jobs-lost-at-sea).

the forgone societal benefits from not achieving 'good environmental status' (WG ESA, 2010; HM Government, 2012). This cost can be estimated following different methodologies, which will be outlined in the section below.

The socio-economic analyses in the MSFD Initial Assessment

The MSFD contains a *de facto* requirement for Member States to assess the natural capital of their marine waters and its economic value to society by including two key analyses in their Initial Assessments (MSFD Article 8.1.c). These analyses can be carried out through different methodologies, including the 'ecosystem services' approach, which is the one we will focus on here. This is because, when these two analyses follow such an approach, combining them can be taken as performing a full ecosystem services assessment considering both the 'supply' and the 'demand' for the services.

One of these analyses is 'an economic and social analysis of the use of those waters', which refers to Member States' marine waters. This analysis aims at providing information on the current use of these waters and on the value of such use to society. In an ecosystem-services context, 'the use of marine waters' is defined as any human activity using or influencing the marine space ([58]) or the ecosystem services provided by marine waters (WG ESA, 2010).

The second analysis required by the MSFD's Initial Assessment is 'an analysis of the cost of degradation of the marine environment' (resulting from the use of marine waters) aiming at describing how much the 'use values' decrease if the state of marine waters degrades. In an ecosystem-services context, this 'degradation' is defined as the reduction in the delivery of ecosystem services over time compared to the expected state of the marine environment if 'good environmental status' is achieved. The 'cost of degradation' is the welfare foregone from the reduction in the value of the (benefits of) ecosystem services provided by the expected state of the marine environment when 'good environmental status' is not achieved (WG ESA, 2010; HM Government, 2012).

Member States were provided with guidance on different methodologies to use in the above-mentioned analyses by the EU-level Working Group on Economic and Social Assessment (WG ESA). This guidance suggested two methodologies for the analysis of the use of marine waters, namely the 'ecosystem services' approach and the 'marine water accounts' approach. The former requires: identifying the ecosystem services in these waters; identifying the drivers and pressures upon them; and identifying and quantifying, when possible, the value of welfare derived from the services, including both 'use' and 'non-use' values (WG ESA, 2010). Only three Member States (Latvia, the United Kingdom and Sweden) chose to follow the 'ecosystem services' approach for the analysis of the use of marine waters (ETC/ICM, 2014 ([59])). However, with the exception of the United Kingdom to a certain extent (see below), this information is very incomplete and mostly qualitative. It is therefore not comparable across these Member States.

WG ESA guidance also suggested three methodologies for assessing the cost of degradation, namely the 'ecosystem services' approach, the 'thematic' approach, and the 'cost-based' approach. The ecosystem services approach has been summarised above. Its application first requires that 'good environmental status' is defined ([60]) and that its relation to ecosystem service delivery is established. It then requires an assessment of the environmental status in a 'business as usual' scenario (i.e. one without 'good environmental status'). Next, it requires a description of the difference between the former and the latter with regard to service delivery in qualitative and, when possible, quantitative terms. Finally, the consequences to human well-being caused by reduced service delivery (from the degradation of the marine environment caused by human use not being in line with having to achieve 'good environmental status') resulting from this difference are described in qualitative, quantitative, or monetary terms (adapted from WG ESA, 2010). Only one Member State (the United Kingdom) chose to follow the 'ecosystem services'

([58]) Note this MSFD-related definition of services is not in line with the CICES definition of services (Section 7.2).

([59]) This information comes from analysing the MSFD Initial Assessment reporting sheets on the socio-economic analyses that were generated under the MSFD Article 12 process. These sheets have been used as the basis for the assessments in this report, rather than the full Member States reports on the Initial Assessment. This is because these sheets are in English, rather than in native languages, and were designed to allow comparability of national assessment outcomes, even if this aim has not been fully fulfilled. In a few instances, however, we have looked at the full national reports on the Initial Assessment and other literature on the MSFD socio-economic analyses, but this has not been done systematically. As a result, there may be some discrepancies between the information presented here and studies that have focused on the full national reports on the Initial Assessment with regard to the countries that followed the ecosystem services approach for the MSFD socio-economic analyses. An example of such discrepancies is that Sweden used a mixture of the 'marine water accounts' and the 'ecosystem services' approaches to estimate the value of the use of its marine waters according to EC (2014a). However, we have investigated many of these differences and also made sure that they do not change the general conclusions from this section.

([60]) Which should, in principle, have been the case through implementation of the MSFD Article 9; although the deadline for that Article was the same as the one for carrying out the socio-economic analyses under the Initial Assessment (Article 8) that are being described here.

approach for the analysis of the cost of degradation (ETC/ICM, 2014 ([61])) (see below).

MSFD 'cost of degradation' analysis following the 'ecosystem services' approach

According to the reporting on the MSFD Article 8.1.c, despite the guidance provided, and regardless of the methodology used, Member States have encountered many obstacles in trying to assess the cost of degradation of the use of their marine waters. Several Member States did not manage to assess the cost of degradation, or did not report it. Other Member States made an assessment on the cost of degradation but only reported limited information (ETC/ICM, 2014). For this reason, all the studies on the MSFD cost of degradation reporting focus on the use of the different WG ESA methodologies mentioned above and on evaluating their suitability in assessing the cost of degradation, rather than on analysing the actual cost of degradation assessment outcomes (EC, 2014a; EC, 2014f; ETC/ICM, 2014). This is because the reported assessment outcomes on the cost of degradation are very limited and consist of mainly qualitative descriptions, with hardly any quantitative information (ETC/ICM, 2014).

In relation to the 'ecosystem services' approach, only the United Kingdom chose to attempt to follow this approach to estimate the cost of degradation (ETC/ICM, 2014) ([62]). This attempt by the United Kingdom built on the (previous) analysis of the uses of marine ecosystem services in its waters, which is in line with the logic of the ecosystem services concept.

The United Kingdom attempt involved first selecting a reduced set of MSFD 'predominant' habitat types (i.e. marine ecosystem components) in its seas. Then it established the linkages between these ecosystem components and service delivery. It also established links between the ecosystem components and the human activities that affect them, ranking the most important pressures on ecosystem components. Finally, the United Kingdom assessed changes that occurred in service delivery because of these human activities, and estimated the cost of degradation associated with those changes.

Nevertheless, not all the above elements were fully reported by the United Kingdom ([63]). Further, the United Kingdom did not manage to conclude the analysis in terms of monetising the cost of degradation as a lot of qualitative information was used (Box 7.5).

Box 7.5 The UK approach to the MSFD 'cost of degradation' analysis

The UK MSFD Article 12 full report on Article 8.1.c includes a 'cost of degradation' section. The section aims to provide an assessment of the costs associated with the degradation in the state of components of the marine environment that can be expected if the targets for 'good environmental status' are not achieved. The assessment uses an ecosystem services approach to understand impacts on human welfare arising from the changes in the levels of ecosystem services that can be expected in the absence of 'good environmental status'. Therefore, the cost of degradation was identified in terms of reductions in several services, which are likely to have impacts on the welfare of both users and non-users of the marine environment. The reductions in ecosystem services are as follows:

- **Provisioning services**: Expected reductions in the delivery of food provisioning from fish stocks not reaching the MSFD MSY target. This will affect the fishing industry (direct consumptive users).
- **Regulating services**: Expected reductions in their delivery as a result of degradation of seabed habitats.
- **Cultural and recreational services**: Expected reductions in their delivery as a result of lower fish stocks, increasing litter levels, and degradation of bird populations. These are likely to impact tourists such as beach visitors (direct non-consumptive users). Fish stock reductions would specifically affect sea anglers and divers.

The UK cost-of-degradation analysis has used a qualitative description of the impacts of degradation (across all groups of users and non-users of the marine environment) when it has not been possible to assess impacts quantitatively (i.e. estimate actual costs) due to the lack of data. In this context, the United Kingdom stated that it is working towards improving its capacity to provide quantitative assessments of the cost of degradation for future MSFD assessments.

Source: Adapted from HM Government, 2012.

([61]) See footnote ([59]). An example of such discrepancies is that five Member States (Ireland, Latvia, Slovenia, Sweden, and the United Kingdom) followed the ecosystem services approach to estimate the 'cost of degradation' of the use of their marine waters according to EC (2014a). However, we have investigated many of these differences and also made sure that they do not change the general conclusions from this section.

([62]) See footnote ([61]).

([63]) This is specifically in the MSFD Initial Assessment reporting sheets on the socio-economic analyses generated under the MSFD Article 12 process. Information in Box 7.5 comes from the full UK report on the Initial Assessment.

In contrast, Ireland managed to estimate the cost of degradation of the use of its marine waters in monetary terms, and considered marine ecosystem services to some extent when doing this. However, the Irish analysis did not follow the 'ecosystem services' approach as defined in the WG ESA guidance (Box 7.6). Moreover, unlike the United Kingdom, the Irish cost of degradation analysis did not directly continue from analysing the use of its marine waters, as that was carried out through the 'marine water accounts' approach.

With a few exceptions, the information reported by Member States on the cost of degradation of the use of their marine waters, regardless of the methodology used for the analysis, is very poor. There is no pan-European common 'metric' that can be extracted from this information and used to provide an EU-level overview of the outcomes from the analysis. The cost of degradation of the use of Europe's seas can therefore not be established as a single number at the EU level.

Wider implications from not using the ecosystem services approach in the socio-economic analyses under the MSFD Initial Assessment

Member States are not yet choosing to make great use of the services concept to develop comparable analysis based on common underlying information under the 'demand-side' approach for service assessment. Therefore, the 'demand-side' approach for assessing marine ecosystem services (i.e. estimating the actual use of — and benefits of — the services) does not yet seem feasible in a common way across the EU. This conclusion is shared by a recent review of the academic literature on this subject (Hanley et al., 2014).

In the context of the MSFD Initial Assessment, the 'demand-side' approach would have involved carrying out the analysis of both the human uses of marine waters and the cost of degradation from such uses following the 'ecosystem services' approach. However, being able to apply this approach would have also

Box 7.6 A marine ecosystem services-related approach to the 'cost of degradation' analysis from Ireland

A Choice Experiment (CE) monetary valuation technique was used to estimate the welfare impacts of failing to achieve the MSFD 'good environmental status' (GES) in Irish marine waters. This approach considered marine ecosystem services to some extent, and represents the first attempt to value the 'cost of degradation' of the marine environment (as set out in the MSFD) in monetary terms.

A survey of 817 people living in Ireland was conducted between September 2012 and November 2012. Each respondent was asked to identify a preferred marine environment state choice among a given set of alternatives, where each alternative was made up of a number of MSFD GES-related attributes that differed in their levels. The levels were described in terms of an improvement, a deterioration, or no change in each attribute.

Attribute selection in the CE was based on several MSFD GES descriptors, namely the state of biodiversity, fisheries sustainability, pollution levels, presence of non-native species, physical impacts, and a cost attribute. The cost attribute was presented as the increase in general taxation per person per year needed to achieve the environmental state described by the attribute levels in each alternative. By observing and modelling how respondents changed their preferred option as a result of the changes in the levels of the attributes, it was possible to determine Irish residents' willingness to pay for the ecosystem attribute levels (i.e. for the level of the potential for marine ecosystem service delivery associated with the alternative marine environmental states).

The CE modelling framework was then used to estimate the potential welfare impacts of a number of hypothetical marine environment degradation scenarios that could become real should the MSFD not be implemented in full. These scenarios incorporate a best guess of how ecosystems would evolve when the MSFD is implemented, or what their alternative state might be should the MSFD not be implemented.

The welfare impact of a change in the marine environmental attributes from the status quo scenario (defined as the achievement of the MSFD GES descriptors above) to three possible future degradation scenarios was then analysed. By aggregating from the mean individual values up to the relevant population, the total loss of welfare (i.e. the cost of degradation) for the entire Irish population was estimated to range from EUR 343 million per annum for the low level of degradation scenario, to EUR 749 million per annum for the high level of degradation scenario.

For the CE above, the *status quo* was specified as the achievement of several MSFD GES descriptors. However, the actual Irish cost of degradation analysis under the MSFD Article 8.1.c was a bit different. For that analysis, the status quo was taken as the current state of the marine environment, although that was also described in terms of the attribute levels used in the CE (improvement, a deterioration, or no change in each attribute). Expert opinion was used to assign the level representing the current state for each attribute. Results differ (between the CE approach and the MSFD cost of degradation analysis) depending on the *status quo* definition used.

Source: Norton and Hynes, 2014; and Hynes pers. comm.

required establishing the service 'supply' (i.e. the ecosystem's potential for service delivery on the basis of ecosystem condition), to start with. Only one Member State chose to attempt such a full marine ecosystem services assessment under the MSFD Initial Assessment. Moreover, Member State assessments of marine ecosystem condition under this Initial Assessment were very limited (Section 7.3).

As we have implied in Section 7.3 and shown earlier in this section, the first cycle of MSFD implementation has not managed to provide a pan-European baseline on the actual state of marine ecosystem services. This baseline is needed to define general targets for the maintenance or improvement of marine ecosystem services in EU marine policy and management. The first cycle of MSFD implementation has not provided clear information on how current management practices can affect marine ecosystem services either ([64]). This lack of clear information makes it very difficult to modify management approaches at the EU level in order to achieve marine ecosystem service targets.

All of the above means that the ecosystem-services concept cannot be made operational across the EU. Therefore, the ecosystem services concept is not yet a 'common language' with which to communicate about all the benefits people get from marine ecosystems in an EU marine-policy and management context. Having such a common language across the EU would help, for example, identify general trade-offs between the conflicting uses of the natural capital of Europe's seas, thereby supporting the application of ecosystem-based management.

Applying ecosystem-based management at the EU level relies on the effective implementation of the MSFD. Such effectiveness includes ensuring that measures to manage all human activities using the sea's natural capital have the desired effect of maintaining or achieving 'good environmental status'. These management measures are outlined in Programme of Measures (PoM) (Section 7.3). The PoMs would not be completely effective nationally if they have not been developed in a way that reflects the full range of societal benefits from marine ecosystem capital. All these benefits should be taken into account in the economic analyses associated with the development of the PoMs nationally, in particular in cost-benefit analyses.

But the PoMs would not be completely effective at the EU marine-regional level either — nor for EU-level marine policy and management — if the full range of societal benefits from marine ecosystem capital is not taken into account in a comparable way. One way to ensure comparability is by adopting and applying the ecosystem services concept. This would imply considering all the benefits of marine ecosystem services for people in the economic analyses associated with the development of the PoMs across the EU.

The PoMs are to be developed this year (2015) and so an opportunity has been probably lost, as we have shown a poor level of development of marine ecosystem service assessments across the EU under the MSFD. However, the PoMs will need to be updated by 2021. Being able to consider all the benefits of marine ecosystem services in the development of the PoMs across the EU requires improving on both the 'supply' and 'demand' aspects of the assessment of marine ecosystem services.

We have seen that the MAES process supporting the achievement of Target 2/Action 5 of the EU Biodiversity Strategy to 2020 seems to have been beneficial in helping Member States to establish the marine ecosystem service 'supply'. Thus, there are more Member States doing this since 2013–2014 than were under the MSFD Initial Assessment of circa 2012 (Section 7.4). However, we do not know if the information on ecosystem condition used for national MAES-type marine assessments is related to MSFD implementation.

Target 2/Action 5 of the EU Biodiversity Strategy also requires that the 'demand-side' approach for assessing marine ecosystem services across the EU is realised by 2020. Synergies between the EU-level process supporting the implementation of the MSFD ([65]) and the MAES process are key to fulfilling the required improvements in marine ecosystem service assessment across the EU. Hopefully, if these synergies are increased, more Member States will be able to produce full marine ecosystem service assessments by the time of the updated MSFD Initial Assessment in 2018.

([64]) See, as an indirect example, the footnote in Section 7.3 illustrating the differences in pressure identification and ranking between the 'marine biodiversity' and 'ecosystems' reporting on the MSFD Initial Assessment. Furthermore, the high percentage of 'unknowns' for the 'overall status' of marine biodiversity (an EU total of 80%) and ecosystems (an EU total of 100%) reported under the same assessment indicates that much of the human use that could impact marine biodiversity and ecosystems across the EU, and the associated potential for service delivery, is probably not being adequately managed due to lack of knowledge of what exactly needs to be done and where.

([65]) This is the MSFD Common Implementation Strategy, composed of Member States' technical and administrative staff, European Commission services, the EEA, and EU-level stakeholders.

7.8 What does the assessment of marine ecosystem services at the EU level tell us about the way we use the natural capital of Europe's seas?

The analyses we have carried out throughout this report, and especially in this chapter, suggest that the way we use the natural capital of Europe's seas is not sustainable, i.e. we may be mismanaging this use. This conclusion is based on two key signals. One key signal is that the self-renewal of marine ecosystem capital, its biotic constituent, may be at risk. This possible risk is due to the significant degradation and loss of marine ecosystems and biodiversity reported across the EU, which is caused by pressures from human use of both marine ecosystem capital and marine abiotic natural capital. In fact, we have indicated that human activities using/sourcing marine abiotic capital can generate a greater range of pressures, both in terms of numbers and type, on marine ecosystems and biodiversity than those activities using marine ecosystem assets and services.

We have also indicated that the main pressures on marine ecosystem capital are physical damage and loss as well as biological disturbance. These pressures can be exerted by human activities such as fisheries, aquaculture, dredge disposal and construction at sea, mineral and aggregate mining, dredging, and marine and coastal tourism. We have further indicated that many of these activities, but not fisheries, are on the increase.

The other key signal suggesting that we may be mismanaging our use of Europe's seas natural capital relates to the additional substantial lack of knowledge on the state of marine ecosystems and biodiversity overall reported across the EU. Thus, managing the risk to the self-renewal of marine ecosystem capital from all human activities becomes difficult when we do not know enough about its condition as a whole to ensure that we can always adequately protect it or restore it as needed.

The possible mismanagement of the use of Europe's seas natural capital has worrisome implications for meeting the basic needs and supporting the well-being and livelihoods of Europeans (as well as for the European economy more broadly) since we all depend on it. Marine ecosystem capital is the part of the sea's natural capital that most directly supports our daily lives because of the potential of marine ecosystems to deliver ecosystem services.

Ecosystem services are the final outputs or products from ecosystems directly consumed, used (actively or passively) or enjoyed by people. These services cannot be replaced by marine abiotic natural capital. In this chapter, we have therefore chosen to look at what happens to marine ecosystem services as a result of human use of the sea's natural capital. This choice should help the reader to better relate to the outcomes from our assessment, in particular how he/she could be affected by a possible failure to the self-renewal of marine ecosystem capital, and what are the possibilities for policymakers across the EU to support this renewal.

The assessment in this chapter, supported by evidence from elsewhere in the report, has concluded that all the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat, i.e. their delivery may not be sustained/continued over time.

Marine ecosystem services have been assessed in this chapter following the 'supply-side' approach for service assessment, which looks at the capacity of ecosystems to deliver services, and infers that an ecosystem in good condition would have maximum potential for service delivery. The ecosystem potential for service delivery has been assessed here at the EU level in a 'top-down' way, and also in a way that is relevant to EU marine policy (and management).

Policy-relevant information available at the EU level is currently insufficient to go beyond this 'supply-side' assessment and provide a full marine ecosystem services assessment. A full services assessment would be one that also looks at how much the services are used by people, and at the value of the benefits resulting from this use, i.e. extending to what is known as the 'demand-side' approach for service assessment. It is important to note that the MSFD reporting stream, which is currently the widest-ranging policy-relevant common information pool on the marine environment at the EU level, is still not enough to fully characterise the state of Europe's seas.

MSFD assessments of the state of ecosystems have not provided a relevant 'metric' for the assessment of ecosystem condition, and thus of the potential for service delivery, here (the 'overall status' of ecosystems has been reported as a 100% 'unknown' across the EU). Due to this limitation, we had to use the state of marine biodiversity as a proxy for the state of ecosystems because MSFD assessments of the state of marine biodiversity can provide such a metric. This proxy is justified because of the key role played by marine biodiversity in the generation of ecosystem services. In addition, it allows us to relate the assessment outcomes to other assessments of marine biodiversity at the EU and 'lower' levels; although these tend to have narrower scopes than the

MSFD's (e.g. fewer habitat types and species covered, or fewer countries).

Marine biodiversity at the EU level has been assessed in this chapter primarily on the basis of information reported by Member States under the MSFD's 'Biodiversity' descriptor. Whether the 'overall status' of the marine biodiversity components making up that descriptor is 'at good environmental status' is currently the single common and comprehensive pan-European 'metric' available to assess ecosystem condition. Thus, this 'metric' can provide an indication of the sustainability of marine ecosystem potential for service delivery. However, Member State assessments of the MSFD 'Biodiversity' descriptor also have many shortcomings.

For example, when considering the overall EU picture, 80% of these assessments show that the 'overall status' of these marine biodiversity components is 'unknown', which means that potential pressures upon them may not be managed any time soon. For the other assessments, only 4% are currently 'at good environmental status', and 2% are 'not at good environmental status', implying that the marine biodiversity components are degraded. For another 14% of assessments, the situation with regard to degradation is unclear (but a possibility). Member States justified the high percentage of 'unknowns' on the basis of lack of both information and of suitable assessment methodologies.

Because of the shortcomings of these Member States MSFD-based assessments, we have used information on the condition of marine biodiversity/ecosystems from elsewhere in the report to supplement the assessment of ecosystem condition, and thus of the potential for service delivery, in this chapter. However, it is important to note that all this information has been synthesised using expert judgment and so the analysis is indicative.

What we come up with is a picture of significant marine ecosystem/biodiversity degradation across the EU:

- All the eight main marine ecosystems/biodiversity components in Europe's seas are either currently degraded (seabed habitats, reptiles, and marine mammals), or their degradation is a possibility (water column habitats, invertebrates, fish, and water birds/seabirds as well as ecosystem processes and functions).

- If marine ecosystems/biodiversity components are not degraded now, they would be so in the next 5–10 years (with the exception of fish and water birds/seabirds where that is only a possibility).

- There are no instances, on the basis of this pool of information, where the condition of marine ecosystem/biodiversity components is currently good, nor where improving trends in this condition dominate.

- This pool of information also indicates that there is 'sufficient' (but not 'good') information to assess the condition of less than half these components (and that it is 'bad' for the others).

Thus, we have expanded the knowledge-base compared with the assessment of the MSFD's 'Biodiversity' Descriptor (and the high percentages of reported 'unknowns'). In closing this knowledge gap a bit, we see more degradation.

A key question that emerges is whether the reported degradation can be remedied by 2020 using, e.g. the MSFD 2015 Programme of Measures (PoM). 2020 is the deadline under the MSFD for all waters to have achieved or maintained 'good environmental status'. It is also the deadline for achieving most targets of the EU Biodiversity Strategy to 2020, including its headline target on halting biodiversity loss and the degradation of ecosystem services. Because we obtain so many benefits from marine ecosystem services, failure to meet these 2020 targets would have a negative impact on our daily lives.

The probability of failure increases when considering the reported lack of knowledge on the state of marine biodiversity (and ecosystems), in particular under the MSFD and the Habitats Directive. Due to, in particular, the high percentage of 'unknowns' for the 'overall status' of marine biodiversity components (80% EU total) and ecosystems (100% EU total) under the MSFD, it is extremely unlikely that the relevant knowledge can be gathered and any potential degradation reversed by 2020 using the 2015 PoMs. In fact, this 'assessment gap' risks creating a 'management gap' whereby the MSFD cannot be fully implemented — and thus all human activities in the marine environment overall would not be adequately managed — until the necessary knowledge is available. This situation of missing knowledge, which undermines the effectiveness of MSFD implementation (and thus of ecosystem-based management), stresses the importance of applying the EU's 'precautionary' and 'polluter pays' principles when it comes to the management of human activities in the marine environment.

Our conclusion on the current threat to the sustainability of the potential of Europe's seas to deliver all marine ecosystem services is a rather general and rough EU overview. However, it is still useful for EU marine policy as it has shown gaps in the knowledge-base, in particular in the MSFD Initial Assessment. It is also still useful for EU-level marine management because it has shown how these knowledge gaps could be risking the effectiveness of the MSFD 2015 PoMs to achieve the sustainable management of all human activities using the natural capital of Europe's seas.

Nevertheless, the assessment in this chapter provides the best current 'top-down' EU-level picture of marine ecosystem capacity for service delivery based on information on 'ecosystem condition' from EU environmental legislation to a very large extent (although it has also used other EU, regional and national information, and the scientific literature). Other possibilities for a better assessment of marine ecosystem services at the EU level exist but have not fully materialised as yet.

As part of the socio-economic analyses associated with the MSFD Initial Assessment (in circa 2012), Member States had the option to carry out a full marine ecosystem services assessment linking the service 'supply' and 'demand' sides. The assessment should have ended up estimating the 'cost of degradation' of the use of marine ecosystem services. However, hardly any Member State chose this option, and when it was chosen, it has not been generally successful in estimating actual costs. This is possibly due to the lack of knowledge on the state of ecosystems and biodiversity reported elsewhere under the MSFD, as this knowledge is what underpins the whole of any services assessment. In addition, other options to estimate the cost of degradation of the use of Europe's seas under the MSFD were not generally successful either. Therefore, this cost cannot be established as a single number at the EU level yet.

It is important to note that Member States had to value the benefits of marine ecosystem services in monetary terms when they chose to apply the ecosystem services concept to the socio-economic analyses under the MSFD's Initial Assessment. Member States were therefore faced with the many shortcomings attached to the economic valuation of marine ecosystem service benefits, in particular when conducted through the Total Economic Value (TEV) framework. These shortcomings include the high data demand to account for changes in ecosystem service delivery and their impact on people. They also include the long time it takes to generate original 'non-market' valuation outcomes. As a result of these shortcomings and others, the end-values from economic valuations are quite subjective and very dependent on their context. This means that monetary estimates are highly uncertain and need to be used with caution.

Some of the shortcomings from applying the TEV framework could be overcome by using ecosystem accounting. This approach aims at measuring ecosystem capital stocks and flows — first in physical terms and then in monetary terms through the cost of the measures required to reverse any degradation caused by human use. The latter is an indirect but, in principle, simpler way to value the benefits of ecosystem services. However, where the TEV approach needs a high level of quantitative information, the ecosystem capital accounting approach also needs this information to be spatially-referenced. These are key challenges in applying these two approaches to marine ecosystems and services.

The 2014 goal of Target 2/Action 5 of the EU Biodiversity Strategy to 2020 was that Member States, with the assistance of the European Commission, mapped and assessed all ecosystems and the associated services in their national territory. An EU-level working group (WG MAES) was set up in 2012 to assist in fulfilling this goal, and it produced EU-level guidance/reference material in 2013 and 2014. Under Action 5, Member States had thus to carry out 'supply-side' assessments of marine ecosystem services, and this is ongoing in 2015.

National MAES-type marine assessments should be based on information from EU environmental legislation, as this is a premise of Target 2. Therefore, in principle, the outcomes from these national assessments could be used (aggregated) to provide a EU overview (a 'bottom-up' EU-level assessment) of the state of marine ecosystem services based on EU policy-relevant information on 'ecosystem condition'. This EU overview can only be compiled once all 23 'marine' Member States complete their assessments and possible problems for comparability are resolved.

There are currently about 11 Member States that have carried out or are carrying out MAES-type marine assessments. Because these assessments are ongoing, we have not analysed them and thus we are unsure of whether they are all really based on EU policy-relevant information on 'ecosystem condition'. If this is the case, it prompts the question of where the assessment information comes from, as it had not generally been available for the MSFD Initial Assessment in 2012. Comparability between these national assessments will be helped if Member States have used the guidance provided by the MAES process. However, many of the marine elements of this guidance require further development. Until this happens, there may still be significant differences between national MAES-type marine assessments. Nonetheless, given that these assessments require a great deal of expert judgment, comparability may always be an issue to a certain extent.

The 2020 goal of Target 2/Action 5 of the EU Biodiversity Strategy to 2020 is that Member States assess the economic value of (marine) ecosystem services, and promote the integration of these values into accounting and reporting systems at EU and national level. Overcoming the above-mentioned challenges for economic valuation of the benefits of marine ecosystem services, and for marine ecosystem accounting is therefore critical to achieving this goal.

There are also important challenges for developing a 'top-down' EU-level assessment of marine ecosystem potential for service delivery on the basis of information on 'ecosystem condition' from EU environmental legislation ('supply-side' approach) that improves on the one provided in this chapter. Several of these challenges are shared with national MAES-type marine assessments, for example those relating to having to use information on 'ecosystem condition' from EU environmental legislation (e.g. MSFD, WFD, HD).

These challenges concern several components of the assessment chain. Thus, there are key open questions regarding the knowledge required for these assessments. These questions include how exactly changes in marine-ecosystem condition influence changes in ecosystem-service delivery (so the link between them can eventually be quantified), and how good ecosystem condition relates to the different status classifications under the relevant legislation. There is also limited EU-level availability of the information needed for the assessment, including with respect to space and time (synchronicity). There would also be methodological gaps that need filling in order to make the MAES conceptual model operational for the assessment of marine ecosystems and their services at the EU level. These gaps are due to the lack of 'EU references' for several of the methodological and mapping steps of the assessment (e.g. there is no EU reference for establishing the linkages between marine ecosystems, services, pressures and drivers); or because the existing 'EU references' are incomplete (e.g. the MAES marine guidance needs further development). Finally, there are limited consistent EU-level mapping approaches to support the assessment (e.g. there is no consistent EU mapping of pelagic habitats, and no new initiatives to map these habitats have been envisaged).

There is on-going EU-level action to overcome some of these challenges. WG MAES continues to support fulfilling Target 2/Action 5 of the EU Biodiversity Strategy to 2020. There is also an initiative to promote the coordinated implementation of the relevant EU environmental legislation. There is a further initiative to increase synergies between the EU-level process supporting the implementation of the MSFD and the MAES process. Once completed, these two initiatives should ensure that the EU-policy relevant information required for a 'top-down' EU-level assessment of marine ecosystem potential for service delivery is available and ready when needed. Furthermore, increased synergies between the EU-level MSFD and MAES implementation processes are key to improve the socio-economic component of the updated MSFD Initial Assessment in 2018 and the 2020 goal of Target 2/Action 5 of the EU Biodiversity Strategy.

Another action at the EU-level is the development of a methodology to provide a 'top-down' EU-level assessment of marine ecosystem potential for service delivery on the basis of information on 'ecosystem condition' from EU environmental legislation. This methodology was commissioned by the EEA. However, it is currently limited to delivering a service-per-service assessment and its feasibility has only been tested on three services so far.

Additionally, a number of national, regional, and other marine ecosystem service assessments were carried out before and around the time the MAES process was set up and/or started running. Several of these assessments have addressed some of the above-mentioned methodological and mapping challenges faced by MAES-type marine assessments, in particular at the EU-level ('top-down'). However, each assessment has tended to resolve the relevant challenges in its own unique way. Nevertheless, the approaches used by these assessments could serve to inspire the development of the missing 'EU references' for several methodological and mapping aspects of MAES-type marine assessments. However, in general, these approaches have not been sufficiently reflected in EU-level initiatives supporting marine ecosystem service assessment.

Research-based approaches could provide 'top down' EU-level assessments of marine ecosystem capacity for service delivery, and of the actual demand/use of the services by people (e.g. the 'coastal protection' service assessment by the JRC). However, in general, research approaches tend not to follow the MAES conceptual model closely enough. In addition, they tend not to use information from EU legislation (e.g. assessment products) but datasets and modelled data. These are two potential drawbacks when trying to use the outcomes from these research-based assessments directly, without some further interpretation, to inform EU marine policy and management.

More time is clearly needed for all the above EU-level actions aiming at tackling some of the challenges for a 'top-down' EU-level assessment of marine ecosystem potential for service delivery (on the basis of information on 'ecosystem condition' from EU environmental legislation) to succeed, and/or for a 'bottom-up' EU-level overview to be possible. Time is needed in particular to further develop some of the new ideas emerging from the MAES process, and to translate the MAES requirements into the assessment and reporting requirements of the relevant EU legislation (so they can be fulfilled nationally). More time is also needed for these ideas to permeate from the EU level to the national level, and to help raise the number of national MAES-type marine assessments. Uptake of these ideas nationally should lead to increased comparability of national MAES-type marine assessments across the EU, therefore facilitating EU-level assessment. In addition, more time is also needed for relevant national, regional, and other marine ecosystem service methodological and mapping approaches developed outside the 'MAES umbrella' to be picked up and integrated in EU-level initiatives supporting this process.

Nevertheless, despite all the actions outlined above, it is possible that a few of the challenges for both 'top-down' EU-level and national MAES-type marine assessments may still remain. One way to minimise this possibility would be to develop an EU common, general methodology for the mapping and assessment of marine ecosystems and their services (an 'EU reference' methodology). The aim of this general methodology would be to make the MAES conceptual model for the assessment of marine ecosystems and services operational in the same way across the EU. The development of this general methodology should prioritise filling the gaps resulting from the lack of or incomplete 'EU methodological and mapping references', as this would go a long way to promote further comparability of national assessments.

All and all, it is early days in terms of the application of the ecosystem services concept for marine ecosystem assessment. Thus, the first cycle of MSFD implementation has not managed to provide a pan-European baseline on the actual state of marine ecosystem services. However, this gap is being filled by Member State efforts since the completion of the MSFD Initial Assessment. These efforts are being carried out under the 'MAES umbrella' and so they are possibly separate from MSFD implementation.

Meanwhile, the ecosystem services concept is not yet a 'common language' with which to communicate about all the benefits people get from marine ecosystems in an EU marine-policy and management context. Having such a common language across the EU would support the application of ecosystem-based management by, for example, facilitating the identification of general trade-offs between our conflicting uses of the marine environment. Indeed sharing a common perspective should help us to better manage all human activities using the natural capital of Europe's seas in order to prevent its misuse.

8 Our seas, our future

This report set out to explore if Europe's seas could be considered healthy, clean and undisturbed, and productive. It also aimed at identifying the main sustainability challenges affecting our seas, and how the EU is responding to these challenges. This work used a variety of sources of information to identify the main trends in the state and use of Europe's marine environment. It thus provides a first European baseline of the state of the main ecosystem characteristics i.e. marine biodiversity groups, and ecosystem processes and functions. Together these ecosystems characteristics constitute marine ecosystem capital, which is the biotic — living — constituent of the sea's natural capital supplying our society with key ecosystem services. The baseline analysis also covers the main pressures and impacts affecting marine ecosystems, and the human activities causing these disturbances. The report also looked at the services and associated benefits people get from marine ecosystems, as well as at the policy response on core issues affecting our seas. This concluding chapter aims to highlight the key findings and messages from the report, and to discuss what these findings and messages mean for a long-term transition to sustainable use of the natural capital of Europe's seas.

8.1 State and outlook for healthy, clean, undisturbed and productive seas

Europe's seas are in poor status, in spite of some improvements

This report showed that although Europe's seas are productive, they cannot be considered to be healthy, clean and undisturbed. Marine biodiversity remains insufficiently assessed while showing patterns of change indicative of poor status. For example, the initial assessments reported in 2012 by Member States under the Marine Strategy Framework Directive (MSFD) show that 80% of the assessments of marine species and habitats are categorised as 'unknown', and only 4% were considered in 'good' status. Additional information for the marine habitats and species protected by the Habitats Directive provides additional insight into this knowledge gap. Between 2007 and 2012, the percentage of marine species assessments in 'favourable conservation status' remains low at 7%, and there are almost four times as many species assessments that show 'unfavourable conservation status' (almost 27%). Further, only 9% of the marine habitats assessments are in 'favourable conservation status' compared to 66% in 'unfavourable conservation status'. The patterns of biodiversity loss and ecosystem degradation observed across all regional seas are indicative of a poor state of many species and habitats. Loss of biodiversity across habitats and species affects ecosystem resilience and makes marine ecosystems more vulnerable to pressures, both human-induced and due to natural processes.

A range of human-induced pressures are affecting the state of marine ecosystems directly. These pressures include physical loss and damage to the seafloor, the capture of fish and shellfish, the introduction of non-indigenous species, and pollution entering from land and the atmosphere. New pressures such as marine litter and underwater noise also appear. Some of these pressures are showing signs of improvement. For example, since 2007 fishing pressure has been brought down back to sustainable levels (i.e. Maximum Sustainable Yield) for an increasing number of stocks in the North-East Atlantic Ocean and Baltic Sea. This decrease in fishing pressure has allowed for the recovery of the reproductive capacity of certain fish stocks. Nutrient pollution has also been reduced significantly in the North Sea and Baltic Sea in the past three decades, but eutrophication continues to be a major problem. The Baltic Sea is particularly affected by eutrophication and has been the witness to a growing oxygen-depleted zone as a consequence in spite of the significant measures taken.

On the other hand some pressures are on the rise. For example, a growing number of non-indigenous species have been entering Europe's seas since the 1950's, with the highest rate of introductions being observed in the 2000's. These species are mostly brought in through shipping and the Suez Canal in the Mediterranean Sea. Pressure on the seafloor is also expected to increase from a wider range of activities, such as seabed mining and offshore energy. Vulnerable areas of the deep-sea are at particular risk of this expansion of human activities. Contaminants and marine litter are widespread in the marine environment, but our knowledge about their consequences to the ecosystem and ultimately to human health remains poorly assessed or understood. In addition, the effects of climate change are now being seen in all Europe's seas.

Although important to monitor and track progress in the efforts to address individual pressures, the interaction between pressures and their consequences on the functioning of the marine ecosystem is a crucial need and challenge. The cumulative effect of pressures and impacts are reducing ecosystem resilience, and thus making them more vulnerable to change. These changes on the ecosystem can push them to altered states, often undesirable to those benefiting from them, and from which recovery may be impossible. This report showed that evidence already exists indicating that changes of this nature have already occurred in Europe's four regional seas.

The pressures affecting the marine ecosystem are stemming from a range of human activities, both at sea and on land. Although land-based activities are important sources of pressure, Europe's seas are the stage for a growing blue economy. This report showed a general increase in maritime activities has occurred over the last decade or more, and more than half of the 'sub-activities' of Europe's blue economy are expected to grow in the future. Europe's seas are thus currently productive but it they are to remain so in the long-term, the development pathway of the blue economy needs to be better coupled with the condition of the marine ecosystem.

The current pattern of human use of the sea shows a range of traditional human activities that continue to develop while news ones emerge. These activities include shipping, fishing, hydrocarbon production, tourism, mining, and bioprospecting, and have all acted to change marine ecosystems. Nevertheless, this report points to how the activities using non-living marine natural capital are exerting a greater range of pressures on the living natural capital (i.e. marine ecosystem capital) than those activities using the latter. This generates equity issues, as those dependant on healthy seas like fishing, aquaculture, tourism and biotechnology, may have their development opportunities hindered by those who do not depend directly on a healthy ecosystem.

Marine ecosystem capital is generated by the ecosystem and its biodiversity, and represents the assets and services from which we derive key benefits. Healthy marine ecosystems are critical to meet people's basic needs by, for example, providing food for our nutrition and absorbing CO_2 thus regulating the climate. Healthy marine ecosystems are also key to our well-being by, for example, providing clean seawater where we can swim and grow seafood. Changed or damaged ecosystems put these ecosystem services at risk, which can thus also impact our livelihoods and the economy more broadly. Therefore, the significant degradation and loss of marine ecosystems and biodiversity observed across Europe's seas is of great concern as it can threaten the potential of marine ecosystems to deliver ecosystem services. A key finding of this report is that all the ecosystem services that can potentially be delivered by marine ecosystems in Europe's seas are under threat, i.e. their delivery may not be sustained/continued over time. This thus risks the self-renewal of marine ecosystem capital in Europe's seas.

These findings thus indicate that management of human activities will need to better understand which activities are threatening marine ecosystem capital and use that knowledge to better prioritise measures and decide on trade-offs, such as those needed when allocating space for activities at sea or on the coast.

What are the prospects for achieving healthy, clean, undisturbed, and productive seas in the near future?

At present, the prospects seem mixed. An indicative summary assessment of the status and outlook for our seas on the basis on all the information put forward in this report is presented in Table 8.1. This assessment shows that Europe's seas cannot be considered healthy, clean and undisturbed today and are unlikely to become so in the future given the current trends. This will also affect their future capacity to remain productive for supporting the growing blue economy.

On the positive side, the EU and its Member States have responded to marine ecosystem change and broader marine environmental problems with a wide range of policies and initiatives. These policies and initiatives are not always efficiently implemented, but some marine ecosystems are starting to respond positively. For example, some marine nature protection and restoration efforts are showing positive local effects on species populations, biodiversity, and biomass. Fish stocks are recovering in northern European seas due to the increasing share of fishing that is conducted at sustainable levels. Aquaculture-mediated invasions of non-indigenous species have been reduced due to the adoption and implementation of proper regulation. The positive effects of policy can also be seen at the whole regional sea level, such as in the Baltic Sea where it appears that nutrient inputs are no longer increasing. These examples show that Europe's seas are still resilient and that it is not beyond our means to help facilitate marine ecosystem recovery. It also shows that policy and management efforts can make an important difference when properly implemented.

Table 8.1 Indicative assessment of key status and outlook for healthy, clean, and productive seas, plus supporting information

Healthy seas?	**Status: ecosystem characteristics**	**5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Seabed habitats				3.2
Water column habitats				3.3
Marine invertebrates				3.4
Marine fish				3.5
Turtles				3.6
Seabirds and waterbirds				3.7
Marine mammals				3.8
Ecosystem processes and functions				3.9, 3.10
Clean and undisturbed seas?	**Status: pressure**	**5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Physical disturbance of seafloor				4.2
Extraction of fish and shellfish				4.3
Non-indigenous species				4.4
Eutrophication				4.5
Contamination				4.6
Marine litter				4.7
Underwater noise and other forms of energy input				4.8
Climate change				4.9
Productive seas?	**Direct dependency on healthy seas**	**Activity 5–10 year outlook**	**Information availability and quality**	**Read more in Section**
Land-based activities	X	-		5.2
Extraction of living resources	√	↗		5.3
Production of living resources	√	↗		5.4
Extraction of non-living resources and disposal of waste	X	↗		5.5
Transport and shipbuilding	X	↗		5.6
Tourism and recreation	√	↗		5.7
Man-made structures	X	↗		5.8
Energy production	X	↗		5.9, 5.10
Research and survey	X	↗		5.11
Military	X	↘		5.12

Legend: Indicative assessment of:			
Status and trends of ecosystem and pressures		Information availability and quality	
	Status not good/deteriorating trends dominate		Limited information
	Status or trends show mixed picture		Sufficient information
	Status good/improving trends dominate		Good information
Note	The indicative assessment builds on the information analysed in the relevant sections and expert judgement. The sources of information include EU reporting obligations, EEA indicators, EU and regional reports, and peer-reviewed papers.	Note	The indicative assessment builds on the availability and quality of the information to make comparable and coherent evaluations at EU level and between regional seas.
Productive seas			
X √	An activity is considered dependent on healthy seas if its production depends on biotic natural capital having good status.	↗ ↘	Trends of the activity build on those presented in Table 5.1.

But despite these positive examples, it must be stressed that marine ecosystems continue to display symptoms of degradation and thus of loss of resilience. The loss or resilience is closely linked to loss of biodiversity, which continues throughout Europe's seas. Loss of biodiversity is evident in decreases of population size and loss of distribution range of marine species, as well as loss of marine habitats. Local losses of individual species will weaken ecosystem structure and functioning, reducing ecosystem productivity. If pushed too far, loss of resilience can lead to ecological 'regime shifts', which are sudden changes in ecosystems. Ecological regime shifts are difficult to recover from, and they jeopardise the services and associated benefits that people can get from healthy marine ecosystems. Therefore a key message of this report is that management of human activities will need to become better at assessing the interaction between pressures, impacts and their effect on the ecosystem. And it will also need to become sharper at picking up negative signs of change at the ecosystem level and acting on them, before ecosystems are pushed beyond the boundaries indicative of a healthy state.

Part of the difficulty in implementing EU policy is the small quantity and poor quality of the data available at the EU level to assess the effectiveness of this policy. This is a widespread problem in EU marine policy implementation, and another key finding of this report. Most of the European data flows that could help improve our knowledge of the state of the marine environment are incomplete. We need such knowledge to better manage our use of the sea's natural capital in order to maintain or restore the health of marine ecosystems. However, there are many status assessments from the implementation of EU environmental legislation that are 'unknown', 'not reported', 'not assessed' and/or 'reported with low confidence'. This makes it difficult to give a sound evaluation of the state of our seas, and of EU policies and nationally implemented measures. It also means that potential pressures on marine ecosystems and their biodiversity may not be appropriately managed, or may not be managed at all. Another key finding of this report is that managing the risk to the self-renewal of marine ecosystem capital from human exploitation becomes difficult when we do not know enough about its state as a whole to ensure that we can always adequately protect it or restore it as needed.

Nevertheless, the prospects for Europe's seas can still be greatly influenced by how well we act on our current knowledge. One of the best ways to act on our knowledge is by adopting an ecosystem-based management approach. This approach integrates our knowledge on the marine environment so that it can be managed as a systemic whole rather than just as a collection of individual components. It means being smarter with the information we have so we can better implement our policies. When comparing management efforts across the different seas, it is clear that Europe has only just begun its work to implement ecosystem-based management. Far more work needs to be done if we are to balance multiple objectives; understand connections within ecosystems and between ecosystem and social systems; assess cumulative pressures and impacts; and integrate spatial characteristics of environmental problems.

Implementing ecosystem-based management can be greatly helped by using the ecosystem services concept as a 'common language' for people to better understand and relate to all the benefits provided by marine ecosystem capital. This common language can help in the formulation of policy and in decision-making, including in the identification of trade-offs and the resolution of conflicts between the different uses of the seas' natural capital (Figure I.1).

Ecosystem-based management also provides a framework for looking at marine ecosystems with a fundamentally new understanding. This new understanding is further explored in the following final section.

8.2 The transition towards sustainable use of our seas and the key role of ecosystem-based management

The challenges faced by Europe's seas should raise concern across our society (Figure 8.1). Keeping marine ecosystems healthy means securing their long-term capacity to provide the marine ecosystem services and associated benefits crucial to our daily lives. If we focus only on short-term economic gains, we put ecosystems — and our own basic needs, well-being, and livelihoods — at risk.

If fisheries continue to use high-impact practices and continue to fish above sustainable limits, our food security is at risk. This would also put fishing communities at risk and endanger the livelihoods they provide.

If we continue to lose biodiversity, we will hamper the development of promising 'blue' biotechnology. In so doing, we would decrease the chances of finding key new compounds and medicines to improve our lives.

If pollution is not better managed at source, the quality of coastal water might promote the growth of species that are harmful to humans. In some cases, pollution might kill off local aquatic life altogether. Activities that depend on clean sea water such as aquaculture or tourism would then have fewer opportunities to develop.

If we continue to allow plastics and toxic chemicals to find their way into our sea, they can be ingested or absorbed by wildlife. This damages biodiversity. And when these chemicals are part of our seafood, it can pose a human health risk. Children and pregnant women are particularly vulnerable.

Beaches and shores are also already changing as a result of marine litter. Sand, rocks, and other coastal landscapes might become permanently mixed with it. These degraded zones will lose their capacity to attract visitors or recreational users, damaging local economies.

The combined effect of these problems disrupt the overall functioning of marine ecosystems. And when these problems combine with climate change, the ecosystem effects can be even more dramatic and worrisome. For example, climate change causes sea water to become warmer and more acidic, which affects the distribution and survival of marine species. These are changes that affect not only coastal communities, but our society as a whole. The effects will be felt for generations to come.

These scenarios may sound drastic but, as this report shows, we can already see signs of such changes throughout Europe's seas. These signs should act as a warning that marine ecosystems are at risk of changing unexpectedly, which would disturb the flow of services and associated benefits they provide to people.

The EU and its Member States have not ignored these changes. Important sectoral policies have been in place for many years and some of these have started to produce positive outcomes for the marine environment. These policies include better wastewater management, stricter environmental regulation for activities at sea, the ban on certain toxic substances, and the protection of the most vulnerable marine species and habitats. However, these policies mostly address the symptoms of 'unhealthy' marine ecosystems. Systemic changes in marine ecoystems have already been set in motion and dealing with them requires integrated responses that address the causes of ecosystem degradation and loss. If policymakers are to formulate systemic responses, they will need to make changes to their ways of thinking. Perhaps the most important change to ways of thinking will be to manage the ecosystem as a whole rather than as the sum of its parts. This is the opportunity offered by ecosystem-based management, a systemic approach that is now at the core of EU environmental policy, in particular EU marine policy.

The Marine Strategy Framework Directive (MSFD) is an example of how the EU promotes ecosystem-based management. The MSFD is the environmental pillar of the EU's integrated maritime policy, and it addresses all aspects of the functioning of marine ecosystems. It also brings together EU policy objectives on the marine environment that will allow to secure healthy, clean and undisturbed, and productive seas for the long-term. If properly implemented, the MSFD provides the opportunity for the EU and its Member-States to truly transition to the sustainable use of our seas. Thus, the MSFD provides the boundaries for human use of the sea's natural capital. However, when these boundaries are uncertain due to insufficient information and knowledge, we should follow a precautionary approach for the management of maritime activities. The MSFD also requires Member States to create ecologically coherent and representative networks of marine protected areas. Protected areas are key tools for securing ecosystem resilience and thus dealing with the uncertainties of our changing marine environment.

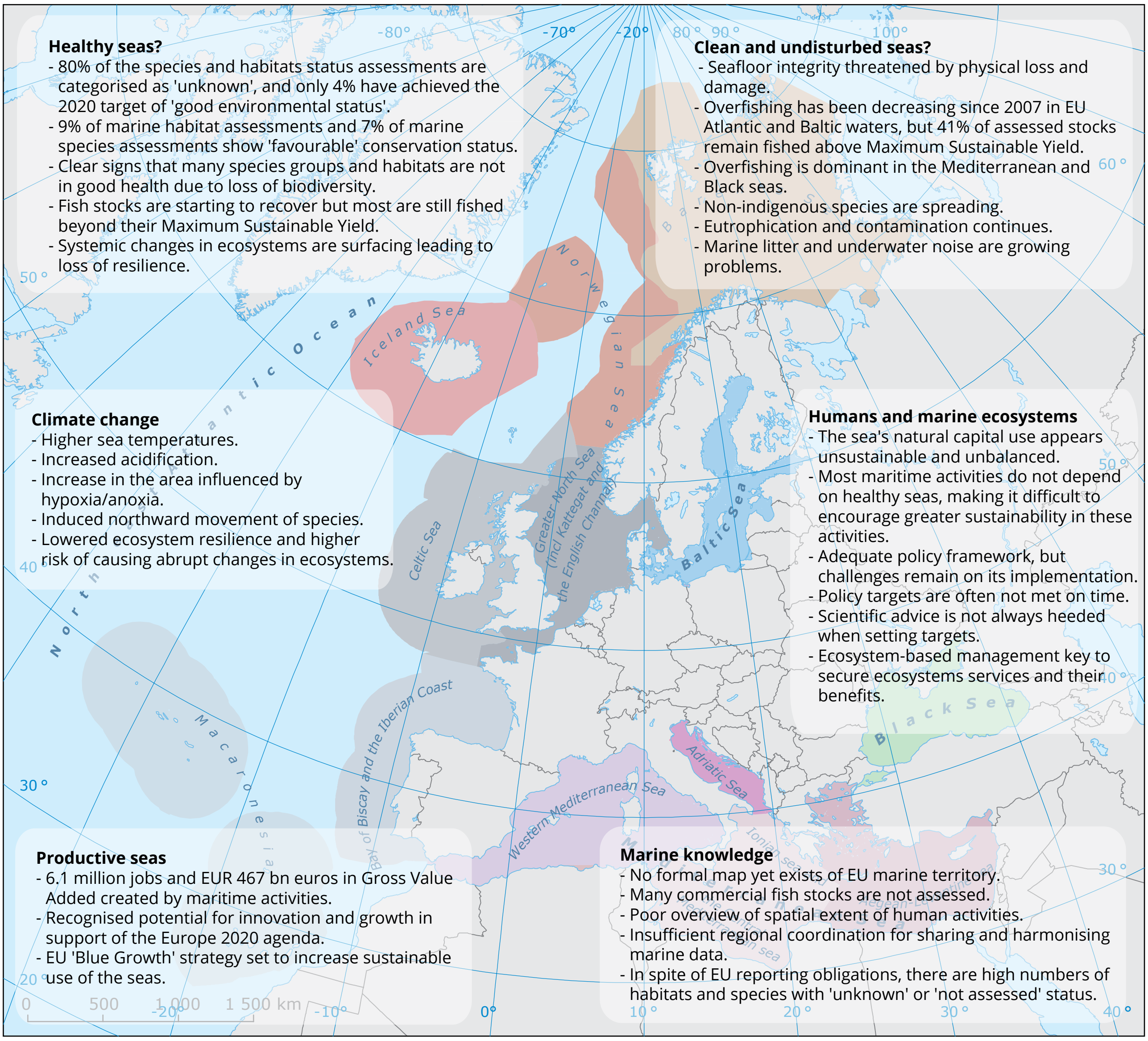
The MSFD can thus support determining the 'safe operating space' to allow Europe's maritime sectors to flourish. It also provides a framework that can be adapted to deal with further changes and uncertainty in the state of Europe's marine environment.

The ambitions for the EU's blue economy are not yet aligned with the current state of and prospects in Europe's seas. However, important connections are already being made. For example, the objectives of the new Common Fisheries Policy recognise the need to ensure coherence with the MSFD. This recognition has set in motion a process to integrate the implementation of both policies in the European Commission. Since the MSFD is the environmental pillar of the EU's integrated maritime policy, the pathway for other sectors to align to it is drawn, and it is critical that they do so. Without sustainable development of the maritime sectors, the EU risks creating a fragile and short-termist maritime economy, which would be dependent on less resilient ecosystems. Such a fragile maritime economy would put jobs, economic growth, and people's well-being at risk.

Sustainable use of the natural capital of Europe's seas and avoiding further marine ecosystem degradation and loss cannot be achieved by marine policy alone. Our environmental challenges today are of an increasingly systemic nature. These challenges are deeply rooted in our society's globalised systems of production and consumption. Addressing these challenges will require a fundamental shift in those systems (EEA, 2015h). That shift can only happen through a re-evaluation of our values, our lifestyles, and the way we interact with nature and its resources. The EU has already embraced this challenge by choosing to transform its model of development into one that builds on a green economy. The green economy can now be the backbone of the development of the blue economy by reconciling ecosystem resilience, economic growth, human well-being, and the increasing demand for resources.

Europe's seas are facing serious challenges, but we have some of the tools we need to address these challenges. We know enough about how to reduce human pressures; we have the governance structures to implement policies following ecosystem-based management; and we benefit from a wealth of new opportunities to re-shape the way we live and interact with our seas. Achieving healthy marine ecosystems should be seen as a smart investment in a system that is key in sustaining human life and securing a prosperous future for our societies. It is a challenge that requires a collaborative response from decision-makers, research institutions, businesses, advocate groups, citizens, and providers of information and knowledge. In short, it requires a European ocean constituency committed to embrace the stewardship of our seas and jointly secure our future.

Figure 8.1 Regional seas surrounding Europe and the many challenges in achieving sustainability



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European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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