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# Balancing the future of Europe's coasts

## — knowledge base for integrated management

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European Environment Agency

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# Contents

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# Executive summary

This report has three elements. Firstly, it gives a snapshot of the current state of Europe's coastal regions. Secondly, it assesses the policies used to manage coastal regions, and discusses the proposal for a new European directive to improve the management of coastal regions. Thirdly, it highlights the need for better information and better monitoring tools to help inform this management process. The three sections below deal with each of these elements in more detail.

## The state of Europe's coastal regions

Coastal regions are tremendously important for Europe's economy. Approximately 40 % of the EU's population lives within 50 km of the sea. Almost 40 % of the EU's GDP is generated in these maritime regions, and a staggering 75 % of the volume of the EU's foreign trade is conducted by sea.

But this important role played by our coasts has come at a cost to the environment. Activities such as shipping, resource extraction, renewable energy and fishing are all putting pressure on marine and coastal areas. These pressures have been felt across most of Europe's coastal regions. This has resulted in habitat loss, pollution and accelerated coastal erosion. Climate change is likely to make these regions — and the societies that live in them — more vulnerable.

Recent data highlight the continued poor quality of many European coastal waters, with the Baltic Sea the worst, followed by the North Sea and the Black Sea. The conservation status of Europe's coastal species and habitats is also generally bad or unknown. Only 13 % of the assessments of coastal species made under the Habitats Directive are favourable. 73 % of the coastal habitat assessments show bad or inadequate conservation status.

## The policy context for coastal management in Europe

This deterioration threatens the continued health of our coastal areas. If these regions are to continue to power our economies, shelter a rich biodiversity, and remain home to millions of Europeans, we must manage them more carefully. This management must also be conducted in an integrated fashion, balancing the competing interests of human development with the need to ensure healthy and resilient coastal ecosystems.

Public policy has already begun to implement this principle of integrated management of coastal zones. In 2002, the European Union adopted a Recommendation on Integrated Coastal Zone Management (ICZM), setting out basic principles. These principles are still valid and include: stakeholder involvement; sensitivity of policy to local needs; the adoption of a long-term perspective; and the creation of links between all levels of governance, from local to European.

Although ICZM principles are increasingly being adopted in the management of coastal areas, progress has not been uniform. The European Commission estimated in 2012 that implementation of ICZM was only about 50 % across the EU as a whole. It identified two shortcomings that are especially important. The first is a lack of clear administrative responsibility for the implementation of ICZM, and the second is an absence of commonly agreed objectives and timeframes in which these objectives should be achieved.

In order to overcome these shortcomings, the European Commission in 2013 issued a proposal for a new directive. This directive would establish a framework for integrated coastal management and for 'maritime spatial planning' (public policy that deals exclusively with managing maritime space but not land space). The Commission hopes that this directive will integrate in a coherent whole all of the EU policies that touch on maritime and coastal issues (such as the Habitats Directive, the Water Framework Directive, Marine Strategy Framework Directive etc.). It also hopes this directive will provide guidance for how to better manage the competing claims of economic sectors on space and resources in coastal and marine areas.

The most important feature of this proposed new directive is the requirement for countries and groups of countries to prepare maritime spatial plans and integrated coastal management strategies. Five years after the adoption of the directive, the Commission will compile a follow-up report based on progress reports submitted by the Member States.

## Improving the knowledge base for successful coastal management

These plans, strategies, and reports must be based on accurate information if they are to help inform the policy process. There is therefore a need to improve the quality of the data used to measure the health of our coastal environment.

One of the most important improvements is the creation of geospatial data. Most of the information currently compiled by Member States about their coastal regions is socio-economic in nature and does not contain location data that would help pinpoint precisely where certain environmental changes are happening. Integrating various data sets from different sources is even more challenging. This lack of quality-assured spatial data hinders effective management. As computer-mapping technology improves, it can be used to monitor these changes in the way space is used by different activities (shipping, fishing, construction etc.).


**Photo:** © iStock/eddyfish

EU Member States should also make more effort to harmonise their data and make it consistent with the data reported by other countries, so that it can be shared. Shared in this way, and enhanced by coordinated indicator sets, coastal data can give a larger and more refined picture of the wider ecosystem area, allowing for more effective management.

With better quality input data, scientists and policy makers can make use of new assessment methods that give a comprehensive picture of coastal areas, making it easier to implement an ecosystem-based management approach. Three of these new assessment methods are particularly promising:

- **Spatial analysis of cumulative impacts.** Improved geospatial data can be used to analyse the effects of a combination of different impacts (e.g. fishing, wind turbines or sediment extraction) on coastal and marine ecosystems. Maps produced with this data can integrate information that has traditionally been studied separately, making them a valuable decision support tool for ecosystem-based spatial planning of coastal and marine areas.

- **Ecosystem capital accounts**. In the same way that financial accounts measure changes in the flows of money, ecosystem capital accounts aim at measuring the changes of our natural capital (everything from fish stocks to the level of biodiversity degradation). The EEA is currently working on such a system of accounts, using datasets specially chosen for coastal/marine systems.

- **Coastal vulnerability assessments**. These are created by identifying particular elements at the coastline that are most at risk from either climate change or other human-related changes. For example, a freshwater lagoon could be vulnerable to saltwater intrusion, or an area of residential settlement could be vulnerable to coastal erosion or flooding.

# 1 Introduction

## 1.1 Purpose and scope of this report

The objective of this report is to frame an analytical approach for coastal areas in Europe, and to place this in the context of the new socio-economic drivers of sustainable growth, and the formation of a new integrated policy framework. This framework builds on an ecosystem-based management approach and integrated spatial planning and management. The report presents some key sustainability challenges for European coastal areas and waters, and highlights the need for a consolidated knowledge base and widespread information-sharing to support informed policy development and management actions.

European coastal zone policy supports Agenda 21 ([1]) of the 1992 Rio de Janeiro Earth Summit, in which coastal nations committed to implement sustainable development of coastal areas and integrated coastal zone management (ICZM). Some 20 years later, these provisions still hold, and the commitment was confirmed and reinforced by the Rio Ocean Declaration ([2]) in the 2012 Rio+20 summit.

This report explores the thesis that coastal zones can only be rendered sustainable through a widely based coalition of policy actions across economic sectors, and the implementation of existing environmental legislation and horizontal policy elements that contribute to increased resilience of coastal areas and communities (see Figure 1.1).

Since the European Environment Agency's (EEA's) last coastal reporting in 2006 (EEA, 2006a), multiple policy initiatives have been realised that favour the above-mentioned framework. The European Union (EU) Integrated Maritime Policy (COM(2007) 575 final) ([3]) has boosted maritime economies and clearly identifies a need for sustainable growth that respects environmental targets. The Blue Growth initiative specifically addresses new and innovative means of achieving economic objectives: renewable ocean energy and marine biotechnology are examples of such means.

Building on the holistic dimension of Water Framework Directive (WFD) (2000/60/EC), the EU environmental *acquis* deploys an ecosystem-based approach. The Marine Strategy Framework Directive (MSFD) (2008/56/EC) and the EU Biodiversity Strategy to 2020 (2011/2307(INI)) have confirmed this commitment, and the outcome depends on effective implementation of set policy targets, as guided, for instance, by the new General Union Environment Action Programme to 2020 (7EAP ([4])).

Building on the heritage of EU policy on ICZM (i.e. the EU ICZM Recommendation) and its gradual uptake by Member States, the new initiatives for maritime spatial planning (MSP) (launched by the EU Integrated Maritime Policy) and coastal and marine issues of climate change adaptation (part of the EU Strategy on adaptation to climate change ([5])) have expanded the horizontal policy platform, and offer new opportunities for integrated spatial management and adaptation of Europe's coastlines.

In this report, ICZM is used as a central conceptual reference: it aims to balance the needs of economic development with the protection of the very resources that support coastal economies and the well-being of local communities. It can be viewed as a conceptual pillar of sustainability. Ecosystem services, the benefits people gain from ecosystems, are central to this vision, although the mapping and assessment of such services are still emerging.

The coastal zone is understood to reflect the coexistence of two margins on both sides of the seashore area. In this report, coastlines are

(1) See http://www.unep.org/Documents.Multilingual/Default.asp?documentid=52.
(2) See http://www.un-ngls.org/IMG/pdf/Rio_Ocean_Declaration.pdf.
(3) See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0575:FIN:EN:PDF.
(4) See http://ec.europa.eu/environment/newprg/pdf/7EAP_Proposal/en.pdf.
(5) See COM(2013) 216 final http://ec.europa.eu/clima/policies/adaptation/what/docs/com_2013_216_en.pdf.

determined using the Corine Land Cover (CLC) database, and the terrestrial portion of the coastal zone is defined by an area extending from the coastline to a 10-kilometre landward limit. Where socio-economic data are used, the spatial extent is defined by 'coastal regions', as determined by Eurostat ([6]). The marine part of coastal zone is defined as a variable zone seaward from the shoreline, depending on the issue at hand (e.g. territorial waters of the Member States, marine regions, navigation routes, fisheries or coastal dynamics). The generic term used throughout this report is **coastal zone**, but **coastal area, coast, coastal space** and **coastal systems** are also used as synonyms when the context suits.

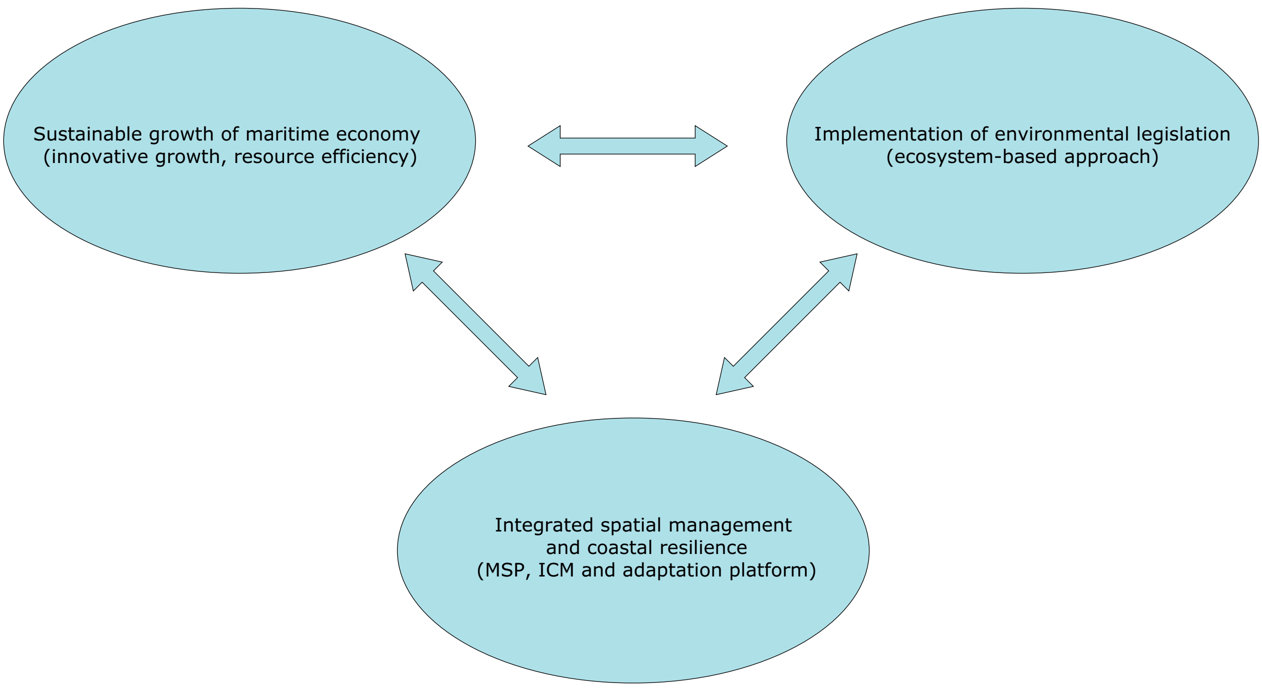
Estimates of the European terrestrial coastal zone vary between 4 % and 13 % of the land mass, depending on what data are used, the definition of the coastal zone extent and the country coverage. Recently revised CLC data suggest that the coastal zones (the terrestrial part) cover approximately 619 000 km$^2$ in the 29 European coastal countries (23 coastal EU Member States ([7]) plus Albania, Bosnia and Herzegovina, Iceland, Montenegro, Norway and Turkey). This area corresponds to 11.3 % of total land mass of these countries (10.1 % for coastal EU Member States).

## 1.2 Europe's coastal areas: a diverse and important asset

The European coastal regions vary widely in terms of coastal ecosystems and habitats, catchments and sea areas. They include coasts exposed to the open ocean, as well as regional seas that are almost entirely landlocked. Europe's exposure to the sea is the highest among the world continents, when expressed by a ratio of total coastline length to the land area ([8]). This puts Europeans in close contact with the sea, regardless of the distance to the coastline. To illustrate, 75 % of Europe's external trade and 37 % of trade within the EU is seaborne (COM(2012) 494 final) ([9]).

Europe's outer fringe is surrounded by the North-East Atlantic Ocean, with seven very different

**Figure 1.1 Coherent policy alliance for sustainable coastal areas**




([6]) See http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Coastal_region.
([7]) The accession of Croatia to the EU on 1.7.2013 is not always reflected in factual material.
([8]) Estimates based on Corine Land Cover data from the EEA and the World Vector Shoreline database (scale 1:250 000) by the World Resource Institute suggest that Europe's coastline-to-land mass ratio (m/km$^2$) is two to three times higher than the global ratio.
([9]) See the communication *Blue Growth opportunities for marine and maritime sustainable growth* (http://ec.europa.eu/maritimeaffairs/policy/blue_growth/documents/com_2012_494_en.pdf).

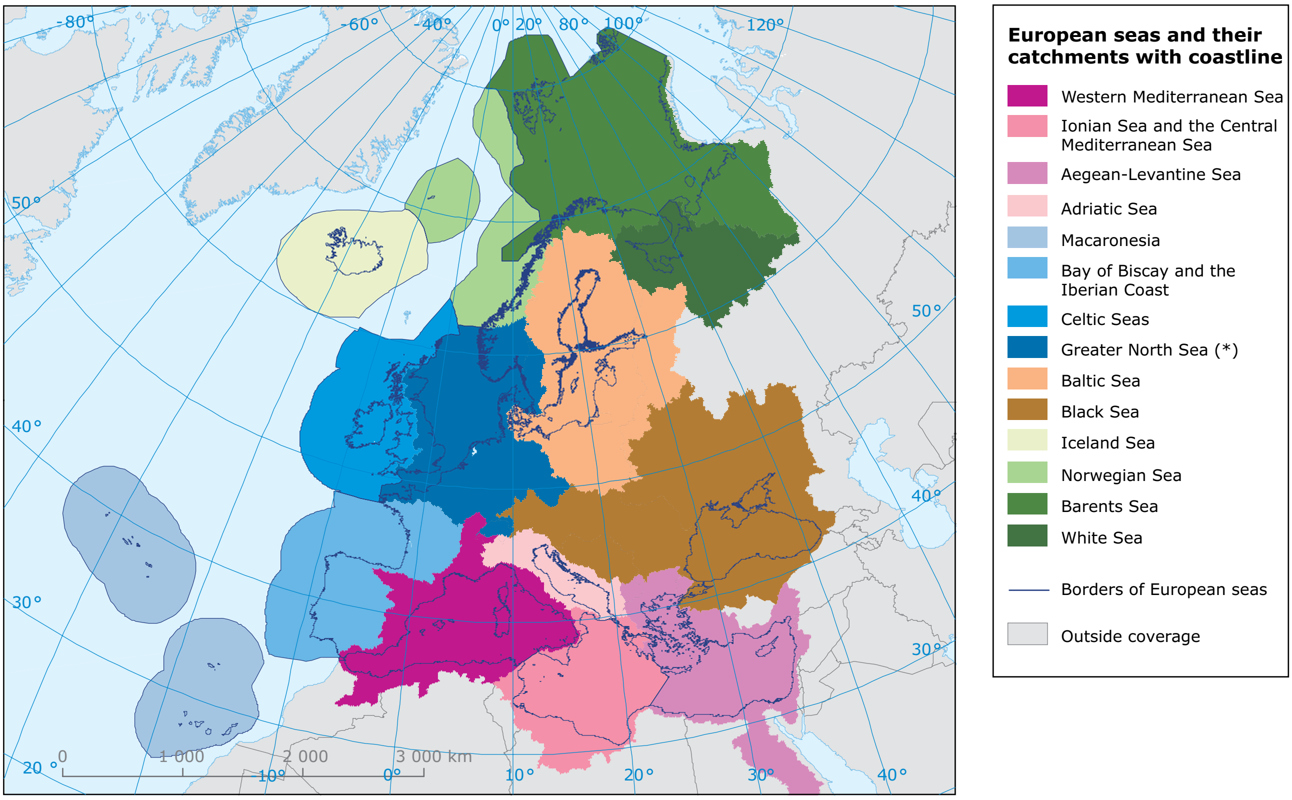
regional seas, from the icy Barents Sea in the north to the mild Macaronesian waters in the south. The cool and brackish Baltic Sea, the warm and salty Mediterranean Sea and further on, the Black Sea, which is characterised by its reduced salinity, (Map 1.1, Table 1.1) extend deep into the continent.

In 2011, approximately 206.2 million people lived in the 378 EU coastal regions, representing 41 % of the total population of the European coastal countries (502.5 million). In almost all (96.7 %) coastal regions, most of the population live by the sea; population density at the coastline is much higher than in coastal regions as a whole (Eurostat, 2011).

The share of the national population living in a coastal area, as well as the population density, depends on many factors: historical trade routes, economic development, climatic differences and geographical characteristics such as the accessibility and configuration of the coastline. Many coastal populations have increased, but some rural coastal regions have lost populations (see Map 1.2).

Several northern coastal areas have seen decreased population numbers due to migratory movements to the main cities, which in most cases are also found on the coasts. In the Mediterranean arc from Andalusia in Spain to Provence-Alpes-Côte d'Azur in France, the coastal population has increased between 10 % and 50 % in some municipalities. Ireland and the United Kingdom, as well as the Atlantic coast of France, Belgium, the Netherlands and Norway are also experiencing an increase in coastal population numbers, mainly due to the development of new infrastructures and residential areas.

**Map 1.1 Seas surrounding Europe and their catchment areas**




**Note:** (*) including the Kattegat and the English Channel.

The seaward boundary in the North-East Atlantic is set at 200 nautical miles. It does not reflect any claims concerning the Extended Continental Shelf nor is it intended to pre-empt any ongoing discussions within the United Nations Convention on the Law of the Sea (UNCLOS) on issues related to maritime boundaries.

## Table 1.1 European seas and their catchments: main figures

| European seas and their catchments | Neighbouring EEA/collaborating countries ([a]) | Sea surface area ($km^2$) | Area of catchment ($km^2$) | EU part of sea ([b])/ catchment (%) | Average and max. depth ([c]) | Sea volume ($km^3$) |
|---|---|---|---|---|---|---|
| **Baltic Sea** | **SE, FI, EE, LT, LV PL, DE, DK** | **394 000** | **1 653 000** | **94/74** | **53 m, 459 m** | **20 800** |
| **North-East Atlantic Ocean ([d])** | **UK, NO, DK, DE, NL, BE, SE, IE, FR, PT, ES** | **7 835 000** | **2 721 000** | **52/61** | **1 950 m, 5 900 m** | **13 714 350** |
| Barents Sea | NO, RU | 1 944 000 | 706 000 | 0/4 | 730 m, 4 160 m | 752 630 |
| Norwegian Sea | NO | 888 000 | 89 300 | 0/2 | 2 000 m, 5 570 m | 1 776 000 |
| Iceland Sea | IS | 756 000 | 103 000 | 0/0 | 1 190 m, 3 410 m | 899 640 |
| *Celtic Seas* | *UK, IE* | *920 000* | *185 000* | *100/99* | *910 m, 4 960 m* | *823 550* |
| *Greater North Sea including the Kattegat and the English Channel* | *DK, SE, NO, DE, BE, NL, FR, UK* | *670 000* | *966 000* | *75/81* | *85 m, 1 010 m* ([e]) | *57 970* |
| *Bay of Biscay and the Iberian Coast* | *FR, PT, ES* | *804 000* | *661 000* | *100/100* | *3 120 m, 5 560 m* | *2 508 480* |
| *Macaronesia* | *ES, PT* | *1 853 000* | *10 300* | *100/100* | *3 500 m, 5 900 m* | *6 881 000* |
| **Mediterranean** | **ES, FR, IT, SI, MT, HR, BA, ME, AL, EL, CY, TR** | **2 517 000** | **1 121 000** ([f]) | **42/72** | **1 550 m, 5 120 m** | **2 377 700** |
| *Western Mediterranean* | *FR, IT, ES,* | *846 000* | *429 000* | *78/98* | *1 700 m, 3 650 m* | *1 433 100* |
| *Ionian Sea and Central Mediterranean Sea* | *IT, MT, EL* | *773 000* | *76 300* | *32/98* | *1 610 m, 5 120 m* | *1 165 640* |
| *Adriatic Sea* | *SI, IT, ME, AL, HR* | *140 000* | *242 000* | *46/67* | *230 m, 1 200 m* | *30 820* |
| *Aegean-Levantine Sea* | *EL, CY, TR* | *758 000* | *374 000* | *11/41* | *1 540 m, 4 840 m* | *1 244 320* |
| **Black Sea** | **BG, RO, TR** | **474 000** ([g]) | **2 414 000** | **15/26** | **1 270 m, 2 212 m** | **551 180** |
| Sea of Marmara | TR | 11 700 | 39 290 ([h]) | 0/0 | 310 m, 1370 m | 3 660 |
| Sea of Azov | RU, UA | 39 900 | 440 000 ([i]) | 0/0 | 7 m, 14 m | 290 |

**Notes:** Bold entries indicate European seas that are identical to Marine Strategy Framework Directive (MSFD) marine regions. Where relevant, the sum of the sub-regional seas is also shown.

Italics are used to indicate European seas that are identical to MSFD marine sub-regions.

([a]) AL: Albania; BA: Bosnia and Herzegovina; BE: Belgium; BG Bulgaria; CY: Cyprus; DK: Denmark; DE: Germany; EE: Estonia; EL: Greece; ES: Spain; FI: Finland; FR: France; HR: Croatia; IE: Ireland; IT: Italy; LT: Lithuania; LV: Latvia; ME: Montenegro; MT: Malta; NO: Norway; NL: Netherlands; PL: Poland; PT: Portugal; RO: Romania; SE: Sweden; SI: Slovenia; TR: Turkey; UK: United Kingdom.

([b]) The EU part of the sea is the combined national waters of EU Member States, excluding the areas of non-EU Member States, and it is used to show what percentage of the sea is covered by EU legislation. Figures should only be considered indicative, since many maritime boundaries are under dispute.

([c]) All depths and sea volumes are based on data from ETOPO1 (Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, March 2009 (see http://ngdc.noaa.gov/mgg/global/global.html).

([d]) The North-East Atlantic is measured from the coast to 200 nm. High seas are excluded.

([e]) Based upon EMODNET bathymetry.

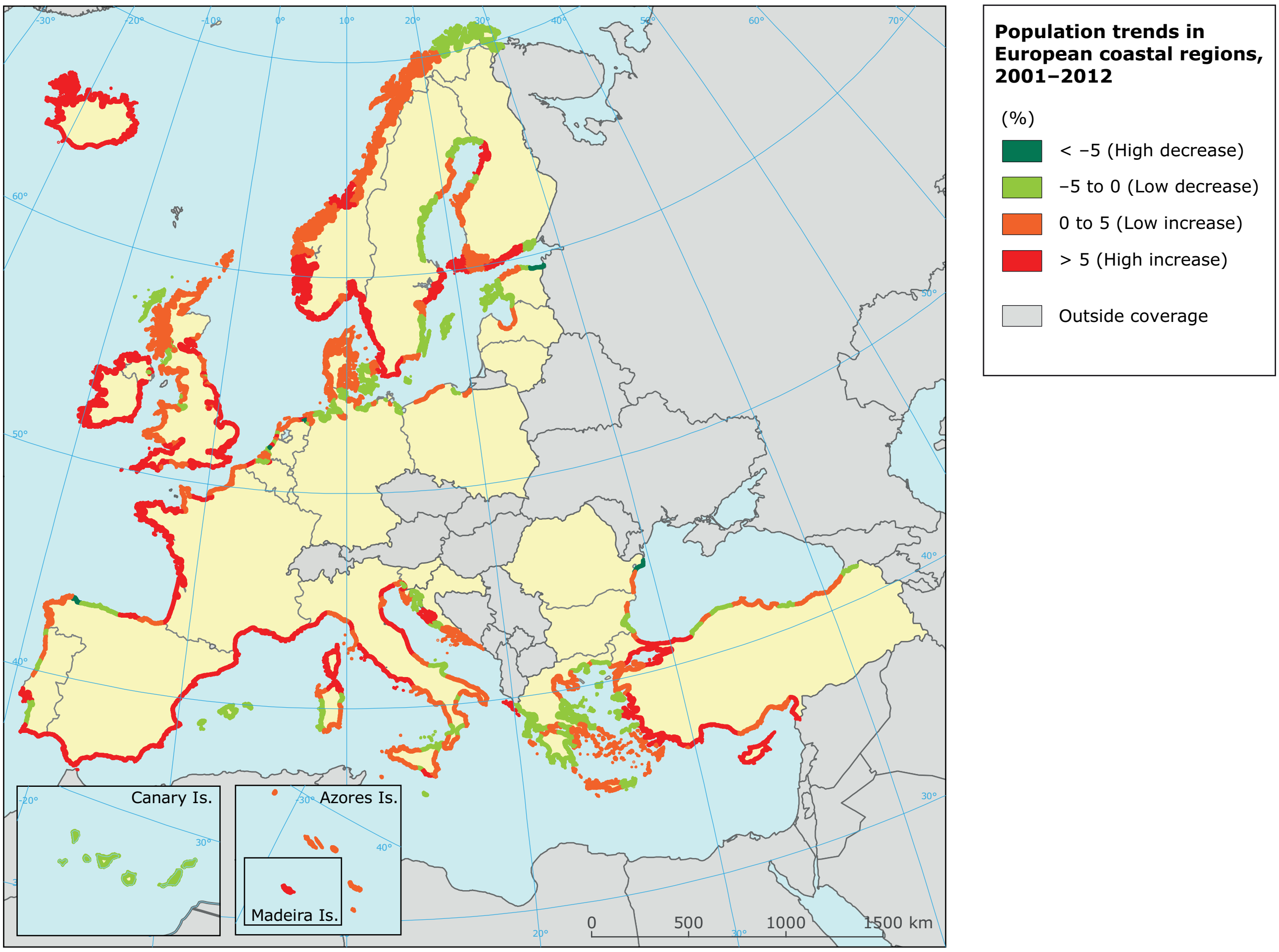
([f]) Catchment data from the Africa and Middle East are incomplete.

([g]) Including the surface area of the Sea of Marmara and the Sea of Azov.

([h]) Smith et al., 1995.

([i]) Balfoort, 1996.

**Map 1.2 Population trends in European coastal regions, 2001–2012**




**Source:** ETC/SIA, population data by coastal region (NUTS 3) from Eurostat.

# 2 Marine and maritime sustainable growth

## 2.1 Economic drivers of coastal development

Coastal regions account for an estimated 40 % of the EU's GDP; the maritime economy represents between 3 % and 5 % of the EU's GDP (EC, 2008a) ([10]), or a yearly gross value of EUR 485 billion. Economic assets within 500 m of the coastline account for an estimated EUR 500 to 1 000 billion (Policy Research Corporation, 2011). It is estimated that a total of 5.4 million people are employed as a result of maritime economic activities alone.

Many maritime sectors are expected to grow substantially in the coming years and decades. The term 'Blue Growth' refers to the maritime dimension of the Europe 2020 strategy. Its aim is to create new job opportunities, and to allow the maritime economy to grow from the oceans, seas and coasts — smartly, sustainably and inclusively (Damanaki, 2012). It targets a wide range of maritime and coastal activities (see Table 2.1).

EU industry accounts for a large part of the global value in shipping and transport (44 %), minerals and aggregates (49 %), marine tourism activities (48 %), and an overwhelming portion of maritime renewable energy (> 90 %) (EC, 2006; GWEC, 2012). European companies own 40 % of the world's shipping fleet and up to 90 % of the EU's foreign trade conducted by sea. Growth across maritime economic activities by 2020 is expected to have an added value of EUR 590 billion and to employ 7 million people (EC, 2012a; ECORYS et al., 2012) (see Table 2.2).

There are regional differences in the development of the maritime sectors. For example, the Baltic Sea region has become a major trade route for the export of Russian petroleum. It is estimated that about 2 000 ships are at sea in the Baltic at any one time, while between 150 and 200 large oil tankers are harboured in 20 ports around the sea each day (HELCOM, 2010a). By 2017, freight transport is expected to have tripled, and oil transport is expected to have increased by 40 % (HELCOM, 2013).

In the North-East Atlantic, the maritime economy provides an estimated 1.8 % of gross domestic product (GDP) and 2.1 % of employment to the OSPAR area. Over a third of this value is generated by coastal tourism and shipping, whereas coastal tourism and fishing are the two largest employers. The fastest-growing industry in the North-East Atlantic waters and on its coasts has been the renewable energy sector (wind, wave and tidal energy production). Oil and gas pipelines cover significant areas in the Greater North Sea. The OSPAR region has an estimated 50 000 km of pipelines transporting oil and gas products from offshore wells to the shore (OSPAR, 2010).

The main maritime economic activities in the Mediterranean are fishing, transport and tourism (UNEP, 2012). Tourism has grown significantly in the last 20 years (CSIL Centre for Industrial Studies and Touring Servizi, 2008) due to increases of both regional and international tourists (UNEP/MAP-Plan Bleu, 2009). Fishing peaked in the 1980s, as authorities had practically no control over the practice: today, fishing grounds remain overexploited. At the same time, marine aquaculture in the Mediterranean Sea has undergone significant growth since the 1990s for species such as sea bass and sea bream, and has also witnessed the 'fattening up' of tuna (UNEP/MAP-Plan Bleu, 2009). Transport in the Mediterranean has also been growing steadily, with a significant rise of 50 % between 1997 and 2006, mainly due to increased flows of energy products, e.g. transit via the Suez Canal.

The Black Sea region countries have experienced significant socio-economic changes over the last 20 years. Since 2000, individual wealth in the area has been growing unequally. The maritime economy of the Black Sea includes fishing, tourism and transport. Black Sea tourism is increasing, raising

([10]) A definition of 'maritime region' is not given in EC, 2008a. As maritime wealth/economy is generated at the coast (or further inland), the term 'coastal region' will be used instead in this report.

**Table 2.1 Main maritime sectors and related coastal activities**

| Activity | Description | Potential environmental issues |
|---|---|---|
| Bio-prospecting (marine) | The exploration of biodiversity for commercially valuable genetic and biochemical resources | Uncertain, possible low impacts related to seabed life disturbance or bio-pollution |
| Coastal protection | Engineering and beach nourishment for protection against flooding, erosion and saltwater intrusions | Sand extraction, obstruction of sediment movement, aggravation of erosion in other sites |
| Coastal tourism | Beach tourism, diving, sailing, water and coastal sports | Plant and soil trampling, wildlife disturbance, removal from nature, littering |
| Cruise tourism | Cruising in open sea, short-term mass tourism in ports of interest | Discharges from cruise vessels in sea and at port, waste, impacts of navigation traffic |
| Seawater desalination | Production of freshwater suitable for human consumption or irrigation | Marine life mortality at seawater intake, impacts of brine outflow |
| Fisheries | Capture fisheries in EU marine waters | Overfishing, disruption of marine food chains, seabed disturbance, pollution from processing plants, marine litter |
| Marine aquaculture | Saltwater aquaculture production (finfish and shellfish) | Fishmeal consumption (low trophic-level fish), water pollution, escapes of alien species, water filtration (by shellfish) |
| Maritime heritage protection | Wrecks, submerged archaeology sites, decommissioned forts | No known impacts, except restrictions on economic use of maritime space |
| Maritime industries | Civil and naval shipbuilding, ship repair and conversion, ship scrapping, construction of offshore platforms | Industrial pollution from shipyard operations |
| Maritime safety and security | Coastal safety installations, surveillance and reconnaissance activities, military training | Area requirements (navigation signs and shooting ranges), underwater (sonar) noise, war legacy (e.g. ammunition dumps) |
| Maritime transport | Cargo handling, deep-sea and short-sea shipping, ferry services, ocean towage, onshore storage, supply boats | Air, noise and water pollution, oil discharges (operational and from accidents), port activities, introduction of alien species, dredging, litter |
| Maritime works (dredging and sea-floor mining) | Dredging of sand, gravel (marine aggregates) and minerals, dumping of dredged materials, sand transport | Damage to specific seabed habitats (i.e. associated with aggregate deposits), seabed smothering by dredging/dumping |
| Nature conservation | Enforcement of designation regime and use restrictions, restoration and visitor activities | Limited access, maintaining the health of natural areas, negligible impact from restoration activities or ecotourism |
| Offshore industrial and fossil energy activities | Oil and gas exploration and production, carbon capture and storage (CCS) | Installation and decommissioning of oil and gas platforms, leaks from drilling works and operation of platforms |
| Pipelines and cables | Energy transport, oil and gas transportation, telecom (fibre optic cables), liquefied natural gas (LNG) terminals | Seabed occupation (high-density hotspots), land requirements for transmission facilities, installation works |
| Recreational boating and fishing | Leisure navigation, boat chartering and renting, marinas, fishing equipment, licensing (links to coastal tourism) | Wildlife disturbance, exhausts from outboard engines, marine litter |
| Renewable energy | Wind, wave and tidal energy | Claims to land and sea areas, installation works (including noise), visual seascape impact, refuge zone for marine organisms |

concerns about environmental damage to the area and its effects on industry (BSC, 2008a). Most tourists come from within the region, and it is estimated that about 4 million visitors come to the Black Sea coastline each summer (BSC, 2008b). The fishing industry has shifted significantly since the 1970s due to overfishing as well as the introduction of alien species, eutrophication and habitat change/damage. The economic importance of fishing in the area remains high, while marine aquaculture remains less developed than in other European marine regions (BSC, 2008a).

Overall, the European maritime economy is in a general state of growth and development. Table 2.2 presents the activities' development stages: introduction, development, growth or saturation. Only fisheries appear to be in general decline.

Marine ecosystems offer a wealth of economic benefits, due to the many resources and ecosystem services that they provide. Apart from growth and employment opportunities, maritime industries are also responsible for a wide range of environmental pressures and impacts on marine ecosystems, as well as potentially causing conflicts between stakeholders.

Spatial interactions (allocation) play a pivotal role in the tensions between maritime industries; they call for a coordinated transboundary management approach.

**Table 2.2 Maritime economic activities by development stage based on size, recent trend and estimated potential ([a])**

| Maritime economic activity | Size today (billion EUR) | Recent trends | Estimated future potential | Comment ([b]) |
|---|---|---|---|---|
| **Mature stage** | | | | |
| Short-sea shipping | 57 | 5.8 % | 2 | 100 % growth by 2050 (Tetraplan et al., 2009) |
| Offshore oil and gas | 107–133 | – 4.8 % | 1 | Globally only 20 % of exploitable oil and gas have been exploited |
| Coastal tourism and yachting | 144 | 3–5 % | 4 | No data |
| Coastal protection | 1–5.4 | 4.0 % | 6 | No data |
| Fisheries | 4.8 ([c]) | – 25 % since 1993 ([d]) | | Only 13 % of European fish stocks are fished at maximum sustainable yield (MSY). Many stocks are not assessed |
| Landings/production | | Annual growth since mid-1990s | | |
| Fishing fleet capacity | | – 2 % | | |
| Employment | | – 4 to – 5 % | | |
| **Growth stage** | | | | |
| Offshore wind | 2.4 | 21.7 % | 6 | By 2030, industry's contribution EU GDP increases fivefold, and employment by factor of three (EWEA, 2012) |
| Cruise tourism | 14.1 | 12.3 % | 5 | Recently, above 10 % annually in the Baltic Sea Region (Cruise Baltic, 2013) |
| Marine aquatic products | 0.5 | 4.6 % | 4 | Aquaculture in many countries is stagnating |
| Maritime monitoring and surveillance | 5.6–10 | Growth expected | 5 | No data |
| **Development stage** | | | | |
| Blue biotechnology | 0.8 | 4.6 % | 5 | 4–12 % (ESF, 2010) |
| Ocean renewable energy (non-wind) | 0.25 | Growth expected | 5 | No data |
| Marine minerals mining | 0.25 | Growth expected | 4 | No data |

**Notes:** ([a]) trend refers to average annual GDP growth over last 5 available years, potential ranking from 1 to 6, with 6 being the highest, 2008 or latest available year.

([b]) Expected growth is based on predictions from various sources, and should only be considered an indication of an expected trend.

([c]) The total income of the entire EU fishing fleet in 2008, for Member States that did report data (excluding Spain, Greece, and Ireland).

([d]) EU-28 plus Albania, Bosnia and Herzegovina, Iceland, Montenegro, Norway and Turkey.

**Source:** Table modified from ECORYS et al., 2012.

For example, such an approach would be necessary to accommodate competition for maritime space between passenger ferries, fisheries and offshore wind farms as well as marine protected areas.

## 2.2 Maritime activities and sustainability challenges at the coast

The pressures and impacts on marine and coastal ecosystems arise from economic activities on the coast and adjacent seas (Section 2.1). These sustainability challenges offer an opportunity for innovative growth: altered hydromorphology requiring restoration of modified water bodies, land use changes calling for effective protection of sensitive terrestrial and freshwater habitats at the coast, invasive alien species that must be contained to avoid disruption to local food-webs, diffuse and point source pollution of nutrients requiring efficient land-based measures to prevent reduced aquatic oxygen conditions, long-term management of hazardous substances to limit their build-up in organisms to dangerous levels, and proper waste recycling incentives to minimise marine litter (debris) with its multiple adverse effects on marine life.

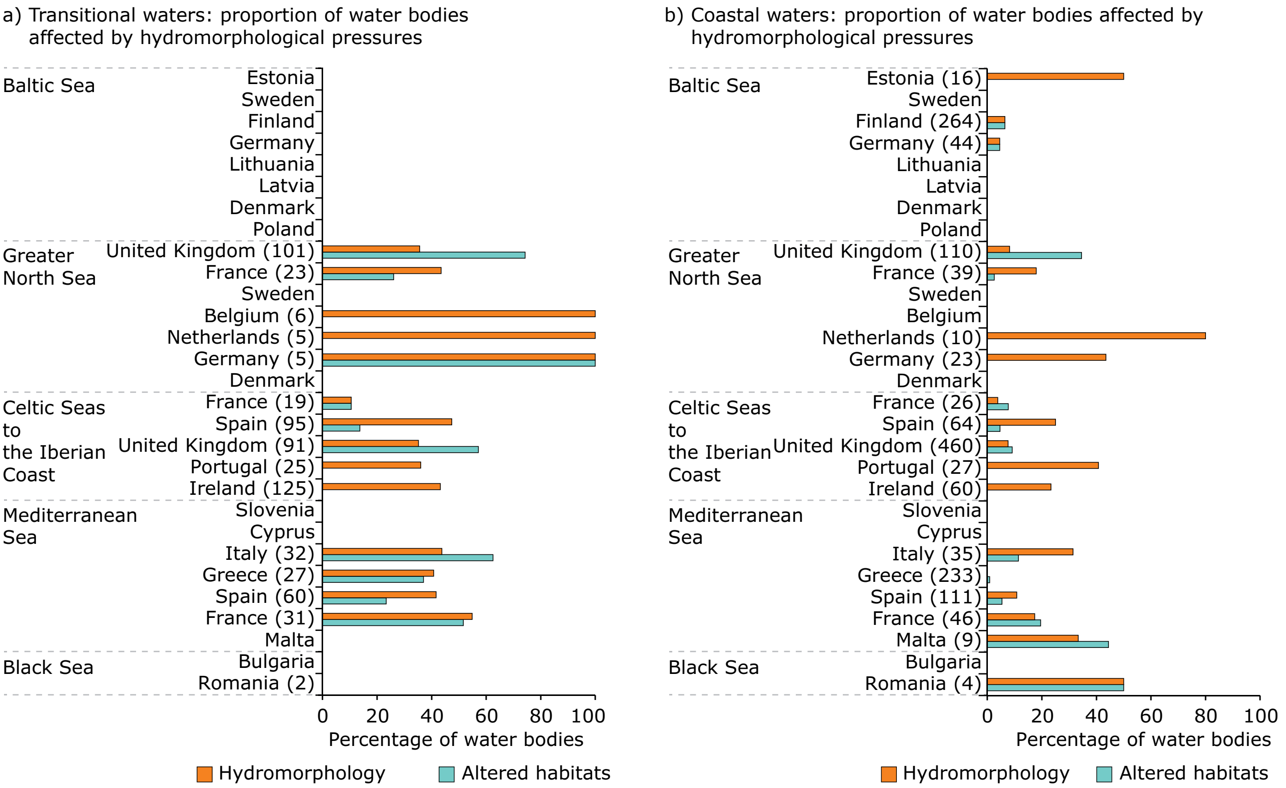
### 2.2.1 *Hydromorphological changes*

Human activities have changed the morphology and hydrology of water bodies, and have modified the natural flow regime and structure of surface waters and related habitats. These pressures affect aquatic fauna and flora, and, depending on scale, significantly impact water status locally or regionally (see Figure 2.1).

Hydromorphological pressures and altered habitats constitute the most commonly occurring pressure, and they impact transitional water bodies in particular. In coastal waters, hydromorphological pressures and impacts are reported for a low proportion of classified water bodies.

Offshore maritime activities add a significant pressure and impact especially on benthic habitats

**Figure 2.1 Proportion of water bodies affected by hydromorphological pressures for transitional and coastal water bodies by marine regions: a) transitional waters, and b) coastal waters**




**Note:** The number of water bodies is provided in parenthesis.

**Source:** EEA, 2012a.

and sea-floor integrity. Fisheries cause physical damage to large areas of the sea floor, e.g. through abrasion or selective extraction of benthic organisms. For example, in the German North Sea, some areas (3 x 3 nautical miles) have been annually fished with up to 150 to 400 hours of large beam trawling, even inside marine protected areas such as Natura 2000 sites (Figure 2.2).

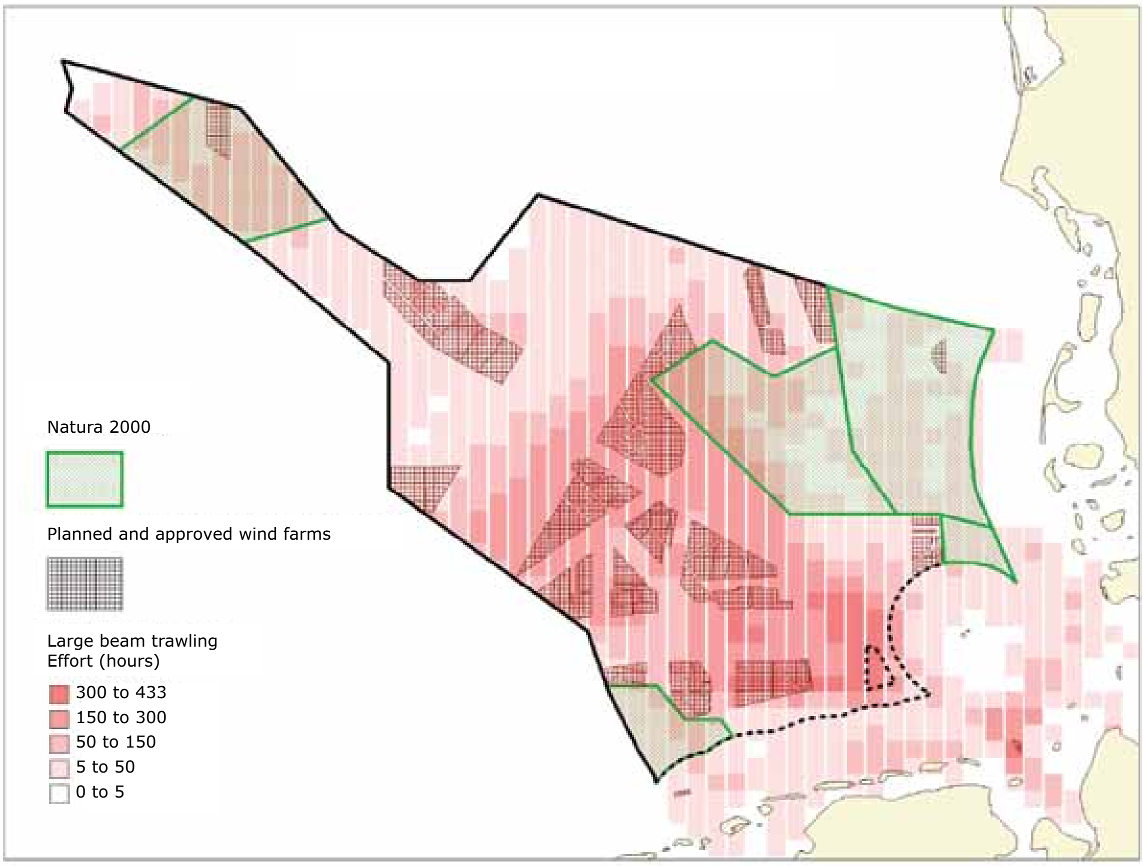
In some marine regions such as the Mediterranean, unsustainable fishing practices like trawling that impact sensitive seagrass (*Posidonia*) beds and deep-sea corals pose a serious problem. In the Greater North Sea, large areas of the benthic habitats are affected by trawling or dredging and the increasing exploitation of sand and gravel for construction and beach nourishment. Important changes in river discharges (as a result of climate change, water storage and sediment trapping in reservoirs and canalisation of natural water courses) also impact upon coastal processes.

### 2.2.2 *Loss of habitats and species*

A serious consequence of habitat degradation, hydromorphological changes and some other environmental pressures is the loss of species or 'ecological extinctions' of local populations from complex ecosystems. A number of key European coastal habitats and species are at risk. The problem is highlighted by the low percentage of coastal and marine habitats and species with favourable conservation status ([11]) (Table 2.3; see also Map 3.1).

Overall, the current pattern of European coastal biodiversity suggests an accelerating fragmentation and loss of habitats, species, and coastal ecosystem services. Changing this pattern is a major challenge: we must acknowledge the trade-offs between short-term overexploitation and long-term maintenance of services, while meeting the dual political ambitions of environmental sustainability and economic growth (see Box 2.1).

**Figure 2.2 Sites of planned and approved wind farms in German North Sea exclusive economic zone (EEZ); fishing effort by large beam trawlers; Natura 2000 marine protected areas**




([11]) Favourable conservation status of habitats requires that natural range and area are stable or increasing, and structure and functions necessary for long-term maintenance are likely to continue to exist in the future; likewise for species as defined by the Habitats Directive.

**Table 2.3 Pattern of change for selected habitats, functional groups and populations in European coastal ecosystems**

| Feature | Status or indication of trends | Reference |
|---|---|---|
| Marine habitats | 10 % of assessments of marine habitats are favourable | EEA, 2010a |
| *Posidonia oceanica* | 5 % decline per year | Duarte et al., 2009 |
| Marine species | 3 % are in favourable conservation status | EEA, 2010a |
| Invertebrates and mammals | Nearly 70 % of assessments for mammals and invertebrates in marine environments are 'unknown' | EEA, 2010a |
| Benthic invertebrates | 22 % reduction in number of species on certain localities in the Kattegat over 10 years | Ærtebjerg et al., 2003 |
| Fish | At least 50 % are in unfavourable conservation status | EEA, 2010a |
| European eel | Current recruitment 1–7 % of 1960–1979 levels | ICES, 2012a |
| Cod | Current total stock biomass in the Kattegat is at approximately 5.6 %, compared to levels in 1971 | ICES, 2012b |
| Coastal habitats | 7 % of assessments for coastal habitats are favourable | EEA, 2010a |
| Coastal species | 13 % of assessments of coastal species are favourable | EEA, 2010a |
| Butterflies | 71 % of butterfly species have experienced a decline and 3.4 % have become extinct in the United Kingdom over the last 20 years (not only coastal) | Thomas et al., 2004 |
| Native plants | 28 % of native plants in the United Kingdom experienced a decline, over 40 years (not only coastal) | Thomas et al., 2004 |

**Box 2.1 Seagrass meadows act as biodiversity hotspots and offer coastal protection**

Seagrass meadows are the natural dominant ecosystems of photic sandy seabeds throughout Europe; they fulfil important trophic and structural functions owing to their high productivity. In northern seas the meadows are dominated by *Zostera marina*, and in the Mediterranean by *Posidonia oceanica*. They provide a range of ecosystem services: regulating services include storm protection, erosion control, carbon sequestration and support, while provisioning services include spawning or feeding grounds for invertebrates and species. It has been estimated that Mediterranean *P. oceanica* meadows bury some 2 megatonnes C year$^{-1}$, host more than 400 plant species and thousands of animal species and deliver substantial amounts of sand to coastal dune systems through material deposited on the beach after heavy storms (Boudouresque et al., 2009; Duarte, Nixon et al., 2009).

The main threats affecting long-term viability of *P. oceanica* meadows are the cumulative effects from water pollution, construction of coastal infrastructures, fishing, shipping, invasive species, changes in water currents and increased storm surges (EEA, 2010b). The reporting carried out under the Habitats Directive (92/43/EEC) suggests that the conservation status of *P. oceanica* is unfavourable/inadequate in the Mediterranean (ETC/BD, 2009).

The rate of decline of *P. oceanica* meadows in the Mediterranean is currently 5 % per year — this places them among the most threatened marine ecosystems on the planet. Recovery can, due to slow growth and colonisation of *P. oceanica*, take several hundreds of years. A circular clone requires 100 years to attain a diameter of 8 m. A clone found in Formentera covering several square kilometres was estimated to be 80 000 to 200 000 years old (Duarte, Nixon, et al., 2009).

Distribution of *Z. marina* in the Baltic Sea region is also under decline. In the 1990s, the cover in Limfjorden, at the entrance of the Baltic Sea, was only at between 20 % and 25 % of the cover in 1900, due particularly to the loss of meadows in deeper waters (Ærtebjerg et al., 2003). The decline has been linked to changes in energy input (light), physical disturbance (increased wave action and extreme temperatures), chemical disturbance (anoxia and sulphide) and biological disturbance (wasting disease), associated with eutrophication (Ærtebjerg et al., 2003) and climatic change (Duarte, Nixon et al., 2009).

European coastal land cover change is similar to the change across Europe — the sprawl of artificial areas is the dominant driver of the coastal zones development, mostly at the expense of former agricultural land and related coastal habitats (Figure 2.3).

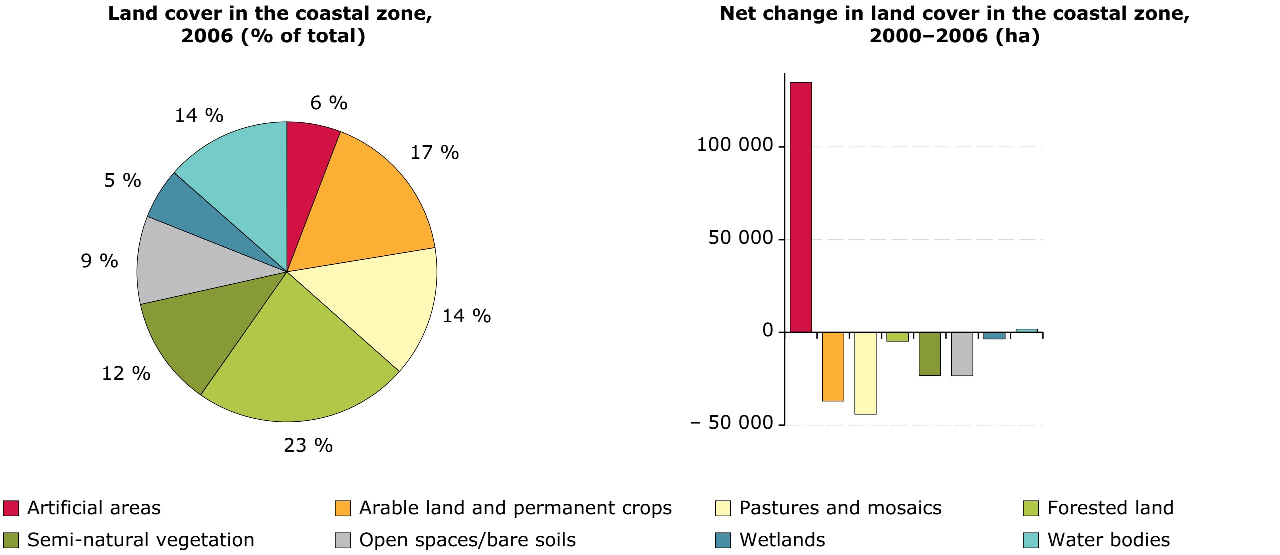
According to the most recent Europe-wide land data ([12]) (2000–2006), 1 347 km² of new urbanised areas have been developed in Europe's coastal zone. The annual rate of urban sprawl (0.66 %) was higher than the European average (0.52 %). The land take was driven mostly by residential sprawl. Other main drivers of urban development were commercial/industrial sites and sports/leisure areas.

More recent data from the European Earth Observation programme Copernicus allows analysis of impervious areas ([13]) across Europe's' coastal zones (see Figure 2.4). In 2009, a total of 20 434 km² was mapped as impervious (2.95 % of coastal zones area in 29 European coastal countries). The 2006–2009 change showed a 4.9 % increase of such areas, although the situation varied across countries.

All types of natural or semi-natural land cover have decreased in the 2000s. Specific coastal habitats include the intertidal flats, of which there were approximately 12 000 km² in 2006, coastal lagoons (almost 4 400 km²), beaches, dunes and sand plains (3 700 km²), and salt marshes (3 000 km²).

The majority of countries have experienced a decrease in coastal wetland areas; wetland coverage only increased in a few areas in northern Scotland, Estonia and Denmark. The reduction of wetlands has been mainly driven by afforestation, conversion to agricultural lands and water bodies (see Figure 2.5).

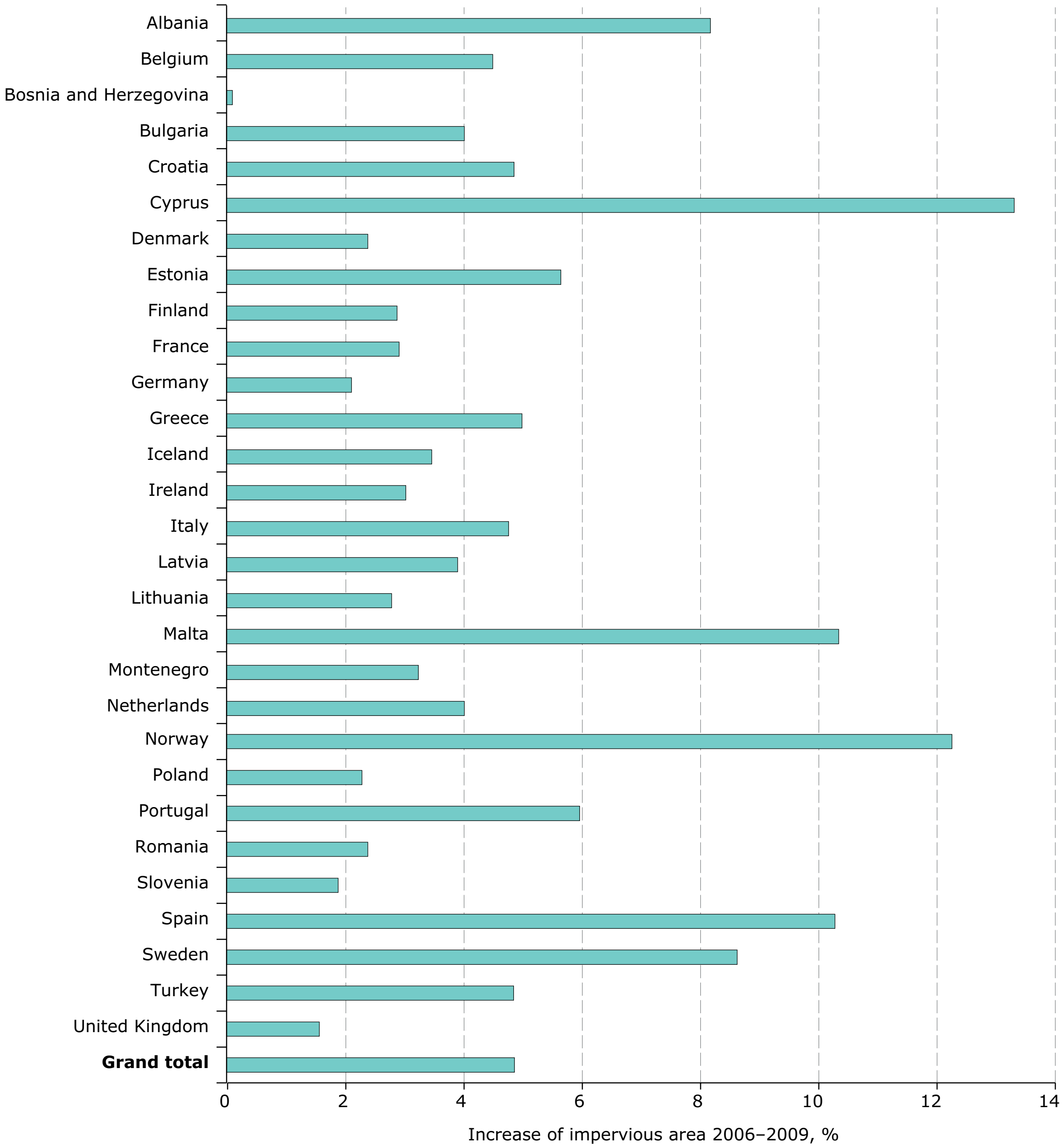
**Figure 2.3 Land cover 2006 (left), and net change in land cover 2000–2006 (right) in coastal zones of 22 coastal countries**




**Source:** EEA; ETC/SIA, based on Corine Land Cover (2006).

([12]) An update of coastal land cover trends (2006–2012) is expected by 2015.
([13]) A high-resolution imperviousness data set provides a spatial distribution of all artificially sealed areas, including the level of sealing of the soil per area unit. The level of sealed soil is produced using an automatic derivation algorithm based on a calibrated Normalized Difference Vegetation Index (NDVI). More information is available from http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness.

**Figure 2.4 Increase of impervious surfaces in coastal zones (0–10 km), 2006–2009**



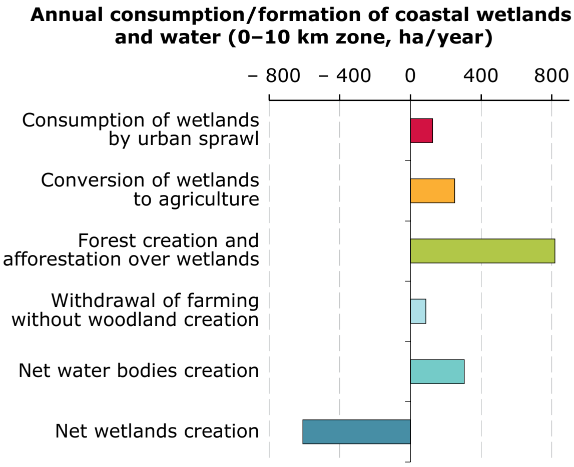

**Note:** The data represents sealed area % change 2006–2009, cloud free. In terms of representation, 'imperviousness' refers to sealed areas. It is not the same as 'land take' that measures change in all artificial surfaces, including non-sealed ones such as green urban areas.

**Source:** Copernicus Land monitoring High Resolution Layer 'Imperviousness', 2013.

### 2.2.3 *Non-indigenous species*

European seas have been reported to harbour 1 369 marine alien species (MAS) (Katsanevakis et al., 2013). They are primarily invertebrates (873 — mostly crustaceans and molluscs), followed by primary producers (326 — plants and microorganisms), and vertebrates (161 — mostly fish). The rate of introductions is increasing continually: almost 300 new species have been reported since 2000. The Mediterranean Sea has the largest share in alien species introductions,

**Figure 2.5 Main trends in Europe's coastal wetland and water area, 2000–2006**




**Source:** EEA; ETC/SIA, based on Corine Land Cover (2006).

totalling more than 1 000 species since the 1950s — on average, a new alien species is introduced in this region every 10 days.

The primary pathways of MAS introductions in European seas are shipping, marine and inland corridors, aquaculture and aquarium trade. A more stringent EU legal framework has reduced introductions via aquaculture activities.

Alien species that have negative impacts on biodiversity, socio-economy or human health are considered invasive (CBD, 2002). There are well-documented cases of invasive species taking advantage of degraded ecosystems that had been weakened by overexploitation like excessive fisheries (e.g. the invasive comb jellyfish *Mnemiopsis leidyi* or gastropod *Rapana venosa* in the Black Sea).

Some positive impacts are also possible, through the creation of new economic activities (e.g. in fisheries and aquaculture), the improvement of aesthetic values, and increased employment in invasive MAS management projects and programmes (Bax et al., 2003).

Although invasive species can impact their surroundings significantly, there are not enough data in Europe for a full assessment. Available examples show that impacts can be serious. Growing populations, trade and tourism have increased opportunities for the establishment and spread of invasive species (Bax et al., 2003). While it is very difficult to predict which species may become problematic, policy and management should focus on precautionary measures and prevent introductions of species that might harm native ecosystems.

### 2.2.4 *Eutrophication, harmful algal blooms and oxygen deficiency*

Eutrophication resulting from nutrient enrichment has been recognised for many years as one of the main pressures acting upon the marine environment; it remains a threat for marine biodiversity in European coastal waters. It is caused by human exploitation, e.g. excessive use of fertilisers by agriculture or insufficiently treated wastewater. The excessive loading of soluble nitrogen and phosphorus compounds is particularly relevant here, but in some cases, so is the ratio of these two key nutrients in aquatic ecosystems.

Regardless of the cause, eutrophication increases algal growth in the water column as well as on the sea floor, and can lead to an ecosystem shift. Ecosystems dominated by benthic primary production can become dominated by pelagic planktonic production characterised by offshore algae blooms (see Photo 2.1).

The key effects of eutrophication include the development of harmful algae blooms (red/brown/green tides) that can release toxins and cause local fish and shellfish poisoning, and development of reduced dissolved oxygen levels (hypoxia and even anoxia) due to depletion of oxygen by algae decomposition. This can lead to fish kills, seagrass loss and loss of communities of long-lived benthic invertebrates (see Box 2.2).

Pollution is reported as a pressure affecting 80 % of the coastal water bodies in Baltic Sea and more than half of the water bodies in the Greater North Sea. In general, transitional waters experience more pollution pressures and water quality impacts than coastal waters. This is the case for pressures from diffuse sources and for point sources, indicating that water quality issues persist in many estuaries throughout Europe (see Figure 2.6).

In spite of measures to reduce nutrient concentrations in European seas, 85 % of measurement stations show no change in nitrogen concentrations, 80 % show no change in phosphorous concentrations, and 89 % show no change in chlorophyll-a concentrations. Winter

**Photo 2.1** Pelagic algal bloom in the central Baltic Sea

© European Space Agency, July 2010

nitrogen oxide concentrations have dropped significantly at 21 % of 268 stations in the Baltic Sea and at 8 % of stations in the North Sea. Little improvement is seen in other seas.

The effects from eutrophication can be aggravated by synergistic effects from other human activities. For example, human exploitation of benthic suspension feeders (e.g. molluscs) can also enhance the effects of eutrophication — sometimes, it even predates eutrophication. A removal of species such as oysters or blue mussels lowers the overall resilience of the ecosystem to land-based nutrient enrichment (Jackson et al., 2001). Similarly, introduction of suspension feeders such as clams can reverse this process (Petersen et al., 2008).

The existence of ecological tipping points and hysteresis has been documented for its response to nutrient abatement (Duarte, Conley et al., 2009). Importantly, the findings showed that the studied ecosystems failed to return to reference status upon nutrient reduction.

Understanding ecosystem response to such multiple shifting baselines will be essential for identifying targets for management response. Ecosystem response thresholds have been also studied in the context of marine regime shifts that are characterised by various drivers, scales and potential for management action (deYoung et al., 2008; Petersen et al., 2008). Dangerous levels of nutrient enrichment and resulting eutrophication may lead to systemic

**Box 2.2 Benthic invertebrates under multiple pressures in coastal ecosystems**

Benthic invertebrates deliver a range of supporting, regulating and provisioning ecosystem services for coastal and marine ecosystems. For example, they help filter large water masses and also mix muddy sediments, thereby enhancing aerobic decomposition of organic matter and the nitrification–de-nitrification processes. They thus play a vital role in nutrient recycling. They are also an important food source for higher trophic levels including humans. Benthic invertebrates are found in abundance throughout European estuaries and coastal bays as well as further offshore.

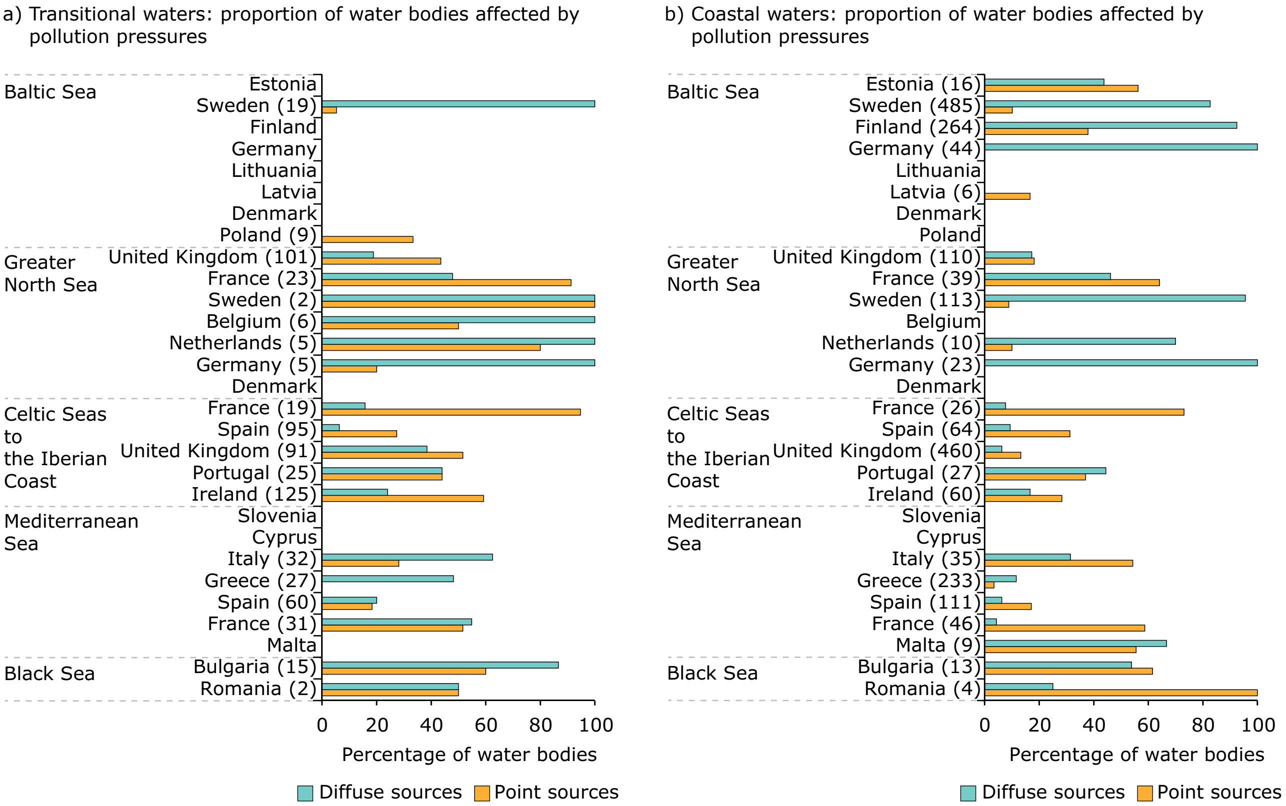
Benthic invertebrates are under pressure from multiple stressors. These include effects from eutrophication, hazardous substances, and indirect and direct physical disturbance. Eutrophication-induced hypoxia in particular led to mass mortality and major changes in community structure affecting semi-enclosed seas such as the Baltic Sea and the Black Sea. Globally, the area of dead zones owing to hypoxia has doubled every decade since 1960s (Diaz and Rosenberg, 2008).

Eutrophication and organic enrichment can generate increased biomass and higher abundances in food-limited communities. However, sensitive and large-sized species do not tolerate such changes; they will be outcompeted by smaller and more tolerant species, resulting in loss of biomass and diversity. At even higher enrichment levels, hypoxia, anoxia and released toxic hydrogen sulphide will eventually kill most benthic invertebrates (HELCOM, 2009).

During 2002, a hypoxia event covering 3 400 km$^2$ was observed in the Kattegat. It was estimated that 371 000 tonnes of benthic invertebrates were killed, from mainly offshore sandy to muddy habitats (Hansen et al., 2004). Over a 10-year period, a loss of 50 species (from 230 to 180 species) occurred at localities in the area (Ærtebjerg et al., 2003). Losses of such magnitude are severely disrupting the food web and overall productivity of benthic invertebrates. It has been shown that introduction of suspension-feeding clams, *Mya arenaria*, can lead to regime shifts in coastal ecosystems, moving production of organic matter from the pelagic turnover to benthic-pelagic coupling. This has resulted in increased water transparency and plant cover (Petersen et al., 2008).

Shallow sandbanks, intertidal mudflats and muddy habitats found within coastal lagoons, estuaries and shallow inlets and bays are protected by the Habitats Directive. No offshore deep muddy or sandy habitats are protected by the directive.

**Figure 2.6 Proportion of water bodies affected by pollution pressures for transitional and coastal water bodies by marine regions: a) transitional waters, and b) coastal waters**




**Note:** The number of water bodies is provided in parenthesis.

**Source:** EEA, 2012a.

threats and even regime shifts affecting marine and coastal ecosystems, particularly in shallow and transitional sea compartments, and when combined with other drivers such as fishing and climate-ocean circulation conditions that do not favour water circulation (see also Box 3.1 on synergistic effects).

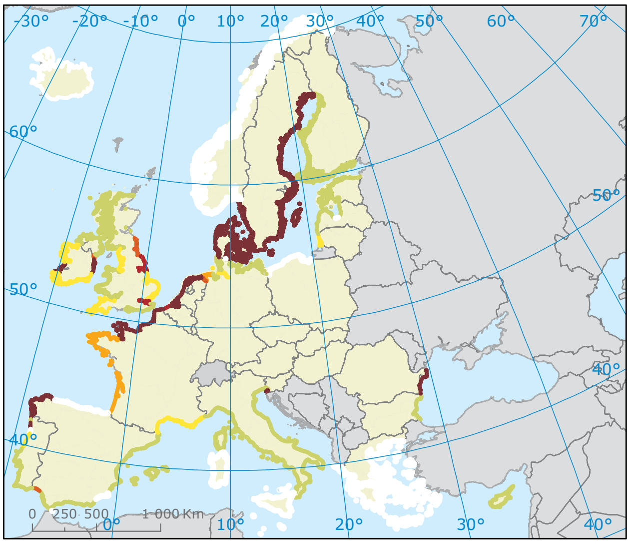
### 2.2.5 *Hazardous substances*

The number of hazardous substances found in transitional, coastal and marine waters is large and is increasing, but few substances are monitored systematically. Emissions of hazardous substances arise from a wide range of land-based and maritime sources, including agriculture and aquaculture, industry, oil exploration and mining, transport, shipping and waste disposal, as well as from domestic sources.

Chemical status for more than 4 000 transitional and coastal water bodies has been reported across 16 and 21 Member States, respectively (EEA, 2012a). Poor chemical status is reported in 10 % of transitional and 4 % of coastal water bodies, while good status is achieved in 35 % and 51 %, respectively. Unknown status is reported for 55 % of transitional and 46 % of coastal water bodies (see Map 2.1).

Transitional and coastal waters with the poorest chemical quality across Europe are typically subject to pollution from a range of individual pollutants that reflect a diverse range of sources. Coastal waters related to the Seine in France, for example, report heavy metals, pesticides and polycyclic aromatic hydrocarbons (PAHs) to be an issue, while in the Belgian Schelde, 12 chemicals including mercury, pesticides, PAHs, Tributyltin (TBT) and the industrial chemical nonylphenol are all a cause of poor status. Similarly, the Romanian coastal part of the Danube RBD is polluted by heavy metals (cadmium, lead and nickel), a range of PAHs and some pesticides. Six Member States report their coastal waters to be in 100 % good status, although in five others (Belgium (Flanders), Denmark, the Netherlands, Romania and Sweden), poor status

**Map 2.1** **Share of water bodies not achieving good chemical status of transitional and coastal waters per river basin district (RBD)**




**Percent of classified surface water bodies with failure to achieve good chemical status for transitional and coastal waters**

< 10 %
10–30 %
30–50 %
50–70 %
70–90 %
≥ 90 %
No data

**Note:** Surface water bodies holding unknown status are not included in calculating percentage of poor chemical status.

**Source:** EEA, 2012a.

exceeds 90 % of those water bodies with a known chemical status (EEA, 2012a).

Hazardous substances can interact with different ecosystem components, and have detrimental effects on biota at molecular, cellular, tissue and organ levels. Substances with endocrine-disrupting properties have been shown to impair reproduction in fish such as the eelpout (*Zoarces viviparous*) and shellfish in Europe, raising concerns for fertility and for population survival. In some polluted areas, malformed larvae are found in more than 80 % of eelpout broods (HELCOM, 2010b) (see Photo 2.2). Organochlorines influence birds and marine mammals, and metals and pesticides are toxic to biota.

Accumulation of dioxins (a family of highly stable and toxic persistent organic pollutants (POPs)) along the marine food web has been demonstrated in the Baltic Sea (HELCOM, 2004). While the concentrations have significantly decreased since peaking in the 1970s, dioxin accumulation in seabed sediments and in some fatty fish such as wild salmon and herring is still cause for concern (Naturvårdsverket, 2013).

### 2.2.6 *Marine litter*

Marine litter is any manufactured or processed solid material that is disposed of, or abandoned, in the marine or coastal environment (UNEP, 2005). This is a growing environmental issue, global in scale and intergenerational in impact due to its pervasiveness in the marine environment (EC, 2012b). The EU's MSFD is a key element in Europe's actions to address marine litter: its Descriptor 10 of the 'Good Environmental Status' overarching objective relates directly to marine litter.

Marine litter includes plastics and derivatives (up to 80 % of total litter), metals, glass, concrete and other construction materials, paper and cardboard, rope, textiles, timber and hazardous materials; it ranges in size from large items (debris) to highly hazardous microplastics. Marine litter can be found floating, on the sea floor and on the coastlines above sea level (Photo 2.3). It is estimated that 15 % of marine debris floats on the sea surface, 15 % remains in the water column and 70 % rests on the seabed (UNEP, 2005). Apart from the adverse impacts on marine life, it is an increasing risk to human health and safety and an increasing cost to society and sectors.

The most important and direct environmental impacts are ingestion and entanglement of marine species and seabirds. However, evidence

**Photo 2.2** The eelpout fish (*Z. viviparous*) shows abnormal development of embryos and larvae due to chronic exposure to contaminants

© Jakob Strand, DCE

**Photo 2.3** Beach litter is a growing problem on coastlines



is accumulating on the importance of other, less well-known impacts of marine litter. By providing a surface for species to attach to, floating or deposited items can assist in alien species invasions (Barnes, 2002). Also, since plastics make up the main category of litter on the oceans by far, they may act as a vector for transferring toxic chemicals to the food chain and potentially cause toxic, carcinogenic and hormone disrupting effects with mostly unknown long-term effects (Thompson et al., 2009).

Marine litter can cause serious economic losses, either due to direct costs or loss of income (UNEP, 2009; Mouat et al., 2010). Those most seriously affected are coastal communities (e.g. increased expenditures for beach cleaning, public health and waste disposal), tourism (e.g. loss of income, bad publicity), shipping (e.g. costs associated with fouled propellers, damaged engines, litter removal and waste management in harbours), fishing (e.g. reduced and lost catches, damaged nets and

**Box 2.3 Scientific evidence on plastic marine litter in marine environments**

According to a 2013 report, a growing number of studies show that marine organisms at all levels of the food web ingest plastics and micro-plastics (IMSA Amsterdam, 2013). Plastics and micro-plastics are thus entering the food chain. In the English Channel, 30 % of fish contain plastic contamination (Lusher et al., 2013) and each gram of North Sea mussels contains one microplastics particle (Van Cauwenberghe et al., 2012). A total of 80 % of marine litter is land-based (SWD(2012) 365 final), and river litter could be an important source.

Recent measurements in the Meuse river suggest that 15 000 items can be transported per hour (Tweehuysen, 2013). Sewage effluents are another source of microplastics. Dutch effluent contains between 10 and 20 particles per litre of effluent (Leslie et al., 2011). The University of Gent reports 300 microplastic particles/kg of sediment in the North Sea seabed. Average concentration of 64 plastic particles per litre (with high variability) is reported in the waters of the Jade Bay, an inshore basin off the coast of Germany in the Southern North Sea (Dubaish and Liebezeit, 2013).

The amount of marine waste on the seabed in the Arctic Ocean has doubled from 1 % to 2 % of the surface covered, since 2002 (Bergmann and Klages, 2012).

other fishing gear, fouled propellers, contamination), fish farming and coastal agriculture (UNEP, 2009).

The effect of marine litter in the marine and coastal socio-ecological system is expected to become a more prominent issue in the future: marine litter concentrations in the marine environment appear to be on the increase continuously, and the negative effects of microplastics are better understood (EC, 2013a). However, systematic collection of marine litter data is still in its formative stage, restricting assessment of marine litter at EU and regional level.

A recent study has placed the fight against plastic marine litter in an overall framework; it also reviews the available related scientific literature (see Box 2.3).

## 2.3 Maritime spatial planning (MSP)

Many of the challenges and opportunities presented in Chapter 2 have a strong spatial component. There is direct competition for space in activities such as the protection of particular habitats, mariculture, harbours or the exploitation of energy resources. Indirect competition for space is also important in many European coastal regions, and it arises when pollution excludes tourism or recreational use, or causes deterioration of habitats, for instance.

Maritime spatial planning (MSP) has been introduced as an approach to deal with and manage spatial interactions of maritime activities. Many countries have adopted different variants of the concept (EC, 2008b).

The expected benefits of MSP are ([14]):

- a reduction of conflicts between sectors, and the creation of synergies between different activities;
- the encouragement of investments through greater predictability, transparency and clearer rules;
- increased coordination between administrations in countries;
- increased cross-border cooperation on infrastructures such as cables, pipelines, shipping lanes and wind installations;
- improved protection of the environment through early identification of impacts and opportunities for multiple use of space.

MSP has borrowed the basic idea to use planning as a tool to manage potential and actual competition for space from land use planning. MSP differs, however, from land use planning in several important respects.

First, ownership is relatively less important in the maritime context than in terrestrial systems. Instead, different temporary rights and concessions determine who is allowed to use maritime space, as well as the conditions of use.

Second, maritime planning operates within three dimensions, addressing activities on the seabed, in the water column and on the surface, allowing for some, and otherwise incompatible, activities to coexist.

Third, the temporal distribution of activities can allow incompatible activities such as fisheries and shipping to utilise the same space sequentially.

Fourth, physical and ecological conditions vary significantly in marine systems: the migratory patterns of fish stocks or birds vary from year to year, and weather conditions affect many activities. This requires flexibility in the use of space as well as robust structures that are able to withstand extreme weather events.

The special characteristics of the marine environment influence the way maritime planning can be meaningfully implemented. The principles of MSP include the following (EC, 2008b):

- using MSP according to area and type of activity;
- defining objectives to guide MSP;
- developing MSP in a transparent manner;
- stakeholder participation;
- improved coordination within countries — simplifying decision processes;
- ensuring the legal effect of national MSP;
- cross-border cooperation and consultation;

([14]) See http://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning/index_en.htm.

- incorporating monitoring and evaluation in the planning process;
- achieving coherence between terrestrial and MSP — relation with ICZM;
- a strong data and knowledge base.

The need for MSP is particularly evident in the case of managing emerging activities, such as marine renewable energy farms, which demand large areas and which interfere with many other uses of marine space. For example, the Scottish government has initiated planning of the sea areas around Scotland in order to reduce tensions between uses and to increase predictability in licensing (Marine Scotland, 2013).

Albeit intuitively appealing, MSP poses a number of challenges. MSP introduces new elements into the management of marine space. As with any change in governance, it faces resistance from those whose rights it appears to restrict. Others see MSP as a way to gain influence and power through the reservation of space and exclusion of certain activities, possibly demoting economically less gainful sea uses, such as marine protected areas. Finally, MSP may entail a shift in regulatory powers between different branches of the administration, something which also is likely to generate conflict.

The challenges of MSP can be met by sufficient political will and leadership capable of developing the legal basis and the practice. Experience to date has highlighted the importance of consulting all actors across governance levels, and of transparently and fairly handling concerns of different groups and interests, as underlined by the principles of MSP (see earlier in this section).

Technical tools, data and analyses of overlaps and interactions are necessary, but these cannot compensate for a poorly managed planning process. Experiences of how to carry out MSP processes in various contexts are accumulating at subnational, national and transboundary level. For example, the Plan Bothnia (Backer and Frias, 2012) illustrates bilateral MSP, and the project 'Transboundary planning in the European Atlantic' (TPEA) ([15]) has gathered further experience on how to overcome problems of shared areas under different jurisdictions.

**Photo 2.4:** Eider duck (*Somateria mollissima*) on Christiansø, Denmark

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([15]) See http://www.tpeamaritime.eu.

# 3 Ecosystem-based management and adaptation: priority for the coasts

## 3.1 Assessing the state of coastal ecosystems

Holistic assessments of the marine and coastal ecosystems show that many vital functions of marine ecosystems have been weakened, impairing overall ecosystem health (Swedish EPA, 2009; HELCOM, 2010c; OSPAR, 2010; UNEP, 2012). This is due to a combination of pressures, including agriculture, fishing, shipping, coastal infrastructure development, tourism and recreation, and inadequate wastewater treatment (Knights et al., 2011).

When taking the MSFD descriptors of 'good environmental status' (GES) as proxies for the state of marine ecosystems and their capacity for service provision, the ODEMM ([16]) project shows that several of the state descriptors across European seas are currently at high risk of failure to achieve GES by 2020 (Breen et al., 2012).

While the distribution, structure and functioning of habitats within coastal ecosystems have always been dynamic, the current rate of change is worrying. The loss of particular coastal habitats exceeds the global loss of rainforests by 4 to 10 times (Duarte, Nixon et al., 2009).

The EU Member States recently examined their coastal and transitional water bodies under the WFD (Table 3.1). The assessment of ecological status shows that many European coastal and transitional water bodies were not able to achieve high or good status (see Figure 3.1).

The worst ecological status in coastal waters is reported from the Baltic Sea, followed by the North Sea and the Black Sea. In coastal waters in the Mediterranean and the open Atlantic coast (Celtic Seas to the Iberian coast) a higher proportion of coastal water bodies hold high or good ecological status. The distribution of pressures and impacts mostly corresponds to reported ecological status; in general, coastal waters with a high proportion of water bodies in good status experience low pressures from human activities.

The assessment of how declining trends in biodiversity affects ecosystem services, and ultimately the economy and well-being of European coastal communities, remains a significant and complex task. There are, however, several European examples of declining coastal populations of species or degraded habitats (see Table 2.3), which can be linked to losses of ecosystem services.

In one of the few holistic assessments of anthropogenic stressors, Jackson et al. (2001) showed that the recent collapse of several, quite different coastal ecosystems could be linked to historical overfishing in combination with the synergistic effects of pollution, mechanical habitat destruction, invasive species and climate change (see Box 3.1).

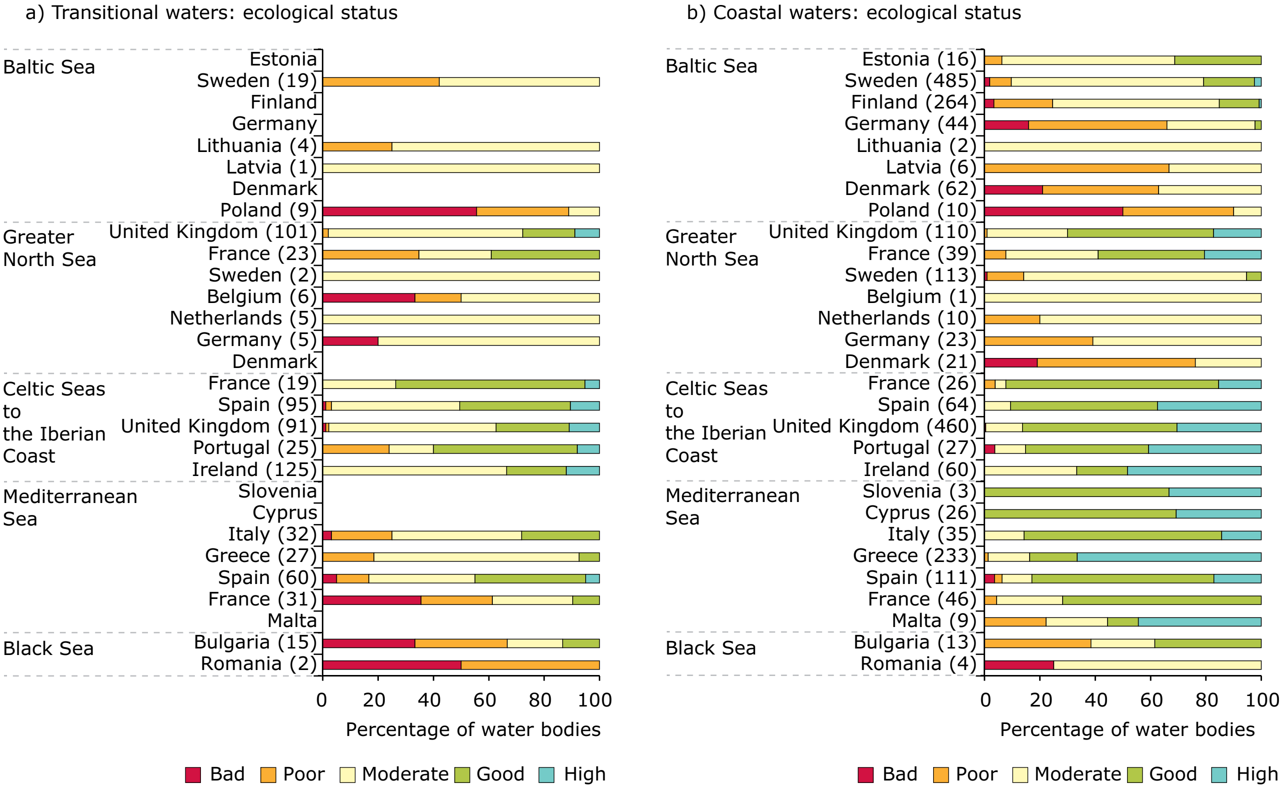
**Table 3.1 Transitional and coastal water bodies reported through the river basin management plans of the Water Framework Directive, 2012**

| Type of waters | Share of RBDs containing water bodies | Number of reporting water bodies | Average size ($km^2$) | Total area ($km^2$) |
|---|---|---|---|---|
| Transitional | Approximately 50 % | 1 000 | 18 | 17 300 |
| Coastal | Approximately 66 % | 2 800 | 97 | 267 000 |

**Source:** EEA, 2012a.

([16]) 'Options for delivering ecosystem-based marine management': see http://www.liv.ac.uk/odemm.

**Figure 3.1 Ecological status of a) transitional and b) coastal waters as reported by Member States under the Water Framework Directive**




**Note:** The number of water bodies is provided in parenthesis.

**Source:** EEA, 2012a.

**Box 3.1 Synergistic effects of anthropogenic stressors on coastal ecosystems**

A key finding of a study by Jackson et al. (2001) was that the ecological extinction of entire trophic levels through hunting and fishing reduces ecosystem resilience to other natural and anthropogenic disturbances. They also found that the effects of multiple stressors acted synergistically, rendering the response of the ecosystem much greater than the sum of individual stressors. Synergistic effects often become apparent through sudden changes in abundance of different kinds of organisms and communities — these changes demonstrate ecological threshold effects or tipping points. To add to the complexity and management challenges, there is rarely a linear relationship between reducing stressors and the return of the ecosystem's status, and related services, to a previous reference or desired state.

There have been efforts to improve conservation status of marine and coastal habitats and species. The Habitats Directive lists more than 40 different types of terrestrial coastal habitats and 8 aquatic coastal and marine habitats that it aims to maintain or restore to favourable conservation status — meaning no further loss of distribution range or extent, good condition of structure and functions, and good future prospects.

Despite progress in designating protected areas for vulnerable habitats, the current conservation status is generally poor, both at habitat and species level. From 2001 to 2006, only 7 % of coastal habitats were assessed to be in a favourable state; 73 % of the assessments concluded that the state was bad or inadequate (EEA, 2010b). For marine habitats, only 10 % of the assessments were favourable. All the favourable assessments were within the Macaronesian biogeographic region; the coasts of mainland Europe had no assessments of favourable states for marine habitats. Assessments of marine habitats suggested that conservation status was inadequate or bad for 50 % of these habitats.

Within European coastal regions, 98 coastal and 52 marine species have been deemed especially vulnerable ([17]). Despite being protected by the Habitats Directive, current conservation status is generally bad. In total, 13 % of the assessments of coastal species were favourable, with 60 % of the assessments being bad or inadequate. Marine species were performing worse, with only 3 % of the assessments being favourable with more than 70 % being categorised as unknown. All of the favourable assessments were within the marine Atlantic region; the coasts of semi-enclosed European seas had no favourable assessments for marine species. In these waters, marine species assessments concluded that 23 % were in an inadequate or bad status.

The conservation status reports have revealed a big gap in the knowledge of habitats: 20 % of the coastal habitat assessments and 40 % of the marine habitat assessments concluded that the status was 'unknown'. For coastal species and marine species, the corresponding figures are 27 % and 74 %, respectively.

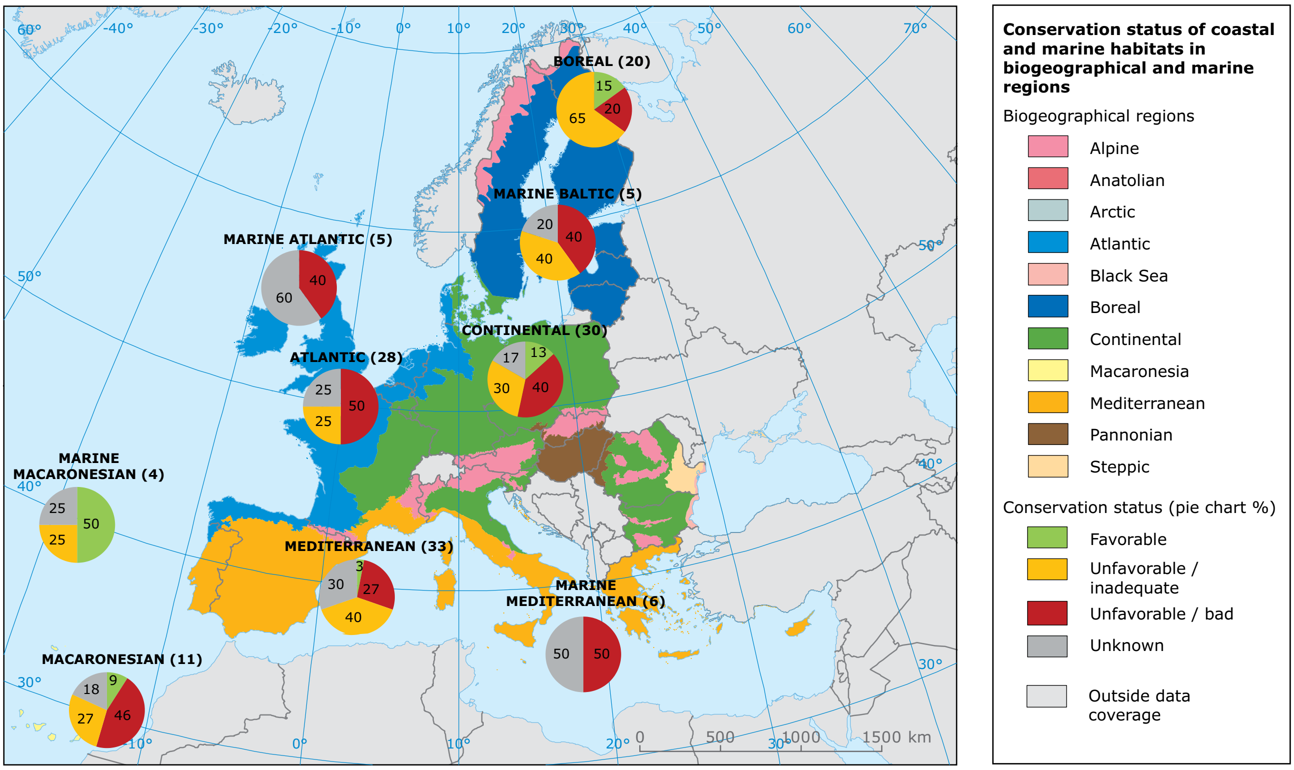
## 3.2 Working with nature — reducing the risks

Activities and settlements along the coast face risks related to sea-level rise and the effects of storms, flooding and erosion. Significant risks are also associated with human activities such as shipping, fishing and exploitation of oil and gas. The consequences of climate change, sea-level rise in particular, increase the vulnerability of many human systems and activities to hazards.

### *3.2.1 Sediment balance and coastal erosion*

The adverse impacts of coastal erosion most frequently encountered in Europe can be grouped in three categories: (i) coastal flooding as a result of complete dune erosion, (ii) undermining of coastal protection associated with foreshore erosion and loss of buffering coastal habitats, and (iii) retreating

**Map 3.1 Conservation status of coastal and marine habitats in biogeographical and marine regions**




**Note:** The word 'marine' preceding the biogeographical region means the assessments of marine habitats. The most recent reporting period was from 2001 to 2006, acting as a baseline for future assessments (the next assessment is in 2013/2014).

**Source:** EEA, 2010a.

([17]) In the EEA 2010 Biodiversity Baseline, the coastal strip is defined as lying 10 km inland and 10 km out to sea.

cliffs, beaches and dunes causing loss of lands of economic and ecological values (Conscience, 2010).

According to latest available Europe-wide assessment (EUROSION, 2004a), one-fifth of the European coastline is under threat of coastal erosion. In the extreme cases, this extends to up to 2 m a year (see Box 3.2), and can be even worse in isolated episodes of storm impact (see Box 3.3). Along the European coastline, the Mediterranean Sea and the North Sea present the highest length of erosion, and the Baltic Sea is the only European sea where the proportion of accumulative coasts is larger than that of eroding coasts (DEDUCE consortium, 2007).

When examining coastal protection as an ecosystem service (Liquete et al., 2013) the combination of the natural potential to withstand erosion (e.g. geomorphology or slope) and the exposure to climatic and oceanographic conditions (e.g. wave action or storm surges) can be mapped as a service flow against demand for such service (e.g. concentration of coastal assets and population).

Human influence, particularly urbanisation and economic activities, has aggravated coastal erosion; on average, the problems along Europe's coastline are growing. One key contributing factor is the persistent sediment deficit (negative sediment balance): this is attributable to the fact that many naturally eroding coastline sections have been sealed and most European rivers bring much less sediment to the coast than they used to. Over the last few hundred years, the major rivers in Europe and the sediment-producing hinterland have been harnessed, regulated and cultivated. As a result, rivers deliver less sediment. For some southern European rivers (e.g. the Ebro, Douro, Urumea and Rhone), the annual volume of sediment discharge represents less than 10 % of their level in 1950 (less than 5 % for the Ebro), consequently causing a considerable sediment shortage at the river mouth, and subsequent erosion (EUROSION, 2004a), see also Box 3.4.

Climate change is likely to increase coastal erosion. Sea levels across Europe are rising in general,

**Box 3.2 Examples of rapid coastal erosion**

The Holderness Coast in north-east England is one of Europe's fastest eroding coastlines. The average annual rate of erosion is around 2 metres per year. This means around 2 million tonnes of material every year (EUROSION, 2004b).

About a quarter of the Portuguese coast shows symptoms of instability due to erosion of cliffs or low-lying sections, particularly in Algarve (Andrade et al., 2002). In central Algarve, retreat rates of 2.27 m/year have been observed (Proença et al., 2011).

**Box 3.3 Storms as important drivers of coastal erosion**

The EU has funded a number of projects focusing on coastal vulnerability (Response, Micore, Conscience, Theseus and Coastance ([18])), with 31 case studies in total on problems related to coastal erosion along European coasts.

The cases have demonstrated that severe and extreme storms are among the main drivers of coastal erosion: about 70 % of the analysed case studies identified storms as the most relevant factor governing the observed erosive processes. Storminess drivers are particularly relevant along the coast of the Atlantic Ocean. Besides coastal erosion, storm waves and storm surges may also induce other effects: dune erosion, flooding, overwash, and in general, alteration or loss of littoral habitats.

**Source:** ETC/CCA contribution, 2012.

([18]) 'Responding to the risk from climate change on the coast' (Response) see http://www.coastalwight.gov.uk/response/index.htm; 'Morphological impacts and coastal risks induced by extreme storm events' (Micore) see https://www.micore.eu; 'Concept and science for coastal erosion management' (Conscience) see http://www.conscience-eu.net/index.htm; 'Innovative coastal technologies for safer European coasts in a changing climate' (Theseus) see http://www.theseusproject.eu; 'Regional action strategies for coastal zone adaptation to climate change' (Coastance) see http://www.coastance.eu.

although regional variations exist (EEA, 2012b). Rising sea levels increase sediment demand, as retreating coastline and higher sea levels will raise extreme water levels, allow waves to break nearer to the coast, and transmit more wave energy to the shoreline. Other climate change drivers that may exacerbate erosion rates are increased storminess, higher waves and changes in prevalent wind and wave directions (Marchand, 2010). The combined effect of sea-level rise and other changes in shallow areas such as coastal wetlands and coastal lagoons may cause them to 'drown' (merge into the sea). In coastal areas with barrier islands in front of the coast, such barriers are likely to erode.

In the view of rising sea levels and increasing coastal erosion, the subsidence of coastal land threatens the landward side of the coast. The combined effect of sea-level rise and subsidence is posing a threat to many coastal settlements located in river deltas where the natural process of sediment compaction occurs (Box 3.5). A heavy aquifer drawdown may also be the cause of ground subsidence. In some cases, subsidence is compensated — or even overturned — by tectonic movements or post-glacial rebound in northern Europe.

In many coastal areas, erosion problems are exacerbated by human activities, and artificially stabilised seafronts are progressively encroaching on sedimentary coastlines and cliffs. Dynamic ecosystems and undeveloped coastal landscapes are gradually disappearing, and lack of sediment is often a major contributing factor. Many places suffer from 'coastal squeeze' — human occupation encroachment at the coastal margin that eliminates the possibility for natural systems to retreat inland, which results in their decline (EEA, 2006b).

Coastal erosion in Europe is responsible for significant economic loss, ecological damage and societal problems. Loss of property, infrastructure and beach width annually cause millions of euros worth of economic damage and loss of valuable coastal habitats, and present significant management issues. At the same time, protection is expensive. For example, in France, some EUR 20 million is spent each year on mitigation measures; in the Netherlands, the annual budget for sand nourishment amounts to some EUR 41 million (Marchand, 2010).

### 3.2.2 *Preparing for coastal hazards and disasters*

The number and impacts of natural and technological disasters have increased in Europe (EEA, 2010c). The potential for a hazard to cause a disaster depends mainly on how sensitive the exposed community is to such hazards, and which coastal protection measures are in place. In Europe, floods and storms are the most frequently registered hazards, while events carrying the largest economic losses are related to floods, earthquakes and storm damages (EEA, 2010c). For coastal areas, the greatest adverse consequences are related to coastal floods, in particular those caused by winter storms, and tsunamis. The most severe impacts of technological accidents are related to oil spills from operations or ship accidents.

***Winter storms***

Winter storms have always been a severe hazard in Europe. In north-western Europe in particular, cyclonic winter storms are common: they are associated with areas of low atmospheric pressure in the North Atlantic (Hanley and Caballero, 2012). These storms emerge annually, and according to

**Box 3.4 The sediment balance of Venice Lagoon**

Venice Lagoon provides an example of the importance of sediment balance. The lagoon is suffering a sediment deficit owing to lack of sediment supply from the rivers. The rivers originally debouching into the lagoon were diverted more than a century ago. Moreover, the sea level is rising, and shipping channels enable relatively large waves to stir up the sediment, which in turn is carried seaward by the tidal currents. The overall result is a net loss of sediment. As a consequence, tidal flats and salt marshes are being eroded. Over the last 70 years, the area of salt marshes and tidal flats in the lagoon has decreased from 25 % to 8 % of the lagoon area.

The yearly loss of sediment can be 'translated' into a yearly deepening of the lagoon. The total lagoon area is in the order of 500 km$^2$. Thus, the yearly loss of sediment (500 000 m$^3$ to 1 million m$^3$) is equivalent to a yearly average of deepening of the lagoon of between 1 mm and 2 mm. Sea-level rise adds another 2 mm per year of deepening of the lagoon. If the deepening of the lagoon were to be compensated by adding sediment from the outside, one would have to nourish a quantity in the order of 2 million m$^3$ of sediment per year. Whether this is feasible depends on the availability of the desired quality of sediment, the cost of the operation, and the ecological consequences of an artificial sediment nourishment of the lagoon.

**Source:** ETC/CCA contribution, 2012.

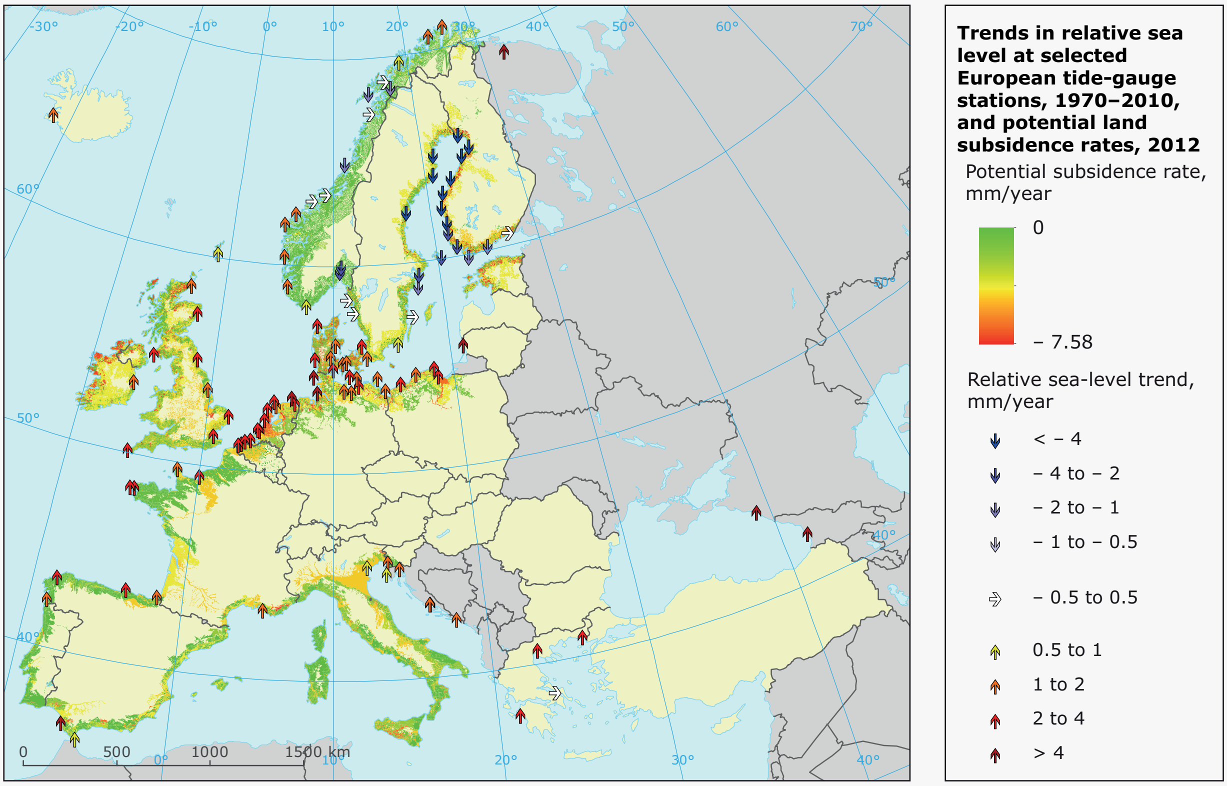
**Box 3.5 Subsidence at coastal areas**

SubCoast is a collaborative project involving 12 partners from seven European countries who aim to develop a pan-European service for assessing subsidence hazards in coastal lowlands, based on satellite and in situ measurements and numerical models ([19]). The core SubCoast product observes terrain height as a function of time, which can be coupled with additional data (such as variations in sea level) in order to improve our understanding of these coupled coastal dynamics. A systematic examination of geo-hazards has been initiated in the Seventh Framework Programme (FP7) PanGeo project ([20]) — a Collaborative Project of the European Commission, which initially will provide hazard information for 52 of the largest towns in Europe.

The SubCoast Potential Subsidence product shows the potential for European coastal zone areas to undergo subsidence due to the natural processes of compaction, dissolution and shrinkage of geological units. The use of One Geology Europe data has enabled the team to predict which geological deposits might undergo such processes, and to map these out across the European coastline.

Measurements of ground motion from satellite radar data were used to calibrate the geological data, thereby enabling potential rates of motion, in millimetres per year, to be assigned to the European coastline. Calibration inputs from the PanGeo project were used: they consisted of interpreted polygons of observed motions and associated Persistent Scatterer Interferometry data. Motion rates were then extrapolated to other One Geology polygons of the same deposit type.

**Map 3.2 Potential subsidence of coastal lowlands and relative sea-level trends in Europe**




**Note:** The presented potential subsidence rates are produced with consideration to surface geological deposits and processes acting upon them. They do not consider deeper-seated tectonic motions. In stable areas, such as the northern Spanish coastline, high rates of sea level rise are mostly due to increases in sea height. On the Finnish coastline, sea levels are shown to be falling, but the potential subsidence indicates relatively high rates of subsidence. This apparent mismatch is explained by the on-going glacio-isostatic uplift found in this region.

**Source:** SubCoast FP7 project, 2013; EEA, 2012b.

([19]) 'Assessing and monitoring subsidence hazards in coastal lowland around Europe', see http://www.subcoast.eu.
([20]) See http://www.pangeoproject.eu/eng/pangeo_explained_overview.

information available to date, no direct relationship between climate change and storm occurrence in Europe has been documented, despite some obvious regional trends (Kont et al., 2011) (see Box 3.6).

The direct consequence of a severe storm at the coast is a storm surge that leads to coastal flooding. In the European Atlantic region, concern is predominantly centred on positive surge events where the surge adds to the tidal level and increases the coastal flooding risk by extreme water levels (see Box 3.7). During recent decades, winter storms have caused economic damages of around EUR 1.9 billion per year and insurance losses of around EUR 1.4 billion per year. This type of insurance loss ranks among the world's highest for natural catastrophes (Mills, 2005), and the trend is increasing.

Climate change can indirectly affect wind-related hazards. In sea areas with regular winter ice cover, a shortening of the ice season can affect storm damages by leaving the coast exposed to wave action and storm surges (BACC Author Team, 2008) (see Box 3.6).

***Tsunami threat***

Historically, gigantic flood waves or tsunamis have been recorded along European coasts (ESPON, 2006). The Mediterranean is the area most susceptible to tsunamis: strong earthquakes caused by offshore faults in the Mediterranean Sea may trigger tsunamis along the coasts of southern Europe, which in turn may cause casualties and damage to buildings, and impact ecosystems. Atlantic coasts may also be affected, as proven by historical records.

Predicting tsunamis with any level of confidence is impossible, but reducing vulnerability to tsunamis is realistic. Following the Councils' Action Plan for Tsunamis (5788/05) and the follow-up Council conclusions (15479/07), EU Member States are cooperating to implement a regional

**Box 3.6 Climate change and winter storms in Estonia**

Extraordinary climatic conditions have been witnessed during the last three decades in Estonia and across the entire Baltic Sea region. The driving force appears to be a change in atmospheric circulation. The intensity of zonal circulation has significantly increased, and the number of cyclones crossing the Baltic Sea in winter has also increased. This has induced warmer winters and springs. The annual mean air temperature has increased by up to 2 degrees. As a consequence, the snow cover duration and the extent of sea ice have significantly decreased. Ice cover duration in the coastal sea of Estonia has decreased by 1 to 2 months over the last 60 years. Storminess in winter has increased over the last decades. For the time period from 1950 to 1969, the mean number of storm days per winter amounted to 6.4. For the time period from 1990 to 2009, this figure has increased to 11.3.

**Source:** Tõnisson et al., 2011.

**Box 3.7 The winter storm Xynthia**

Xynthia, the powerful Atlantic storm that battered western Europe with hurricane force at the end of February 2010, caused high waves and exceptional tide levels. In France, it was described by the civil defence as the most violent since the Lothar and Martin cyclones in December 1999. At least 51 people were killed, with 12 more said to be missing. A further 12 people lost their lives in neighbouring European countries.

Most of the deaths in France occurred when a powerful storm surge topped by battering waves up to 7.5 m high, hitting at high tide, smashed through the sea wall off the coastal town of L'Aiguillon sur Mer. In France, a total of 500 000 persons suffered material damages due to the storm. In the Vendée, 11 000 hectares of agricultural lands were affected by the salt seawater. In Charente-Maritime, 45 000 hectares of agricultural land were flooded by seawater corresponding to 10 % of the total agricultural lands in this department. Damages to dikes, harbours, boats, pontoons and landings were also reported. Overall, it is estimated that the insured damages reached the EUR 2.5 billion mark.

This event demonstrated the need for an appropriate flood-warning system. Lessons learned from the storm showed that full implementation of such a flood warning system is only possible if the following conditions are fulfilled: first, the warning system must take into account how local communities actually perceive the risk of storm, erosion and submersion; and second, the warning system must take into account public awareness of how to react before the intervention of any emergency service.

**Source:** ETC/ICM, 2011.

early warning system, established in 2005 by the Intergovernmental Oceanographic Commission of UNESCO ([21]).

According to some scenarios, rapid alterations in the earth's crust, such as ice-sheet instability, have potential to trigger earthquakes, volcanic eruptions and large-scale sea-floor landslides. Increased tectonic activity beneath rapidly melting glaciers has been recorded (Ekström et al., 2006). It has been suggested that a combination of earthquakes and accelerated movement of glaciers can lead to rapid geophysical disturbances such as tsunamis and even increase volcanic activity (Blanchon et al., 2009). On the Shetland Islands, a tsunami reached onshore heights at least 20 m above the sea level around 8 000 years ago. This was during a period of rapid climatic change in north-western Europe (Bondevik and Mangerud, 2003). Unsustainable practices on the coast, such as the destruction of sheltering habitats, excessive sand mining on the coastal sea bottom or massive residential build-up of the waterfronts, increases the vulnerability of the coast to the impact of tsunamis (EEA, 2010c). Therefore, sustainable coastal management measures, such as building codes, land use planning and protective infrastructures, are important measures for reducing the threat (Council, 15479/07).

***Technological hazards and accidents***

Oil operations and transport, energy and chemical industries, as well as water pumping and treatment can significantly affect coastal populations and ecosystems.

From 1998 to 2009, nine major oil spills (more than 700 tonnes) originating from ships in European coastal areas and one major oil spill caused by an oil pipeline were recorded. Between 2003 and 2009, there were also smaller spills along most parts of the European coastline, with the majority occurring either near major ports (such as Algeciras and Rotterdam) or in areas of dense traffic, such as the English Channel (EEA, 2010c).

According to statistics, 644 vessels were involved in 559 accidents (sinkings, collisions, groundings, fires/explosions and other significant accidents) in and around EU waters in 2010 (EMSA, 2010). The number of oil spills from vessel accidents, as well as their impacts, has declined since the peak years of 2007/2008, and is expected to decrease even further. A similar declining trend in the number of acute crude oil spills at sea is reported for the Norwegian shelf during the period from 2001 to 2011 (Petroleumtilsynet, 2012). Nevertheless, transportation of crude oil or oil products by ship still poses a significant hazard.

Favourable trade and logistics conditions at marine port areas have led to the growth of the chemical industry, and an accompanying risk of chemical accidents. Potential threats may also arise from oil and gas platforms and pipelines for transporting chemicals and oil. Natural gas is increasingly transported offshore: an example is Nord Stream in the Baltic Sea, which is the longest subsea pipeline in the world.

Europe has a high concentration of nuclear power plants. They are mostly located either along rivers or the coast, as large quantities of water are required for the cooling process. Discharges of warm cooling water can affect coastal ecosystems and could change the abundance of local fish stocks. The 2011 Fukushima disaster in Japan drew attention to the fact that events of very low probability (such as combination of earthquake and tsunami) can have serious consequences for complex technological systems. Nuclear plants can also be at risk from coastal erosion. In the United Kingdom, hard and soft sea defences, including new wetlands, have been constructed to protect nuclear installations from the sea.

The environmental impacts of Europe's growing desalination industry can be prevented by measures such as slow seawater intake, dispersion of brine outflow and cogeneration for energy efficiency.

## 3.3 Adapting to climate change

Climate change will likely affect the coastal environment in many aspects (CLAMER, 2011; Philippart et al., 2011; EEA, 2012b). It is possible to reduce vulnerability to hazards that are often associated with climate change, i.e. sea-level rise, increased coastal erosion, storm surges, and loss of specific habitats (Table 3.2). As most of the European littoral is intensely used and artificialised, working with nature to sustain coastal ecosystems and minimise response costs is challenging but can also be rewarding (Andrade et al., 2002). New policy approaches such as the EU Adaptation Strategy

([21]) The Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (ICG/NEAMTWS) (see http://neamtic.ioc-unesco.org/neamtws).

Package (22) and the Green Infrastructure Strategy (EC, 2013b) are seeking alternatives to traditional grey infrastructure solutions, and also apply to coastal areas by aiming for multifunctional coastal protection measures.

Coastal zones across Europe have different sensitivities to sea-level rise: the extensive, low-lying coastal zones of Belgium, the Netherlands, Germany, and Poland are highly sensitive, and in Belgium and the Netherlands particularly, the coast is also densely populated; other countries (e.g. France or Norway) have specific regions that are highly sensitive; in the Mediterranean, concern over sea-level rise is focused on its impacts on the highly valuable beaches and the low-lying deltas. In such places, coastal ecosystems that are already intensively exploited will likely come under additional pressure, given accelerated sea-level rise. As a response, an increasing number of countries have developed or are in the process of developing climate adaptation plans (23).

In the period from 1998 to 2015, the total planned investment in coastal protection and climate change adaptation to safeguard Europe's coastal zones from flooding and erosion amounts to EUR 15.8 billion (Policy Research Corporation and MRAG, 2009). Projections of impacts on coastal systems show potentially significant economic costs (without adaptation).

The project ClimateCost has suggested costs in the range of EUR 11 billion/year for the mid estimate of temperature–sea-level response by the 2050s (2040–2070) for mid-level emission scenarios (24). For comparison, the cost of adaptation was estimated at around EUR 1 billion to 1.5 billion per year for the 2050s (EU, 2005 prices, undiscounted), and reduced damage costs to low residual damages, with a benefit-to-cost ratio of 6:1 (Brown et al., 2011). The uncertainties in the cost estimates are, however, large. Estimates can differ by an order of magnitude or more (Hof, 2013).

Nicholls and Klein (2005) have identified five objectives of proactive adaptation for coastal zones: increasing robustness of infrastructural designs and long-term investments; increasing flexibility of vulnerable managed systems; enhancing adaptability of vulnerable natural systems; reversing

**Table 3.2 Main climate change hazards and vulnerabilities in different European marine regions and sub-regions**

| Main hazards and vulnerabilities | Affected European marine regions and sub-regions |
|---|---|
| Storms surges | Baltic Sea; Greater North Sea; Celtic Seas |
| River flooding | Baltic Sea; Greater North Sea |
| Coastal flooding | All sea regions, with varying intensity, depending on coastal morphology |
| Coastal erosion | Greater North Sea, Celtic Seas; Bay of Biscay and Iberian Coast; Macaronesian biogeographic region; Western Mediterranean Sea; Adriatic Sea, Ionian Sea and Central Mediterranean Sea; Aegean–Levantine Sea; Black Sea |
| Salt water intrusion | Baltic Sea; Greater North Sea; Western Mediterranean Sea; Adriatic Sea; Ionian Sea and Central Mediterranean Sea; Aegean–Levantine Sea |
| Altered salinity | Baltic Sea; Greater North Sea; Mediterranean Sea |
| Loss of marine habitats, ecosystems and biodiversity | All sea regions with varying vulnerabilities: for example, alien species are a particular concern in the Mediterranean |
| Socio-economic vulnerabilities | All sea regions, with varying vulnerabilities: for example, summer tourism is an issue in the Mediterranean, whereas loss of particular fisheries may be an issue in northern waters |
| Freshwater scarcity | Mediterranean Sea |

**Source:** Modified from ETC/CCA & ETC/ACC reports (Hodgson et al., 2010; Ramieri et al., 2011).

(22) In particular, accompanying document Climate change adaptation, coastal and marine issues, SWD(2013) 133 final (see http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_133_en.pdf).
(23) For up to date information see country pages in ClimateADAPT (see http://climate-adapt.eea.europa.eu).
(24) 'The Full Costs of Climate Change': see http://www.climatecost.cc/home.html.

maladaptive trends; and improving societal awareness and preparedness.

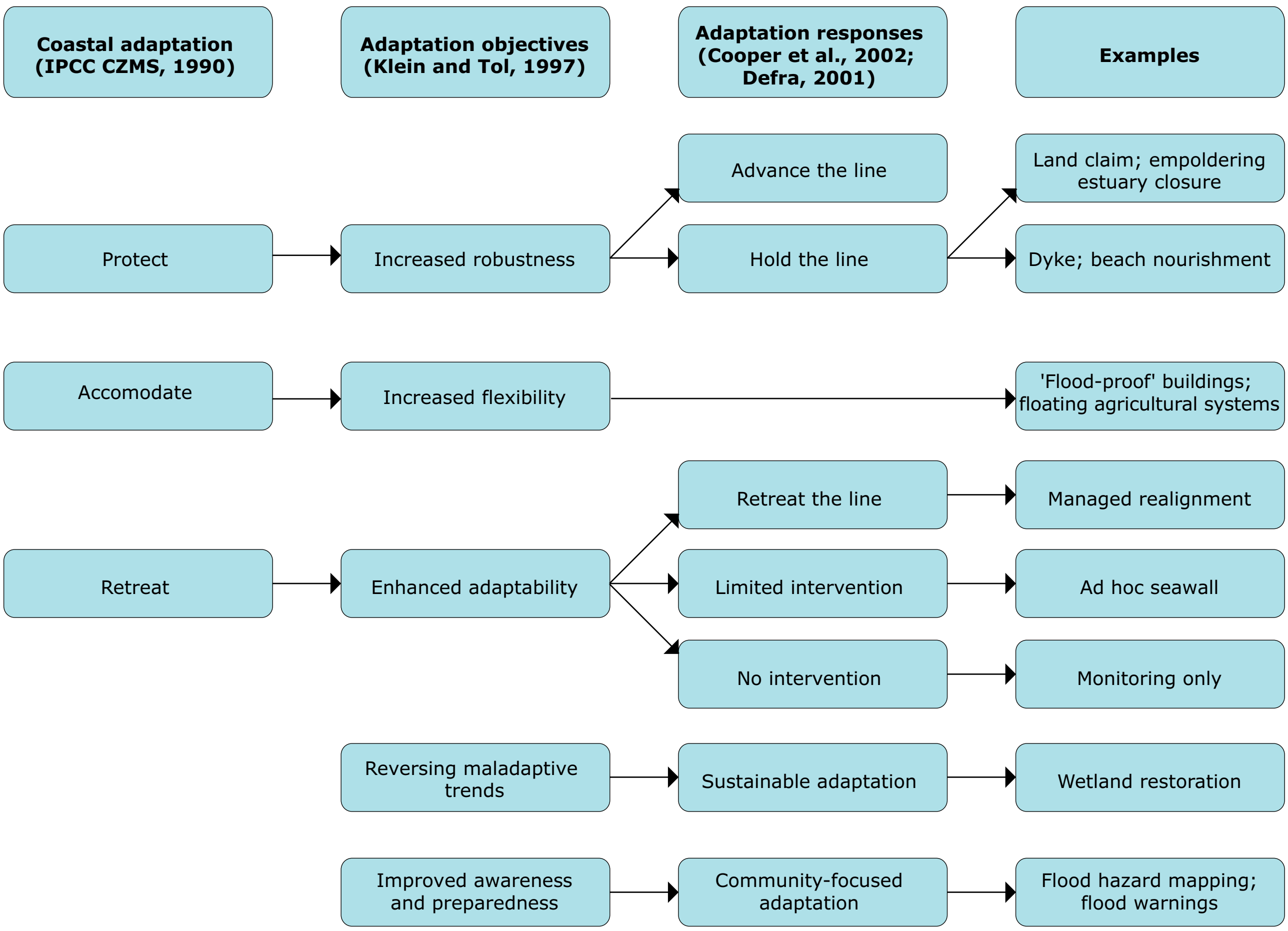
For coastal zones, three basic adaptation strategies are often used: protect in order to reduce the risk of the event by decreasing the probability of its occurrence; accommodate to increase society's ability to cope with the effects of the event; and retreat to reduce the risk of the event by limiting its potential effects (Smit et al., 2001; Nicholls and Klein, 2005). Nicholls et al. (2007) illustrated the linkages between these approaches and the evolution of thinking with respect to planned adaptation practices in the coastal zone, as shown in Figure 3.2.

Adaptation can greatly reduce the impact of sea-level rise and other coastal changes (Tol et al., 2008). The assessment of adaptation opportunities must take into account appropriate country-specific economic, institutional, legal and sociocultural contexts and should rely on adequate scientific knowledge of the dynamic behaviour of the coastal system (Andrade et al., 2002). Ultimately, the choice of adaptation options is both a technical and a socio-political exercise, based on considerations of which measures are desirable, affordable and sustainable in the long term (Nicholls and Cazenave, 2010).

## 3.4 Integrated coastal planning and management approach

Human activities have impacts on the coastal environment and coastal ecosystem services, but also depend on these services. This confirms the importance of ecological, social, economic and technological interactions that are particularly complex at coastal areas. For example, the concept of 'coastal squeeze' highlights the process in which buildings and other infrastructures spread and grow closer to the shoreline at the expense of natural

**Figure 3.2 Evolution of planned adaptation practices in coastal zones**




**Source:** Nicholls et al., 2007.

systems that normally act as buffers between the sea and the land (see Photo 3.1).

There is a need for integrated management strategies and planning practices that can deal with management of coastal resources for the benefit of all and that can also balance competing and potentially conflicting interests in a sustainable way.

The EU ICZM Recommendation (2002/413/EC) defined the principles of sustainable management and use of coastal zones (see Box 3.8). These include the need to base planning on sound and shared knowledge, to take a long-term and cross-sector (e.g. tourism, fisheries) perspective, to proactively involve stakeholders, and to take into account both the terrestrial and the marine components of the coastal zone. ICZM can help reducing the negative environmental impact of activities carried out in the coastal areas, including those activities that are sources of pollution.

There is no universal or rigorous definition for ICZM implementation, but many coastal countries have interpreted the ICZM principles in developing their national or local coastal management plans and indicator systems.

Since the ICZM recommendation, many activities have been initiated to test and develop the approach in different coastal areas (EC, 2007; Meiner, 2010). Collections of cases following the standard format have been gathered in the OURCOAST database ([25]), for example, and a number of projects designated as ICZM have been carried out along the European coastline in different regional seas. Tools that guide the practical use and interpretation of the principles have also been developed: the ICZM Assistant is an example of such a tool ([26]).

An important step for integrated coastal management was the adoption of the ICZM Protocol to the Barcelona Convention ([27]) in 2008, the first legally-binding international instrument specifically dedicated to ICZM ([28]).

It is fair to argue that the ICZM recommendation has contributed to the management of coastal activities in most EU coastal Member States, but in 2007, the Commission noted in its review that 'a mature and

**Box 3.8 Principles of Integrated Coastal Zone Management (2002/413/EC)**

- **A broad overall perspective** (thematic and geographic), which will take into account the interdependence and disparity of natural systems and human activities with an impact on coastal areas.
- **A long-term perspective, which will take into account the precautionary principle** and the needs of present and future generations.
- **Adaptive management** during a gradual process, which will facilitate adjustment as problems and knowledge develop. This implies the need for a sound scientific basis concerning the evolution of the coastal zone.
- **Local specificity and the great diversity of European coastal zones**, which will make it possible to respond to their practical needs with specific solutions and flexible measures.
- **Working with natural processes and respecting the carrying capacity of ecosystems**, which will make human activities more environmentally friendly, socially responsible, and economically sound in the long run.
- **Involving all the parties concerned** (economic and social partners, organisations representing coastal zone residents, non-governmental organisations and the business sector) in the management process, for example by means of agreements and based on shared responsibility.
- **Support and involvement of relevant administrative bodies** at national, regional and local level, between which appropriate links should be established or maintained with the aim of improved coordination of the various existing policies. Partnership with and between regional and local authorities should apply when appropriate.
- **Use of a combination of instruments** designed to facilitate coherence between sectoral policy objectives and coherence between planning and management.

([25]) See http://ec.europa.eu/ourcoast.
([26]) Developed by the Interreg IV B project 'Sustainable Coastal Development in Practise' (SUSCOD); see http://www.ICZMassistant.eu.
([27]) The Convention on the Protection of the Mediterranean Sea against Pollution.
([28]) See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:034:0019:0028:EN:PDF.

**Photo 3.1:** Buildings and other infrastructures close to the shoreline



well-functioning ICZM involving all relevant levels of governance is still rarely observed' (EC, 2007). In 2012, the implementation level was considered to be about 50 % (EC, 2013c). This suggests that there are significant practical obstacles to achieving an ideal ICZM. The EC impact assessment for the relevant legislative proposal has identified several shortcomings (EC, 2013c).

These shortcomings can be grouped into two main categories. The first is related to the lack of agency and clear administrative responsibility, which leads to lack of coordination and dedicated financing, ad hoc planning, unclear points of contact and poor consultation processes. The second category of shortcomings is cognitive and political: it results in inadequate analysis and common time-frames, and a lack of commonly agreed objectives.

These two categories of shortcomings interact and are likely to reinforce one another. The crucial question is to what extent they can be alleviated by introducing the mandatory elements foreseen by the proposal for a directive establishing a framework for maritime spatial planning and integrated coastal management (see Section 4.1). There is also an intense debate on the appropriate level of governance for mandatory requirements.

# 4 Formation of a new integrated policy framework

## 4.1 From conceptual framework to integrated plans and strategies

Despite early efforts to integrate the policy approach (EC, 2000), Europe's coastal zones have been regulated by much legislation that has remained fragmented, and allowed or even encouraged contradicting practices at sea or land. Building on the EU ICZM Recommendation (2002) and provisions of EU Integrated Maritime Policy (2007), the latest effort to develop a framework for integrated and coherent governance of coastal areas is the proposal for a directive establishing a framework for MSP and integrated coastal management (COM(2013) 133 final).

Most existing policies for nature, water and marine environment only address part of the diverse and complex character of coastal zones and related territorial issues. Yet there are numerous direct and indirect links between the different policies that affect the coastal and marine environments. The Commission has identified the key problems: competition for maritime and coastal space, and the inefficient use of resources (EC, 2013c) (see Box 4.1).

The overarching problem of competition for space and inefficient use of resources has been broken down into five more specific problems: 'conflicting claims on maritime and coastal space (problem 1), leading not only to inefficient and unbalanced use of maritime and coastal space (problems 2 and 3) and suboptimal exploitation of economic potentials (problem 4), but also to insufficient adaptation to climate risks and degradation of marine and coastal environment (problem 5)' (EC, 2013c).

Challenges inherent in overcoming the problems are twofold. First, sectoral and specialised policies and policy instruments (such as those promoting renewable energy, fishing or shipping) need to fully recognise the existence and impacts of other policies, including opportunities for positive synergies. Second, instruments that aim at ecosystem-based management approaches (e.g. those included in Framework Directives for Water and Marine Strategies, Floods Directive and EU Strategies for Biodiversity and Climate change adaptation), need to be developed and better implemented. Interactions between policies must be handled skilfully, but the land-sea interactions (Figure 4.1) must also be understood and handled. This is not easily done when there is a history of strong sector interests that have developed their own institutions, including a legal base, and practices.

The European Commission's communications on governance, knowledge base and MSP have strived to implement a systemic vision for the coastal and marine areas. The Integrated Maritime Policy (IMP) and the Blue Growth strategy ([29]) and related policy documents are expected to provide the overall frame for integrated management of the sea and coastal resources in the spirit of sustainable development (e.g. the MSFD being the environmental pillar of the IMP) and directly or indirectly link all other policy areas (the outer circle in Figure 4.1).

**Box 4.1 Reforming the EU common fisheries policy (CFP)**

The poor state of fisheries has been recognised by the European Commission in its proposals for reforming the CFP. In May 2013, an agreement was reached on four key issues: the maximum sustainable yield objective; the discard ban; regionalisation; and fleet capacity management (EC, 2013d). The overall aim of the reform is to bring fish stocks back to sustainable levels in order to provide EU citizens with a long-term stable and healthy food supply. At the same time, the objective is to provide and secure jobs and growth in coastal regions (EC, 2011).

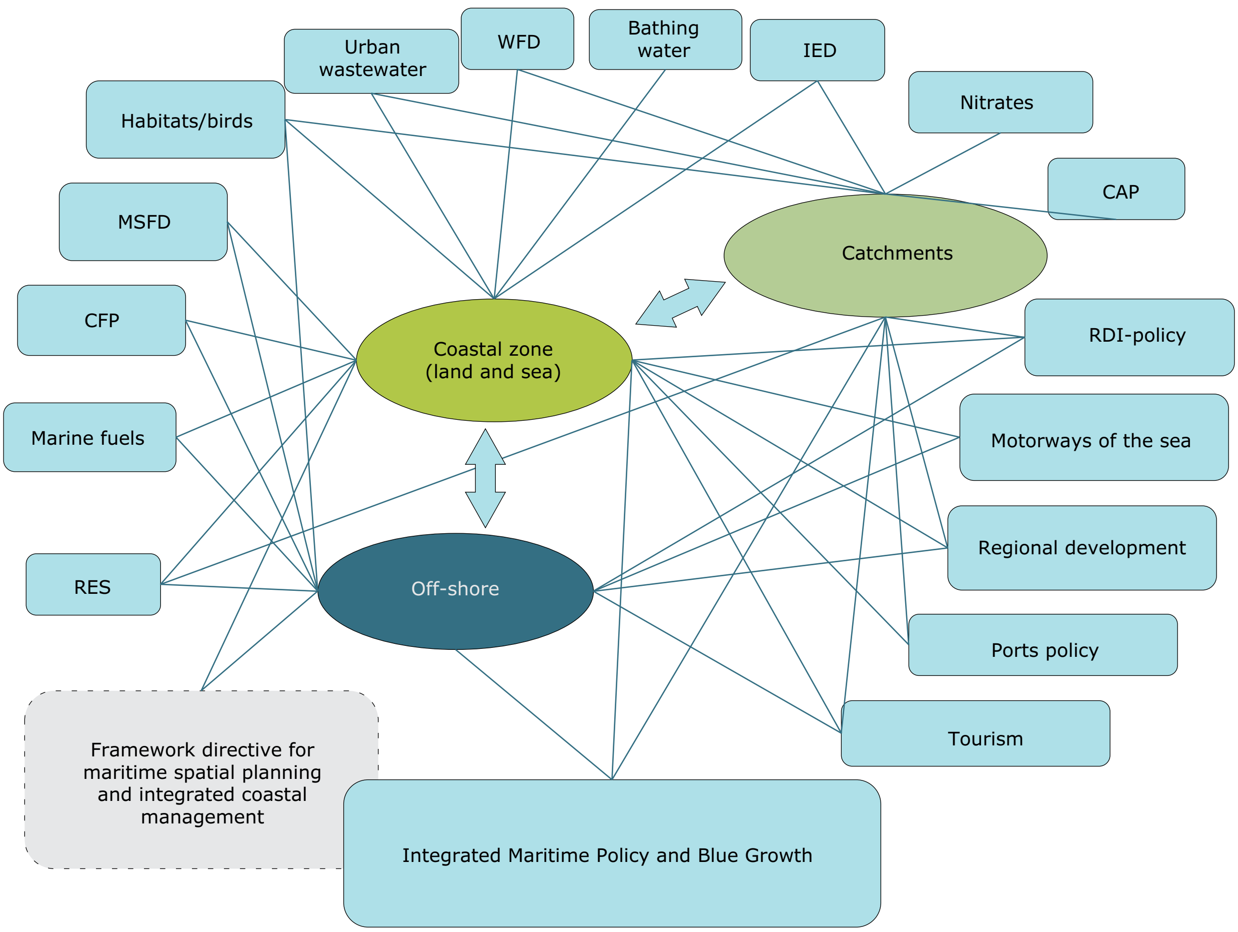
([29]) See http://ec.europa.eu/maritimeaffairs/policy/blue_growth/index_en.htm.

The framework directive for MSP and integrated coastal management is expected to strengthen the coherent implementation of the diverse set of policies by providing the necessary tools for dealing with different activities in an integrated way. The joining of maritime spatial planning and the ICZM concept is viewed as vital in meeting the challenges. This is supported by the need to deal with a large number of relevant policies and policy instruments and related stakeholder interests (see Figure 4.1 and Table 4.1)

The preparation of maritime spatial plans and integrated coastal management strategies is the central element of the proposed framework directive. These plans and strategies should be based on an ecosystem approach, and a governance system for their implementation should be set up. Potential conflicts are to be handled through public participation, cross-border cooperation and strategic environmental assessments (e.g. the Strategic Environmental Assessment (SEA) Directive (2001/42/EC)). The aim is to deliver plans dealing with at least the five main areas that have been identified in the proposal (Figure 4.2).

The legal status of the plans and strategies has not been specified in the proposed directive, allowing for variation between Member States, depending on the history and general legal regime for coastal and marine matters. Five years after the directive's adoption, a follow-up report will be compiled, based on Member States' progress reports. It will show to what extent the planning and management approach has been able to overcome current obstacles to the use and governance of the marine and coastal environment.

**Figure 4.1 Selected policies and policy instruments related to the land–coast–sea nexus, and their interactions**




**Note:** The boxes refer to EU-level policies and directives. Acronyms are expanded upon in the list of abbreviations, page 53. Climate change policies are not included.

**Source:** ETC/CCA.

**Table 4.1 Non-exhaustive list of EU policies and policy instruments affecting coastal areas**

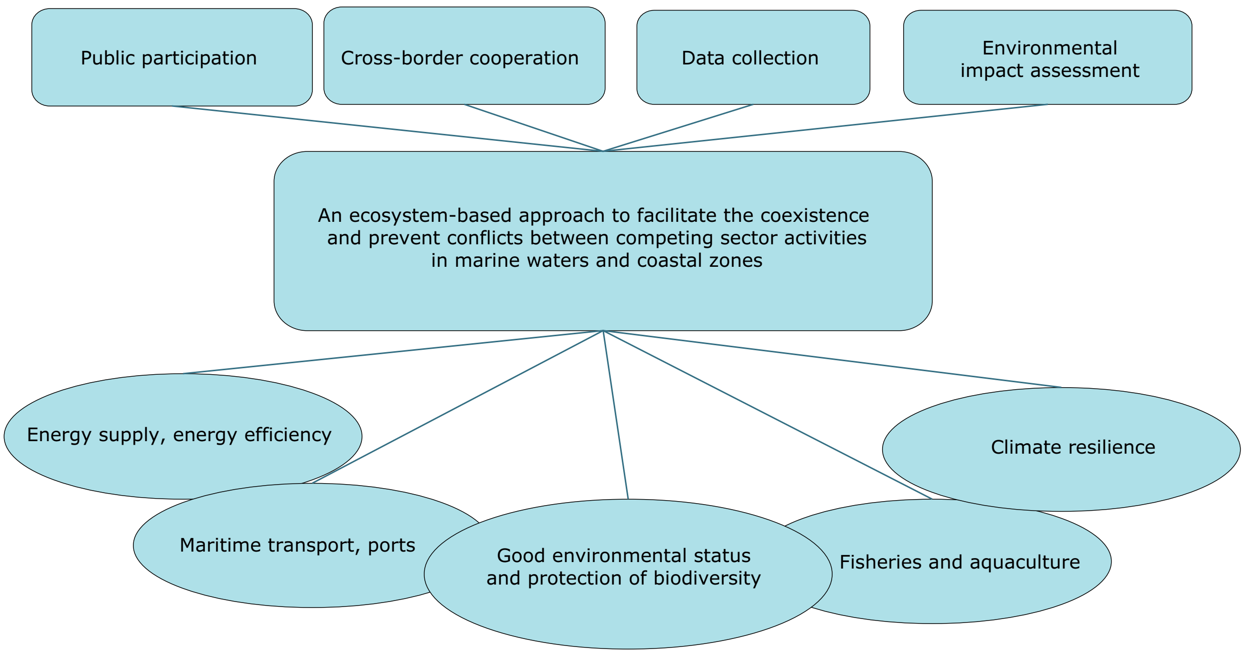
| Policy or policy instruments | Relevance to coastal areas |
|---|---|
| **General policies** | |
| Roadmap to resource efficient Europe (COM(2011) 571) | Cross-cutting aspects of sustainable growth |
| Programme to support the further development of an Integrated Maritime Policy (Regulation (EU) No 1255/2011); Integrated Maritime Policy work programme 2011–2012 (C(2012) 1447 final); Blue Growth (COM(2012) 494 final) | Coordinated and coherent decision-making for sustainable development, economic growth and social cohesion. Work programme for grants and procurement. Fostering all economic activities that depend on the sea |
| Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC) | Wind and wave energy, use of space on land or at sea, impacts on coastal habitats |
| Common Agricultural Policy (CAP) | Factors affecting diffuse loading, habitat protection |
| Common Fisheries Policy (CFP) and related legislation (Council Regulation 2371/2002, revision 865/2007; Shellfish Water Directive 2006/113/EC; European Eel Fishery Regulations 1100/2007; Aquaculture Animal Health Directive 2006/88/EC); European Fisheries Fund Axis 4 | Sustainable exploitation of coastal natural resources, impacts on habitats, protection of species and health of products.<br>Sustainability of coastal fishery communities |
| Regional Development and Cohesion Policy, Territorial Agenda 2020 | Development of coastal communities and their economy |
| EU Strategy on adaptation to climate change | Support for adaptation measures at all levels, from local to regional and national. Specific focus on transboundary coastal management, with emphasis on densely populated deltas and coastal cities |
| **Protection of biodiversity and ecosystems** | |
| Our life insurance, our natural capital: an EU biodiversity strategy to 2020 COM(2011) 244 final | General strategy for the conservation of biodiversity, biodiverstity, ecosystems restauration and sustainable fisheries |
| Habitats (79/409/EEC) and Birds (2009/147/EC) Directives | Designation of protected areas, conservation of coastal species and habitats, and their status assessments |
| **Protection and management of waters** | |
| Water Framework Directive (2000/60/EC; 2008/32/EC) | River basin management, aiming for good status of lakes, rivers and near shore waters |
| Urban Waste Water Directive (91/271/EEC; amendment 98/15/EEC) | Minimum requirements on urban waste water treatment and discharge |
| Nitrates Directive (91/676/EEC) | Reduction of nitrogen loading to coastal waters |
| Management of Bathing Water Quality (2006/7/EC) | Monitoring of public beaches |
| Marine Strategy Framework Directive (2008/56/EC) | Framework for protection of the seas |
| Flood Risk Directive (2007/60 EC) | Flood risk management (including at the coast) |
| **Prevention of pollution** | |
| Directive on industrial emissions 2010/75/EU (IED) | Regulation of emissions in coastal waters, replacement of the integrated pollution prevention and control (IPPC) Directive (2008/1/EC) |
| Regulation on European Pollutant Release and Transfer Register (E-PRTR) (*) | Public information on emissions of significant industrial installations |
| Directives on Chemical Accidents (Seveso I, II and III) — Prevention, Preparedness and Response | Risk assessments and management for potential risks of industrial installations |
| Priority Substances Directive (2008/105/EC) | Protection against pollution from specific hazardous substances |
| Dangerous Substances Directive (2006/11/EC) | Restriction on use and emissions of dangerous substances |
| Directive 2005/33/EC amending Directive 1999/32/EC as regards the sulphur content of marine fuels | Reduction of sulphur emissions from shipping |
| The Port Reception Facility Directive (2000/59/EC), new proposal expected in 2013 | Reduction of discharges of ship-generated waste and cargo residues into the sea by improving the availability and use of port reception facilities in all EU ports |

**Table 4.1 Non-exhaustive list of EU policies and policy instruments affecting coastal areas (cont.)**

| Policy or policy instruments | Relevance to coastal areas |
|---|---|
| **Transport policies** | |
| Framework for funding the 'motorways of the sea' (Article 12a of the TEN-T Guidelines of 29 April 2004 — Official Journal L 167 | Increase attractiveness of sea transport, corridors for 'floating infrastructures' in European seas |
| Communication and action plan for a European maritime transport space without barriers (COM(2009) 10) | Improved conditions for short sea shipping, contribution to increased popularity |
| Communication from the Commission on European Ports Policy (COM(2007) 616) | Development of port infrastructure and capacity |
| **Tourism** | |
| Communication from the Commission on Tourism (COM(2010) 352): Europe, the world's No 1 tourist destination — a new political framework for tourism in Europe | Expanding and sustainable tourism |
| **Procedures for environmental protection and planning** | |
| Environmental Impact Assessment (85/337 EC; amendments 97/11/EC; 2003/35/EC) | Scrutinising and minimising environmental impacts of significant projects |
| Strategic Environmental Assessment (2001/42/EC) | Scrutinising and minimising environmental impacts of significant plans and programmes, including those affecting land use |
| ICZM recommendation (2002/413/EC) | General approach for integrated management of coastal areas |
| ICZM protocol of Barcelona convention | Binding specific instrument for integrated coastal management in the Mediterranean, signed by the EU |
| Regional Seas Conventions (OSPAR, HELCOM, Barcelona Convention, Black Sea Convention) | Conventions for the protection and management of the regional seas with numerous specific measures, recommendations and regulatory elements |

**Note:** (*) see http://prtr.ec.europa.eu.

**Figure 4.2 The basic elements of the marine spatial plans and integrated coastal management strategies, according to the proposed framework directive**




**Source:** ETC/CCA.

An important objective of maritime spatial plans and integrated coastal management strategies will be to ensure climate resilient coastal and marine areas. In the 2009 White Paper 'Adapting to climate change: Towards a European framework for action' (COM(2009) 147 final), the Commission announced the development of guidelines on adaptation in coastal and marine areas to ensure a coordinated and integrated approach to adaptation in coastal and marine areas. The Commission is aiming to develop such guidelines in order to support Member States in the implementation of integrated coastal management strategies.

## 4.2 Outlook and uncertainties

The OECD *Environmental Outlook to 2050: The Consequences of Inaction* (OECD, 2012) presents projections of socio-economic trends over the next four decades, and their implications for four key areas of concern: climate change, biodiversity, water and the health impacts of environmental pollution. Despite the recent recession, the global economy is projected to nearly quadruple by 2050. Rising living standards will be accompanied by growing demands for energy, food and natural resources — and also by more pollution. World energy demand in 2050 will be 80 % higher: it could lead to a 50 % increase in greenhouse gas (GHG) emissions globally and could worsen air pollution. A significant part of these pressures will affect coastal regions and increase the urgency of policies that are able to foster sustainable solutions for Europe's coasts.

Coastal land-use planning and MSP at the level of regions and Member States will continue to play a crucial role, as European coasts are and will remain highly populated. The future of the coastal regions (on both sides of the shoreline) will be heavily affected by economic developments, but increasingly also by climate change, in particular due to vulnerability to sea-level rise and extreme weather events (EEA, 2013).

Both of these are characterised by significant uncertainties but also by interdependencies that may involve non-linear developments and abrupt changes (tipping points). An uncontrolled development of the coastal regions will increase environmental risks, including those attributable to climate change (see Box 4.2).

**Box 4.2 Impacts of policy alternatives on European coastal zones, 2000–2050**

The scenario-modelling results for two policy alternatives were analysed in order to understand possible future evolutions of European coastal zones, by means of the land use model EUClueScanner. The 'Uncontrolled' and the 'Sustainable' options have been compared against a third neutral development deduced from the SRES Scenario B1. The model has been run implementing the 1-kilometre spatial resolution, 10 land-use classes configuration, for the period from 2000 to 2050.

The land use changes, and in particular the growth of built-up areas, are taken as the main metric to evaluate the pressure on coastal zones. Indeed, the share of built-up areas in the costal zones is almost double that of the overall EU continental surface. This is confirmed in the results of the simulations.

The difference between the two policy alternatives can be observed both for all of Europe and for the coastal zones only, but in the latter case, the difference is more evident. For the overall EU-27 area, the increase in built-up areas for the Uncontrolled policy alternative between 2000 and 2050 is 7.49 percentage points higher than the same increase under the Sustainable policy alternative. Taking into account just the coastal zones — as defined in the context of this report — for the same period, the increase in built-up areas is 7.85 percentage points higher under the Uncontrolled than under the Sustainable policy alternative.

Coastal zones are thus more likely to suffer from environmental impacts brought about by the increasing shares of built-up land in Europe. This is even more relevant if we consider the intrinsic vulnerability of coastal zones.

The difference between the two policy alternatives entails contrasting environmental impacts. Therefore, under the Uncontrolled policy alternative, a higher proportion of built-up areas is exposed to coastal erosion and coastal flooding, leading to more potential assets at risk (i.e. social and economic losses).

**Source:** Lavalle et al., 2011.

# 5 Knowledge base for integrated management

An analytical framework for assessments of Europe's coastal areas should fulfil the following criteria:

- the results should be relevant for policies in the EU, directly or indirectly aiming at the sustainability of the coasts and supporting the principles of integrated coastal management;
- it should provide options for assessment of ecosystems and ecosystem-based management approaches;
- it should provide added value by integrating data sets and coastal indicators in a way that allows repeatable evaluations and trend analysis.

Marine (sub)regions established by the MSFD (Table 1.1) represent major marine and coastal ecosystems of Europe and create a basis for assessment and data collection, aiming at an ecosystem-based management approach. Such regional delineation also provides for trend analysis and results aggregation for coastal zone assessments.

## 5.1 Call for innovative assessment methods

Assessing the state of coastal areas across territorial, sectoral and adaptation domains is a demanding task. Linking environmental data with socio-economic variables (particularly across the sea-land interface in the context of spatial management and change monitoring) presents serious challenges to existing assessment frameworks, and requires innovative methods for data integration, assimilation and modelling. For analysis at the level of a marine region (e.g. the Baltic Sea region) or across all of Europe, the task becomes even more complex, since transboundary considerations must also be taken into account.

There is an increasing potential to employ emerging tools that use spatial integration and GIS analysis. The assessment of cumulative pressures and impacts, coastal ecosystem capital accounts and assessment of coastal climate vulnerability illustrate approaches that can be used at different spatial scales.

### *5.1.1 Spatial analyses of cumulative pressures and impacts*

Spatial data on human uses of the sea, the water quality, as well as the spatial distribution of species and ecosystems have become increasingly available throughout Europe. This makes it possible to produce maps showing where potentially damaging human activities, high levels of pollution and potentially sensitive ecosystems, populations of coastal and marine life, or biodiversity hotspots overlap (Coll et al., 2012). However, the sensitivity of coastal and marine ecosystems to some stressors, and especially to combinations of multiple stressors, is often unknown. Expert judgement can link the spatial distribution of human maritime activities and pollution with the spatial distribution of important ecosystems. Such analysis provides a global map of human impacts on marine ecosystems (Halpern et al., 2007, 2008 and 2012).

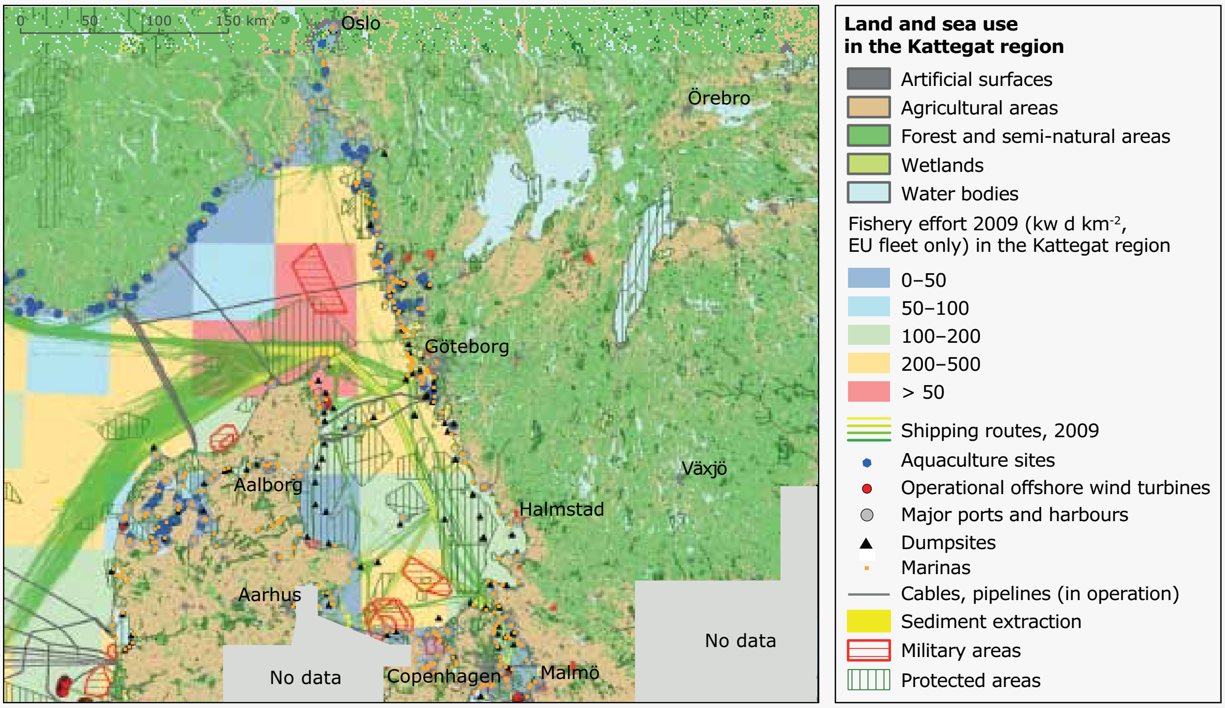
The spatial analysis approach has been applied and refined in studying regional human impacts on coastal and marine ecosystems in the Pacific (Halpern et al., 2009; Selkoe et al., 2009; Ban et al., 2010), the Baltic Sea (Korpinen et al., 2012) and the eastern North Sea (Andersen and Stock, 2013) (see Box 5.1 and Figure 5.2).

The basic approach involves three steps (Andersen and Stock, 2013). First, the most important anthropogenic stressors and biological features (which may be broad-scale ecosystems or species) of the study area are identified, and maps showing their spatial distribution are collected or created and normalised. Second, the sensitivity of the broad-scale ecosystems or key species to different human stressors is estimated using an expert survey. The sensitivity of each ecosystem or species to each stressor is represented by a number derived from the experts' qualitative responses. Third, for each location

**Box 5.1 Mapping of activities and their demands in the Kattegat**

The Kattegat is a mostly shallow coastal sea in southern Scandinavia. Water depths greater than 50 m occur only in the northern part. The Kattegat is a transition area, connecting the brackish Baltic Sea (via the Øresund and the Belt Sea) with the saline North Sea. Much of the Kattegat coast is generally used for recreation (e.g. sailing) by locals and tourists alike. In addition to local discharges of nutrients and pollutants, the Kattegat is strongly affected by outflow from the Baltic Sea.

**Figure 5.1 Some human uses of coastal and marine waters in the Kattegat region**




**Note:** Norwegian military areas and fishing by the Norwegian fleet are not shown in this map. For data sources, see Andersen and Stock (2013) annexes.

The Kattegat is the major entry point for ships into the Baltic, with many thousands of ships passing through each year. Many commercial ports are scattered throughout the region. Shipping lanes are dredged in some shallower areas. In Denmark, dredging is also practiced for sediment extraction.

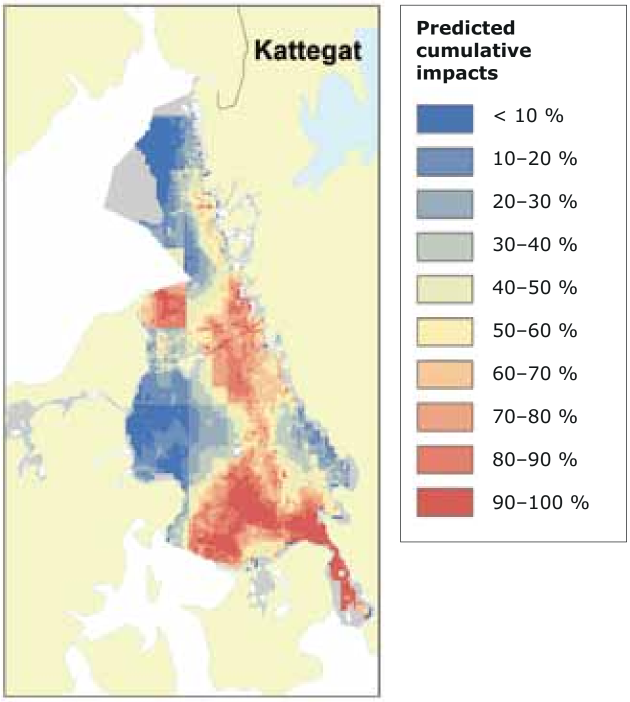
Commercial fishing in the Kattegat has a long history, and is still of economic importance. Shellfish farms are found in the Danish Limfjord and along the northern part of the Swedish west coast.

Nearly one quarter of its sea area and more than half of the Kattegat's total length of coastline is protected (although often only the geolittoral or the hydrolittoral parts). In addition, there are two large cod closure areas.

in the study area, the impact of each stressor on each ecosystem component is assessed, by combining the sensitivity scores and the spatial distribution maps for the ecosystems or species. For example, benthic ecosystems, which are sensitive to bottom trawling, will have a high sensitivity score for this stressor. However, an impact is only estimated to occur where the respective ecosystems and stressors are present according to the distribution maps. Furthermore, the magnitude of the impact depends on the intensity of the stressor at the location in question (for example, frequency of bottom trawling).

In order to estimate cumulative impacts, the impacts predicted for all combinations of stressors and ecosystems or species are summed. Thus, the predicted impacts are additive rather than multiplicative, as detailed knowledge of multiplicative effects is lacking. The additive model is considered reasonable because the more individual stressors that affect an ecosystem,

**Figure 5.2 Predicted cumulative human impacts in the Kattegat (no absolute statement made about the magnitude of impacts)**




**Note:** The map is coloured according to deciles of the predicted impacts: for example, the '< 10 %' class contains the 10 % of each study area for which the lowest cumulative impacts were predicted, but that does not mean that only minor or no impacts would occur in these areas. Instead, the map should be read to indicate that in these areas, either fewer or less-intensive anthropogenic pressures occur, or that the broad-scale ecosystems and species found there are not sensitive to those pressures which occur.

**Source:** ETC-ICM, based on the HARMONY Project.

the greater the effects. This results in maps showing deciles of predicted cumulative impacts (see Figure 5.2).

The analysis of cumulative human impacts on the coastal and marine environment is a new and developing field (Ban et al., 2010). Better data, for example detailed maps of fishing efforts based on Vessel Monitoring System (VMS) and logbook data, can reduce some of the uncertainties currently resulting from lack of data.

Considering their power to integrate information that has traditionally been studied separately, cumulative impact maps can be a valuable decision-support tool. They can show the concentration of human activities, pollution, and their potential impact on ecosystems in a way that individual sector-by-sector or species-by-species assessments cannot. In combination with more specific and detailed assessments, cumulative impact maps have much potential to contribute to the 'bigger picture' of human impacts required for ecosystem-based marine spatial planning.

### 5.1.2 *Coastal ecosystem capital accounts*

International work on ecosystem capital accounting began as a result of the 1992 Rio Conference on Sustainable Development, when the United Nations and the World Bank launched the first System of Integrated Economic and Environmental Accounting (SEEA). The work is organised through the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA), which steers current and ongoing development in this area of research.

In 2009, the EEA began an experimental project on 'fast-track implementation of simplified ecosystem capital accounts' for Europe (EEA, 2011), which was based on the Land and Ecosystem Accounting (LEAC) methodology developed in previous years. Through ecosystem capital accounting, the EEA aims to support the global policy process (i.e. SEEA volume II (experimental accounts)) and the European policy process (e.g. Target 2/Action 5 of the EU 2020 Biodiversity Strategy ([30])) by providing a method to measure and map the productivity and health of ecosystems.

The full extent of the Simplified Ecosystem Capital Accounts (SECA) approach accounts for ecosystem capital depreciation as a result of the net loss in physical stocks, and resulting ecosystem degradation. Capital depreciation can then be measured as the costs associated with undertaking remediation. Ecosystem capital can also increase in the event of increases in physical stocks, which results in an improvement in ecosystems.

When ecosystem capital is measured in physical units, one can calculate a composite index of ecosystem capability, which characterises the status of ecosystem capital in a specific area. When ecosystem capability is compared over time, changes in ecosystem flows provide information on the

([30]) With regards the requirement to assess the economic value of ecosystem services, and promoting the integration of these values into accounting and reporting systems at EU and national level by 2020.

physical 'account balance' of ecosystem capital. In the next step, the benefits and costs resulting from the interaction of economic and ecosystem capitals are valued and expressed in monetary units, for example, as the costs of ecosystem restoration in order to ensure provision of the desired services.

The EEA is currently implementing the SECA approach with the aim of delivering a first set of land-based European experimental accounts. The EEA is also implementing a coastal component that focuses on terrestrial ecosystems at the coastal zone. For marine ecosystems the agency has started by trying to account for marine fish populations. The coastal ecosystem capital accounting approach is generally set up in three phases and in several steps: preparatory steps (e.g. establishing the relation between selected ecosystems and their services; selection of indicators or proxies for each account); operational steps (calculation of net accessible physical stocks of ecosystem capital and their flows); and interpretation of physical accounting results (e.g. determining the ecosystem capability and final expression of change in ecosystem capital).

The EEA is exploring ways to test the method outlined above for the coastal zone. In so doing, the agency is also trying to determine how capital accounting could contribute to the holistic management of coastal resources and ecosystem services in accordance with the principles of ICZM.

The first test calculation of coastal physical ecosystem capital has been carried out for the Spanish coastal area by the Strait of Gibraltar. Preliminary outcomes have revealed significant implementation gaps and offer important guidance for further improvements of methodology and data requirements.

### *5.1.3 Coastal vulnerability assessments*

The IPCC has defined vulnerability as the 'degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. It is measured as a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity' (IPCC, 2007). In addition to climate change, other factors also determine coastal vulnerability. Management of the coastal zone can affect coastal processes such as the sedimentation of deltas, and therefore the local patterns of terrestrial inundation (Vandenbruwaene et al., 2011).

The starting point for an assessment of European coastal vulnerability is to identify which aspects of coastal systems should be prioritised for policy decisions on climate change and risk management. Vulnerability depends on perspective — it can refer to human systems, such as housing, business premises, agricultural land, industry, and ports.

Equally, the term vulnerability can refer to natural ecosystems and the services that they provide. For example, coastal freshwater ecosystems may be vulnerable to saltwater intrusion, or salt marshes may experience increased vulnerability to coastal erosion. In the case of coastal ecosystems, the loss of habitat may result in a less suitable habitat available for bird species, or the increased risk of extinction of locally endemic species. In the case of saltwater intrusion, the vulnerable systems would be the services provided by the freshwater ecosystem, such as drinking water.

Hazard and risk are key concepts in assessing vulnerability of coastal features. Hazard is any source for potential damage and the magnitude of adverse effects under certain conditions, while risk is the probability of occurrence of a hazard that can cause adverse consequences.

Methods for reliable assessment of coastal vulnerability are applicable at different scales (Iglesias-Campos et al., 2010; Mcleod et al., 2010; Ramieri et al., 2011).

The methods can be roughly grouped into two main categories:

1. index- and indicator-based approaches, including related GIS applications and also GIS-based decision support systems;

2. methods based on dynamic computer modelling for sectors or integrated assessment.

**Index-based approaches** express coastal vulnerability by a one-dimensional, and generally unitless, index. This is calculated through quantitative or semi-quantitative evaluation and combination of different variables. These approaches are not immediately transparent, since the final index does not provide information on the assumptions and aggregations that have been included. A clear explanation of the adopted methodology is therefore essential in index-based approaches.

The Coastal Vulnerability Index (CVI) approach is one of the most commonly used and simple methods to assess coastal vulnerability to sea-level rise, in particular due to erosion and/or inundation (Gornitz et al., 1991) (see Box 5.2).

**Indicator-based approaches** express the vulnerability of the coast with a set of independent elements (i.e. the indicators) that characterise key coastal issues such as coastal drivers, pressures, state, impacts, responses, exposure, sensitivity, risk and damage. These indicators are in some cases combined into a final summary indicator. This approach allows the evaluation of different aspects related to coastal vulnerability within a consistent assessment context and conceptual framework (e.g. that of Drivers, Pressures, State, Impact and Responses (DPSIR)).

Relevant examples at European level include applications in the EUROSION ([31]) and DEDUCE ([32]) projects. On the basis of the DPSIR framework, EUROSION identified 13 indicators (9 sensitivity and 4 impact indicators) to support the assessment of coastal erosion status and trends throughout Europe and the related sustainable management (EUROSION, 2004a). Sensitivity and impact indicators were then aggregated to derive relative sensitivity and an impact score whose combination defines the 'risk of coastal erosion', subdivided into four classes.

GIS tools may support the spatial application of index and indicator-based methods, but are also used to develop GIS-based decision-support systems (see Box 5.3).

The second category of available methods is represented by **dynamic computer modelling**. The approach can include sector and integrated assessment methods (see Box 5.4). Several models focus on specific processes that influence coastal vulnerability. These include the Risk Assessment of Coastal Erosion (RACE) model used to evaluate coastal erosion hazards and impacts in England and Wales within the National Coastal Erosion Risk Mapping Project (NCERM) (Halcrow Group et al., 2007a and b). Other models focus on specific coastal systems: for example, the Barataria-Terrebonne Ecosystem Landscape Spatial Simulation (BTELSS) model (Reyes et al., 2000; Martin et al., 2002) and the Sea Level Affecting Marshes Model (SLAMM) model (Park et al., 1989

**Box 5.2 Applying the Coastal Vulnerability Index (CVI) approach: examples**

Özyurt and Ergin (2010) developed a CVI to specifically assess impacts induced by sea-level rise. The index is determined through the integration of five sub-indices, each one corresponding to a specific impact related to sea-level rise; i.e. coastal erosion, flooding due to storm surges, permanent inundation, saltwater intrusion on groundwater resources and saltwater intrusion on rivers/estuaries. Each sub-index is calculated through the semi-quantitative assessment of both physical- and human-influence parameters. The author applied this methodology to the Göksu Delta in Turkey.

Szlafsztein and Sterr (2007) formulated the composite vulnerability index that combines a number of separate variables reflecting natural and socio-economic characteristics that contribute to coastal vulnerability due to natural hazards. The authors applied the index to the Brazilian coastal areas, considering the following natural parameters: coastline length and sinuosity, coastline density in municipal areas, coastal features (estuaries, beaches, etc.), coastal protection measures, fluvial drainage and flooding areas. Socio-economic parameters were total population and total population affected by floods, population density, non-local population (i.e. born elsewhere but living in considered areas), poverty and municipal wealth.

McLaughlin and Cooper (2010) developed a multiscale CVI, specifically addressing erosion impacts. The index integrates three sub-indices: (i) a coastal characteristic sub-index, describing the resilience and coastal susceptibility to erosion, (ii) a coastal forcing sub-index, characterising the forcing variables contributing to wave-induced erosion, (iii) and a socio-economic sub-index, describing targets potentially at risk. The authors applied the index to a multiscale system including Northern Ireland (national scale), Coleraine Borough Council (regional scale) and Portrush East Strand (local scale).

([31]) 'A European initiative for sustainable coastal erosion management': see http://www.eurosion.org.
([32]) 'Développement Durable des Zones Côtières Européennes'.

**Box 5.3 GIS tools can be used to develop GIS-based decision-support systems**

DESYCO (Decision support system for coastal climate change impact assessment) is a GIS-based decision-support system based on open-source libraries. It is designed for the assessment and management of multiple climate change impacts — from this perspective, it can be considered an integrated assessment method — on coastal areas and related ecosystems e.g. beaches, wetlands, forests, protected areas, groundwater and urban and agricultural areas (Torresan et al., 2010). It adopts an ecosystem approach and implements a Regional Risk Assessment (RRA) methodology, based on Multi-Criteria Decision Analysis (MCDA), in order to identify and prioritise areas and targets at risk in the considered region. Up to now, DESYCO has been tested in the coastal area of the North Adriatic Sea and in the Gulf of Gabès, Tunisia; the decision-support system is currently being applied to other coastal areas. DESYCO can in principle be upscaled to European or regional sea level, e.g. the Mediterranean.

and 2003; Warren Pinnacle Consulting, Inc., 2013) are both tailored for the analysis of coastal wetland changes and vulnerability (see Box 5.4).

The choice of assessment method to be used depends on the specific problems to be evaluated and the policy and/or scientific objective to be addressed. These also influence the complexity of the approach to be used (Ramieri et al., 2011).

- Indicators and index-based methods are simple to calculate, good for a scoping or 'first look' assessment, and useful for communication. However, they are not well suited to a more detailed quantitative assessment of coastal vulnerability and the related identification of adaptation measures.

- Sector modelling methods enable detailed quantitative analysis of a particular sector or process, are capable of assessing non-linearities and may be able to consider interactions between different processes. They are most useful for addressing specific key factors of coastal vulnerability, in particular at local and regional scales.

- Integrated assessment models can evaluate the vulnerability of coastal systems to multiple climate change impacts. They can cope with cross-sector analysis of interaction

**Box 5.4 Integrated assessment models**

Integrated assessment models aim to evaluate the vulnerability of coastal systems to multiple climate change impacts, including cross-sector analyses of the interaction among different impacts and/or considering changes in other factors affecting the coastal system (mainly the socio-economic context and adaptation measures).

'Dynamic and Interactive Vulnerability Assessment' (DIVA) is widely applied at European level as an integrated model to assess the biophysical and socio-economic effects of sea-level-rise driven impacts on coastal zones and socio-economic development (Hinkel, 2005; Richards and Nicholls, 2009; Hinkel et al., 2010; Global Climate Forum, 2013). In the CIRCE ([33]) project, DIVA was also used to assess coastal vulnerability for the Mediterranean Basin.

Another integrated approach to modelling the impacts of climate change on the coastal zone was demonstrated by the RegIS ([34]) project (Holman et al., 2007; Mokrech et al., 2008; Richards et al., 2008), on behalf of the United Kingdom’s department for agriculture (now the Department for Environment, Food and Rural Affairs (Defra)). At the end of the RegIS project, the authors suggested this methodology could be expanded to cover whole of the United Kingdom, and the ongoing FP7 CLIMSAVE ([35]) (2010–2014) project will extend this tool to European level, at an 18-kilometre-grid resolution.

Other examples of integrated assessment methods include SimCLIM, a software package to assess climate change risk and climate change adaptation (Warrick et al., 2001 and 2005; SimCLIM, 2012) and FUND, the Climate Framework for Uncertainty, Negotiation and Distribution (Tol, 2006a and 2006b; FUND, 2013).

([33]) 'Climate change and impact research: the Mediterranean environment': see http://www.circeproject.eu.
([34]) 'Regional Impact Simulator': see http://climate-adapt.eea.europa.eu/viewaceitem?aceitem_id=2806.
([35]) 'Climate change integrated assessment methodology for cross-sectoral adaptation and vulnerability in Europe': see http://www.climsave.eu/climsave/index.html.

among different impacts and the synergetic effects of changes in climate, socio-economic development and adaptation measures. Given these characteristics, integrated assessment models are very useful in supporting policy- and decision-making at various scales. However, due to their complex nature, implementation can require significant expertise.

Coastal vulnerability assessments should preferably adopt an integrated approach that considers climate-induced and non-climate-induced environmental changes, socio-economic developments and the mutual interaction among these factors. However, separate analyses of the effects induced by each type of driver (i.e. climate change, other environmental and socio-economic drivers) are also important, since they can provide additional insights into the relative contributions of different drivers.

## 5.2 Improved data integration and sharing

Effective coastal management critically depends on high-quality data, particularly in geospatial format. There is still a deficit of harmonised, consistent and compatible European spatial data relevant to coasts.

The assessment has taken stock of relevant spatial data available at EU level at the time of drafting this report. In total, 257 European data sets (or full databases) were analysed and contributed to this report, through the work of involved European Topic Centres in 2011 and 2012. Thematic breakdown of these data indicated strong prevalence of socio-economic data sets (statistics) and general lack of spatially distributed data of good quality.

Compared to previous EEA reporting (EEA, 2006a), the availability of information that can be used for coastal zone assessment at European level has now improved greatly. The prospects for future coastal zone assessments are even better.

For example, Member States' reporting activities under the Habitats Directive (reference year 2006) and WFD (2012) allowed first-time reporting on the status of habitats and species, and coastal water bodies. The implementation of the MSFD has evolved considerably from 2010 to 2013, and will allow for a marine baseline assessment in 2014. Other key data sources, such as the 2012 update of Copernicus Land monitoring data, as well as new reporting under the Habitats Directive (Article 17) and Birds Directive (Article 12) will allow updates on coastal land take or conservation status of coastal habitats and species (new data will become available in 2014 and 2015).

**Box 5.5 Support tools and information dissemination for coastal management**

In order to strengthen the exchange of good practice examples on adaptation and coastal zone management, the following tools have been created over the last years.

- **Climate-ADAPT:** the European Climate Adaptation Platform was launched in March 2012. It was developed to share information on adaptation case studies throughout the EU and offers potential adaptation options in order to help users (e.g. researchers, policymakers) develop their own climate change adaptation policies. Coastal areas and marine and fisheries are two of the sectors covered by the database (alongside agriculture, biodiversity, health, etc).
- **OURCOAST:** the OURCOAST database is a comprehensive compilation of hundreds of case study summaries that reflect successful cases of integrated coastal management applied throughout Europe, including many cases focusing particularly on climate change adaptation information and communication systems, planning and land management instruments, and institutional coordination mechanisms. The OURCOAST database will be updated in 2014.
- **EMODnet:** the European Marine Observation and Data Network was initiated in 2006 and finalised in 2008. EMODnet is a common gateway for researchers and service providers to high-quality marine data — geological, hydrographic, chemical, biological, and data concerning physical habitats — as well as to the human activities that impact our seas and oceans. Thematic data sets of European coverage are made available via web portals (Box 5.6).
- **WISE-Marine:** the marine component of the Water Information System for Europe (WISE) is currently under development; it should incorporate information reported by Member States under the MSFD (except the underlying datasets, which should be incorporated into EMODnet).

**Source:** EC, 2013e.

European policy action, coordinated by the EU Strategy on Adaptation to climate change, provides a basis for linking existing European databases on marine and coastal data (see Box 5.5). Several research and transboundary cooperation projects are also contributing, e.g. IMCORE ([36]) CoastAdapt ([37]), BaltCICA ([38]), among many others.

Currently, systems for environmental reporting are progressively based on access, sharing and interoperability. The overall aim is to maintain and improve the quality and availability of information required for environmental policy, while keeping the associated reporting burdens to a minimum. A set of principles for the Shared Environmental Information System (SEIS) has been proposed on which to base the collection, exchange and use of environmental data and information (EC, 2008c). This approach is currently evolving into a new vision of structured implementation and information frameworks (EC, 2012c and 2013f). Based on international standards for geospatial data and services, European and national or regional coastal information systems will be increasingly able to exchange data and services, as promoted by SEIS principles and implemented by Member States following the INSPIRE Directive (2007/2/EC) and respective regulations on interoperability of spatial data sets and services.

Other marine and maritime data systems are also increasingly engaged in data sharing: an example is the Common Information Sharing Environment (CISE) for surveillance of the EU maritime domain (EC, 2010a).

Several sustainable development indicators have been produced over the last decades (Plan Bleu, OECD, Eurostat and others), but few were focused on coasts. The indicators are designed for national-level use, do not extract the coastal regions, and often lack a spatially distributed format. They seldom present temporal changes. Gaps include representativity (scoping of indicators), suitability (completeness, reliability of data) and compatibility (fitness for thematic integrations) of data (Meiner, 2013).

Driven by the EU's ICZM Recommendation, specific indicators for coasts were produced for the EU's ICZM Expert Group. Although these indicators were well tested and documented (via the Interreg IIIC DEDUCE project), the evaluation of ICZM implementation (EC, 2007) showed that countries have been slow in making use of them for practical reporting and coastal management. This has demonstrated a particular need to focus on coastal indicators and information that can guide action (Rapport and Hildén, 2013).

**Box 5.6 Example of European Marine Observation and Data Network (EMODnet) activities: integration of data for marine geology**

The EMODnet-Geology project collects information held by the project partners, and updates existing data sets with geological data owned by geological survey organisations in Europe. In this respect, the project has been largely successful in delivering the information layers on seabed sediments, seabed geology, and coastal behaviour required by the European Commission. Appropriate map layers have been also compiled for geological events and minerals, although the compilation of information held by third parties has been problematic. For minerals in particular, issues have arisen regarding the use and maintenance of data owned by government agencies (e.g. aggregates), or by the oil and gas industry.

In general, the approach of accessing geological information directly from source, including the national mapping programmes of European countries, would ensure the long-term maintenance of the EMODnet-Geology portals. For example, integrating the outputs of the UK Marine Environmental Mapping Programme (MAREMAP), the Irish INFOMAR ([39]) programme and the Norwegian MAREANO programme at European level would be a significant step forward in making geological information accessible at an international scale.

**Source:** European Commission, Maritime forum ([40]).

([36]) 'Innovative management for Europe's changing coastal resource': see http://www.imcore.eu.
([37]) See http://coastadapt.org.
([38]) 'Climate change: impacts, costs and adaptation in the Baltic Sea Region': see http://www.baltcica.org.
([39]) 'Integrated mapping for the sustainable development of Irelands marine resource: see http://www.infomar.ie/about.
([40]) See https://webgate.ec.europa.eu/maritimeforum/content/3068.

New approaches for coastal indicators have been developed: these include the approaches of QualityCoast ([41]) and of the Interreg IVC SUSTAIN ([42]) project (SUSTAIN, 2012). A set of socio-economic coastal indicators is emerging from Eurostat ([43]) — defining EU 'coastal regions' and providing several essential statistics for these regions has been an important improvement in information on coastal zones.

There are also opportunities to use novel tools of citizen science to make progress by mobilising voluntary contributors. Tools such as 'Eye on Earth' can be applied for a wide range of topics, for example, beach litter or bathing water quality. The IOC-UNESCO IODE ([44]) project on the International Coastal Atlas Network (ICAN) has advanced the concepts of semantic interoperability (the ability to automatically interpret information exchanged) and promotes federation of coastal and marine atlases at various governance levels, from local to continental (Dwyer et al., 2012).

Further efforts to improve data resolution (both temporal and spatial) and compatibility are needed. Data availability is still hampered by access or copyright restrictions. The establishment of a European marine knowledge platform (EC, 2010b) and national spatial data infrastructures (implementing the INSPIRE Directive) have improved the situation, but further progress is needed to provide adequate and timely data for ICZM and MSP.

**Photo 5.1** © Peter Kristensen

([41]) See http://www.qualitycoast.info.
([42]) See http://www.sustain-eu.net/what_is_sustain/index.htm.
([43]) See http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Coastal_region_statistics.
([44]) The programme 'International Oceanographic Data and Information Exchange' (IODE) of the 'Intergovernmental Oceanographic Commission' (IOC) of UNESCO: see http://www.iode.org.

# Abbreviations and acronyms

The table below presents abbreviations and acronyms used in this report. Acronyms of research projects have not been included, as links are given in footnotes in the main body of the text.

| Acronym or abbreviation | Name | Reference |
|---|---|---|
| A1 | See SRES | |
| A1B | See SRES | |
| A1FI | See SRES | |
| A1T | See SRES | |
| A2 | See SRES | |
| B1 | See SRES | |
| B2 | See SRES | |
| CAP | Common Agricultural Policy | |
| CC IVA | Climate change impacts, vulnerability and adaptation | |
| CCS | Carbon Capture and Storage | |
| CFP | Common Fisheries Policy | |
| CISE | Common Information Sharing Environment | |
| Climate-ADAPT | European climate adaptation platform | http://climate-adapt.eea.europa.eu |
| Corine Land Cover (CLC) | Coordination of Information on the Environment Land Cover database | http://www.eea.europa.eu/data-and-maps/data#c5=all&c11=landuse&c17=&c0=5&b_start=0 |
| CVI | Coastal Vulnerability Index | |
| DG | Directorate-General (of the European Commission) | |
| DIVA | Dynamic Interactive Vulnerability Assessment | http://www.diva-model.net |
| DPSIR | Drivers, Pressures, State, Impact, Responses indicator framework | |
| EDO | European Drought Observatory (JRC) | http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000 |
| EEA | European Environment Agency | http://www.eea.europa.eu |
| EEZ | Exclusive Economic Zone (sea areas) | |
| EMODnet | European Marine Observation and Data Network with seven different areas:<br>Lot 1 — bathymetry<br>Lot 2 — geology<br>Lot 3 — physical habitats<br>Lot 4 — chemistry<br>Lot 5 — biology<br>Lot 6 — physics<br>Lot 7 — human activity | |
| ESPON | European Observation Network for Territorial Development and Cohesion | http://www.espon.eu/main/Menu_Programme |
| ETC/ACM | European Topic Centre for Air Pollution and Climate Change Mitigation | http://acm.eionet.europa.eu |
| ETC/BD | European Topic Centre on Biological Diversity | http://bd.eionet.europa.eu |
| ETC/CCA | European Topic Centre on Climate Change impacts, vulnerability and Adaptation | http://cca.eionet.europa.eu |
| ETC/ICM | European Topic Centre on Inland, Coastal and Marine waters | http://icm.eionet.europa.eu |
| ETC/SIA | European Topic Centre on Spatial information and Analysis | http://sia.eionet.europa.eu |
| ETC-ACC | (Former) European Topic Centre on Air Pollution and Climate Change | In 2011, the responsibilities of ETC-ACC was divided into two new topic centres: ETC-CCA and ETC-ACM (see above) |
| EU SDS | EU Sustainable Development Strategy | |
| Eurostat | The Statistical Office of the European Union | http://ec.europa.eu/eurostat |
| FAO | The Food and Agriculture Organization of the United Nations | http://www.fao.org |
| FP7 | Seventh Framework Programme for Research and Technological Development | http://cordis.europa.eu/fp7/home_en.html |

| Acronym or abbreviation | Name | Reference |
|---|---|---|
| GCM | General circulation model | |
| GDP | Gross domestic product | |
| GES | Good environmental status | |
| GHG | Greenhouse gas; the most important anthropogenic greenhouse gases are carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) | |
| GIS | Geographical Information System | |
| GMSL | Global mean sea level | |
| HELCOM | Helsinki Commission; the governing body of the 'Convention on the Protection of the Marine Environment of the Baltic Sea Area' (Helsinki Convention) | http://www.helcom.fi |
| IAM | Integrated assessment model (of climate change) | |
| ICAN | International Coastal Atlas Network | |
| ICES | International Council for the Exploration of the Sea | http://www.ices.dk |
| ICZM | Integrated Coastal Zone Management | |
| IED | EU Industrial Emissions Directive (2010/75/EU) | |
| IMP | Integrated Maritime Policy | |
| IOC | Intergovernmental Oceanographic Commission of UNESCO | http://ioc-unesco.org |
| IODE | International Oceanographic Data and Information Exchange | http://www.iode.org |
| IPCC | Intergovernmental Panel on Climate Change | http://www.ipcc.ch/ |
| IPPC | Integrated pollution prevention and control | |
| LNG | Liquefied natural gas | |
| MAREMAP | Marine Environmental Mapping Programme | |
| MAS | Marine Alien Species | |
| MCDA | Multi-Criteria Decision Analysis | |
| MSFD | EU Marine Strategy Framework Directive (2008/56/EC) | |
| MSP | Maritime Spatial Planning | |
| MSY | Maximum Sustainable Yield | |
| NCERM | National Coastal Erosion Risk Mapping | |
| NUTS (2,3) | Nomenclature of Territorial Units for Statistics;<br>NUTS 2 = states/provinces;<br>NUTS 3 = regional areas, counties, districts | http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction |
| OECD | Organisation for Economic Co-operation and Development | http://www.oecd.org/unitedkingdom |
| OSPAR | OSPAR Commission, as successor to the Oslo and Paris Commissions, to administer the OSPAR Convention | http://www.ospar.org |
| PAH(s) | Polycyclic aromatic hydrocarbon(s) | |
| ppm | Parts per million | |
| RACE | Risk Assessment of Coastal Erosion | |
| RBD | River basin district, based on the WFD | |
| RDI | Research Development and Innovation policy | |
| RES | EU Directive on the promotion of electricity produced from renewable energy (2001/77/EC) | |
| RRA | Regional Risk Assessment | |
| SEA | Strategic Environmental Assessment | |
| SECA | Simplified Ecosystem Capital Accounts | |
| SEEA | System of Integrated Economic and Environmental Accounting | |
| SEIS | Shared Environmental Information System | |
| SLAMM | Sea Level Affecting Marshes Model | |
| SRES | IPCC Special Report on Emissions Scenarios | http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0 |
| TBT | Tributyltin | |
| TDA | Transboundary diagnostic analysis | |
| TEN-T | Trans-European transport network | |
| UNFCCC | United Nations Framework Convention on Climate Change | http://unfccc.int |
| VMS | Vessel Monitoring System | |
| WFD | EU Water Framework Directive 2000/60/EC | http://ec.europa.eu/environment/water/water-framework |
| WHO | World Health Organization | http://www.who.int |
| WISE | Water Information System for Europe | http://water.europa.eu |

# References


Ærtebjerg, G., Andersen, J.H. and Hansen, O.S. (Eds), 2003, *Nutrients and Eutrophication in Danish Marine Waters — a Challenge for Science and Management*. National Environmental Research Institute, Copenhagen.

Andersen, J.H. and Stock, A. (Eds), 2013, *Human uses, pressures and impacts in the Eastern North Sea*. Technical Report from DCE. Danish Centre for Environment and Energy, Aarhus, http://www2.dmu.dk/Pub/TR18.pdf (accessed 18 October 2013).

Andrade, C., Freitas, M.C., Cachado, C., Cardoso, A., Monteiro, J., Brito, P. and Rebelo, L., 2002, 'Coastal Zones'. In: *Climate Change in Portugal, Scenarios, Impacts and Adaptation Measures* (F.D. Santos, K. Forbes and R. Moita, eds.), 173–219. Gradiva, Lisbon.

BACC Author Team, 2008, *Assessment of Climate Change for the Baltic Sea Basin*. Springer, Berlin, Heidelberg, http://www.springer.com/earth+sciences+and+geography/atmospheric+sciences/book/978-3-540-72785-9 (accessed 18 October 2013).

Backer, H. and Frias, M. (Eds), 2012, *Planning the Bothnian Sea-key findings of the Plan Bothnia project*. Finepress, Turku.

Balfoort, H.W., 1996, *Integrated Water Resource Management — Azov Sea*. Deltares, Netherlands, http://repository.tudelft.nl/view/hydro/uuid%3A12cca73b-5c9b-4102-bc1c-16c2f53fec38 (accessed 18 October 2013).

Ban, N.C., Alidina, H.M. and Ardron, J.A., 2010, 'Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study', *Marine Policy* 34(5), 876–886, doi:10.1016/j.marpol.2010.01.010.

Barnes, D.K.A., 2002, 'Biodiversity: Invasions by marine life on plastic debris', *Nature* 416(6883), 808–809, doi:10.1038/416808a.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E. and Geeves, W., 2003, 'Marine invasive alien species: a threat to global biodiversity', *Marine Policy* 27(4), 313–323, doi:10.1016/S0308-597X(03)00041-1.

Bergmann, M. and Klages, M., 2012, 'Increase of litter at the Arctic deep-sea observatory HAUSGARTEN', *Marine Pollution Bulletin* 64(12), 2 734–2 741, doi:10.1016/j.marpolbul.2012.09.018.

Blanchon, P., Eisenhauer, A., Fietzke, J. and Liebetrau, V., 2009, 'Rapid sea-level rise and reef back-stepping at the close of the last interglacial highstand', *Nature* 458(7240), 881–884, doi:10.1038/nature07933.

Bondevik, S. and Mangerud, J., 2003, 'Record-breaking height for 8000-Year-Old tsunami in the North Atlantic', *EOS* 84, 289–300.

Boudouresque, C.F., Bernard, G., Pergent, G., Shili, A. and Verlaque, M., 2009, 'Regression of Mediterranean seagrasses caused by natural processes and anthropogenic disturbances and stress: a critical review', *Botanica Marina* 52(5).

Breen, P., Robinson, L.A., Rogers, S.I., Knights, A.M., Piet, G., Churilova, T., Margonski, P., Papadopoulou, N., Akoglu, E., Eriksson, A., Finenko, Z., Fleming-Lehtinen, V., Galil, B., Goodsir, F., Goren, M., et al., 2012, 'An environmental assessment of risk in achieving good environmental status to support regional prioritisation of management in Europe', *Marine Policy* 36(5), 1 033–1 043, doi:10.1016/j.marpol.2012.02.003.

Brown, S., Nicholls, R.J., Vafeidis, A., Hinkel, J. and Watkiss, P., 2011, 'The Impacts and Economic Costs of Sea-Level Rise in Europe and the Costs and Benefits of Adaptation. Summary of Results from the EC RTD ClimateCost Project'. In: *The ClimateCost Project. Final Report. Volume 1: Europe.* Stockholm Environment Institute, Stockholm.

BSC, 2008a, *Black Sea transboundary diagnostic analysis (TDA)*. Commission on the Protection of the Black Sea Against Pollution, Istanbul, http://www.blacksea-commission.org/_tda2008-document2.asp (accessed 18 October 2013).

BSC, 2008b, *State of the Environment Report 2001–2006/7* (No. 2008-3). Publications of the Commission on the Protection of the Black Sea Against Pollution (BSC). Commission on the Protection of the Black Sea Against Pollution, Istanbul, http://www.blacksea-commission.org/_publ-SOE2009.asp (accessed 18 October 2013).

CBD, 2002, Decision VI/23 of the Conference of the Parties to the Convention on Biological Diversity, Annex, footnote to the introduction (No. Decision VI/23). COP 6. CBD, http://www.cbd.int/decision/cop/default.shtml?id=7197 (accessed 18 October 2013).

CLAMER, 2011, *Climate Change and Marine Ecosystem Research — Synthesis of European Research on the Effects of Climate Change on Marine Environments* (Deliverable No. 1.2). Marine Board — special report. Marine Board, http://www.clamer.eu/images/stories/deliverables/clamer%20marine%20board%20special%20reported.pdf (accessed 18 October 2013).

Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W.W.L., Christensen, V., Karpouzi, V.S., Guilhaumon, F., Mouillot, D., Paleczny, M., Palomares, M.L., Steenbeek, J., Trujillo, P., Watson, R. and Pauly, D., 2012, 'The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves', *Global Ecology and Biogeography* 21(4), 465–480, doi:10.1111/j.1466-8238.2011.00697.x.

Conscience, 2010, Assessment of European coastal erosion policies in relation to ICZM (Deliverable No. D11). Task Report. Deltares, the Netherlands, http://www.conscience-eu.net/documents/deliverable11-assessment.pdf (accessed 18 October 2013).

Cruise Baltic, 2013, *Market Review 2013: One Sea — Oceans of adventures*. Cruise Baltic, Copenhagen, http://www.cruisebaltic.com/media%284669,1033%29/Cruise_Baltic_Market_Review_2013.pdf (accessed 18 October 2013).

CSIL Centre for Industrial Studies and Touring Servizi, 2008, *The Impact of Tourism on Coastal Areas: Regional Development Aspects* (Report No. IP/B/REGI/IC/2006-166-Lot 01-C03-SC01). European Parliament,http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/the_impact_of_tourism_en.pdf (accessed 18 October 2013).

Damanaki, M., 2012, *Our Future is Blue*. Presented at the Opening ceremony of the European Maritime Day, Gothenburg, Sweden, http://ec.europa.eu/maritimeaffairs/maritimeday/conference/programme_en.htm (accessed 18 October 2013).

DEDUCE consortium, 2007, *Indicators Guidelines — To adopt an indicators-based approach to evaluate coastal sustainable development*. Department of the Environment and Housing, Government of Catalonia, Barcelona, http://www.im.gda.pl/images/ksiazki/2007_indicators_guidelines.pdf (accessed 18 October 2013).

deYoung, B., Barange, M., Beaugrand, G., Harris, R., Perry, R.I., Scheffer, M. and Werner, F., 2008, 'Regime shifts in marine ecosystems: detection, prediction and management', *Trends in Ecology & Evolution* 23(7), 402–409, doi:10.1016/j.tree.2008.03.008.

Diaz, R.J. and Rosenberg, R., 2008, 'Spreading Dead Zones and Consequences for Marine Ecosystems', *Science* 321(5891), 926–929, doi:10.1126/science.1156401.

Duarte, C.M., Conley, D.J., Carstensen, J. and Sánchez-Camacho, M., 2009, 'Return to Neverland: Shifting Baselines Affect Eutrophication Restoration Targets', *Estuaries and Coasts* 32(1), 29–36, doi:10.1007/s12237-008-9111-2.

Duarte, C.M., Nixon, S., Fulweiler, R.W., Dennison, W. B., Valiela, I., Hughes, T. and Bordalba, N.M., 2009, *Global loss of coastal habitats: Rates, causes and consequences*, 1st ed. Fundación BBVA, Bilbao.

Dubaish, F. and Liebezeit, G., 2013, 'Suspended Microplastics and Black Carbon Particles in the Jade System, Southern North Sea', *Water Air and Soil Pollution* 224:1352, DOI 10.1007/s11270-012-1352-9.

Dwyer, N., Kopke, K., Berman, M., Belpaeme, K., O'Dea, L., Haddad, T. and Wright, D., 2012, *Report of International Coastal Atlas Network Workshop 5: Coastal Atlases as Engines for Coastal and Marine Spatial Planning*. Coastal and Marine Research Centre, Cork, http://ican.science.oregonstate.edu/files/ican/ICAN5_Wkshp_Rpt.pdf (accessed 18 October 2013).

EC, 2000, Communication from the Commission to the Council and the European Parliament on integrated coastal zone management: a strategy for Europe (Communication from the Commission No. COM 547 final). Communication from the Commission. European Commission, Brussels.

EC, 2006, Maritime facts and figures. European Commission, Brussels, http://bookshop.europa.eu/en/maritime-facts-and-figures-pbKL7506396/downloads/KL-75-06-396-EN-C/KL7506396ENC_002.pdf?FileName=KL7506396ENC_002.pdf&SKU=KL7506396ENC_PDF&CatalogueNumber=KL-75-06-396-EN-C (accessed 18 October 2013).

EC, 2007, *An evaluation of Integrated Coastal Zone Management (ICZM) in Europe* (Report No. COM(2007) 308 final). Report from the Commission to the European Parliament and the Council. European Commission, Brussels, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0308:FIN:EN:pdf (accessed 18 October 2013).

EC, 2008a, a Strategy for Marine and Maritime Research, a coherent European Research Area framework in support of a sustainable use of oceans and seas (Communication from the Commission No. COM(2008) 534 final of 26 June 2008). EC, Brussels, http://ec.europa.eu/research/mmrs/documents/pdf/the_strategy.pdf (accessed 18 October 2013).

EC, 2008b, Roadmap for Maritime Spatial Planning: Achieving Common Principles in the EU (Communication from the Commission No. COM(2008) 791 final). Communication from the Commission. European Commission, Brussels. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0791:FIN:EN:PDF (accessed 18 October 2013).

EC, 2008c, Towards a Shared Environmental Information System (SEIS) (Communication from the Commission No. COM(2008) 46 final). Communication from the Commission to the European parliament, the Council, the European Economic and Social committee and the Committee of the Regions. European Commission, Brussels. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0046:FIN:EN:PDF (accessed 18 October 2013).

EC, 2010a, Draft Roadmap towards establishing the Common Information Sharing Environment for the surveillance of the EU maritime domain (Communication from the Commission No. COM(2010) 584 final). Communication from the Commission to the European Parliament and the Council. European Commission, Brussels, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0584:FIN:EN:PDF (accessed 18 October 2013).

EC, 2010b, MARINE KNOWLEDGE 2020 marine data and observation for smart and sustainable growth (No. COM(2010) 461 final). Communication from the Commission to the European Parliament and the Council. European Commission, Brussels. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0461:FIN:EN:PDF (accessed 18 October 2013).

EC, 2011, Reform of the Common Fisheries Policy (Communication from the Commission No. COM(2011) 417 final). Communication from the Commission to the European parliament, the Council, the European Economic and Social committee and the Committee of the Regions. European Commission, Brussels, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0417:FIN:EN:PDF (accessed 18 October 2013).

EC, 2012a, Blue Growth Study — Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts | Maritime Forum. European Maritime Forum, https://webgate.ec.europa.eu/maritimeforum/content/2946 (accessed 12 August 2013).

EC, 2012b, Overview of EU policies, legislation and initiatives related to marine litter (Commission Staff Working Document No. SWD(2012) 365 final). Commission Staff Working Document. European Commission, Brussels, http://ec.europa.eu/environment/marine/pdf/SWD_2012_365.pdf (accessed 18 October 2013).

EC, 2012c, Improving the delivery of benefits from EU environment measures: building confidence through better knowledge and responsiveness (Communication from the Commission No. COM(2012) 95 final). Communication from the Commission to the European parliament, the Council, the European Economic and Social committee and the Committee of the Regions. European Commission, Brussels, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0095:FIN:EN:PDF (accessed 18 October 2013).

EC, 2013a, Green paper on a European Strategy on Plastic Waste in the Environment (No. COM(2013) 123 final). European Commission, Brussels.

EC, 2013b, Green Infrastructure (GI) — Enhancing Europe's Natural Capital (Communication from the Commission No. COM(2013) 249 final). Communication from the Commission to the European parliament, the Council, the European Economic and Social committee and the Committee of the Regions. European Commission, Brussels. http://eur-lex.europa.eu/LexUriServ/LexUriServ.

do?uri=COM:2013:0249:FIN:EN:PDF (accessed 18 October 2013).

EC, 2013c, Impact assessment accompanying the document proposal for a Directive of the European Parliament and of the Council establishing a framework for maritime spatial planning and integrated coastal management (Commission Staff Working Document No. SWD(2013) 65 final). Commission Staff Working Document. European Commission, Brussels, http://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning/documents/swd_2013_65_en.pdf (accessed 18 October 2013).

EC, 2013d, Reform of the common fisheries policy, *http://ec.europa.eu/fisheries/reform*, http://ec.europa.eu/fisheries/reform (accessed 14 August 2013)

EC, 2013e, Climate change adaptation, coastal and marine issues (Commission Staff Working Document No. SWD (2013) 133 final). Commission Staff Working Document. European Commission, Brussels, http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_133_en.pdf (accessed 18 October 2013).

EC, 2013f, EU Shared Environmental Information System Implementation Outlook (Commission Staff Working Document No. SWD(2013) 18 final). Commission Staff Working Document. European Commission, Brussels, http://ec.europa.eu/environment/seis/pdf/seis_implementation_en.pdf (accessed 18 October 2013).

ECORYS, Deltares and Oceanic Development, 2012, *Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts* (Final Report No. MARE/2010/01). ECORYS Nedeland BV, Rotterdam, https://webgate.ec.europa.eu/maritimeforum/system/files/Blue%20Growth%20Final%20Report%2013082012.pdf (accessed 18 October 2013).

EEA, 2006a, *The changing faces of Europe's coastal areas*, EEA Report No 6/2006. European Environment Agency, Copenhagen, Denmark.

EEA, 2006b, *The continuous degradation of Europe's coasts threatens European living standards*, EEA Briefing No 3/2006. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/publications/briefing_2006_3 (accessed 18 October 2013).

EEA, 2010a, *EU 2010 Biodiversity baseline*, EEA Technical report No 12/2010. European Environment Agency, Copenhagen, Denmark.

EEA, 2010b, *Marine and coastal environment — SOER 2010 thematic assessment*. *The European environment — state and outlook 2010*. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/soer/europe/marine-and-coastal-environment/download (accessed 18 October 2013).

EEA, 2010c, *Mapping the impacts of natural hazards and technological accidents in Europe*, EEA Technical report No 13/2010. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/publications/mapping-the-impacts-of-natural (accessed 18 October 2013).

EEA, 2011, *An experimental framework for ecosystem capital accounting in Europe*, EEA Technical report No 13/2011. European Environment Agency, Copenhagen, Denmark

EEA, 2012a, *European waters — assessment of status and pressures*, EEA Report No 8/2012. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/publications/european-waters-assessment-2012 (accessed 18 October 2013).

EEA, 2012b, *Climate change, impacts and vulnerability in Europe 2012*, EEA Report No 12/2012. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012 (accessed 18 October 2013).

EEA, 2013, *Adaptation in Europe — Addressing risks and opportunities from climate change in the context of socio-economic developments*, EEA Report No 3/2013. European Environment Agency, Copenhagen, Denmark, http://www.eea.europa.eu/publications/adaptation-in-europe (accessed 18 October 2013).

Ekström, G., Nettles, M. and Tsai, V.C., 2006, 'Seasonality and Increasing Frequency of Greenland Glacial Earthquakes', *Science* 311(5768), 1 756–1 758, doi:10.1126/science.1122112.

EMSA, 2010, *Maritime Accident Review 2010.* European Maritime Safety Agency, http://www.emsa.europa.eu (accessed 18 October 2013).

ESF, 2010, Marine Biotechnology: a New Vision and Strategy for Europe (Position Paper No. 15). Marine Board-ESF Position Paper. European Science Foundation, Marine Board, Brussels, http://www.marine.ie/NR/rdonlyres/C076682C-2B32-437C-A781-

B2EACBAA6B62/0/ESFMBmarine_biotechnology_paper15LR.pdf (accessed 18 October 2013).

ESPON, 2006, *Spatial effects of natural and technological hazards* (Final Report No. 1.3.1). ESPON 2006 Project. Geological Survey of Finland, Espoo, http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/ThematicProjects/NaturalHazards/fr-1.3.1_revised-full.pdf

ETC/BD, 2009, *Posidonia beds* (Report No. 13 July 2009). Habitats Directive Article 17 Reporting. European Topic Centre on Biological Diversity, http://forum.eionet.europa.eu/x_habitat-art17report/library/datasheets/habitats/coastal_habitats/coastal_habitats/1120-posidonia_oceanicae (accessed 18 October 2013).

EUROSION, 2004a, *Living with coastal erosion in Europe: Sediment and Space for Sustainability — PART 3 — Methodology for assessing regional indicators*. EUROSION, http://www.eurosion.org/reports-online/part3.pdf (accessed 18 October 2013).

EUROSION, 2004b, Holderness Coast (United Kingdom). EUROSION Case Study. DHV Group, Amersfoort, http://copranet.projects.eucc-d.de/files/000164_EUROSION_Holderness_coast.pdf (accessed 18 October 2013).

Eurostat, 2011, 'Chapter 13: Costal regions'. In: *Eurostat regional yearbook 2011*, 170–183. Eurostat, Luxembourg.

EWEA, 2012, Green Growth — The impact of wind energy on jobs and the economy. European Wind Energy Association, Brussels, http://www.ewea.org/uploads/tx_err/Green_Growth.pdf (accessed 18 October 2013).

FUND, 2013, FUND — Climate Framework for Uncertainty, Negotiation and Distribution, http://www.fund-model.org (accessed 20 August 2013).

Global Climate Forum, 2013, DIVA Model, http://www.diva-model.net (accessed 16 August 2013).

Gornitz, V.M., White, T.W. and Cushman, R.M., 1991, 'Vulnerability of the U.S. to future sea-level rise'. In: *Proceedings of Seventh Symposium on Coastal and Ocean Management. Long Beach*, 2 354–2 368. Long Beach, CA (USA).

GWEC, 2012, *Global Wind Report — Annual market update 2012*. Global Wind Energy Council, Brussels, http://www.gwec.net/publications/global-wind-report-2/global-wind-report-2012 (accessed 18 October 2013).

Halcrow Group, Lee, M. and Terry Oakes Associates, 2007a, *Risk assessment of coastal erosion Part One* (No. FD2324/TR1). R&D Technical Report. Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2324_7453_TRP_pdf.sflb.ashx (accessed 18 October 2013).

Halcrow Group, Lee, M. and Terry Oakes Associates, 2007b, *Risk assessment of coastal erosion Part Two — Tools* (No. FD2324/TR2). R&D Technical Report. Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2324_7454_TRP_pdf.sflb.ashx (accessed 18 October 2013).

Halpern, B.S., Kappel, C.V., Selkoe, K.A., Micheli, F., Ebert, C.M., Kontgis, C., Crain, C. M., Martone, R.G., Shearer, C. and Teck, S.J., 2009, 'Mapping cumulative human impacts to California Current marine ecosystems', *Conservation Letters* 2(3), 138–148, doi:10.1111/j.1755-263X.2009.00058.x.

Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., Katona, S.K., Kleisner, K., Lester, S.E., O'Leary, J., Ranelletti, M., Rosenberg, A.A., Scarborough, C., Selig, E.R., Best, B.D., Brumbaugh, D.R., et al., 2012, 'An index to assess the health and benefits of the global ocean', *Nature* 488(7413), 615–620, doi:10.1038/nature11397.

Halpern, B.S., Selkoe, K.A., Micheli, F. and Kappel, C.V., 2007, 'Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats', *Conservation biology: the journal of the Society for Conservation Biology* 21(5), 1 301–1 315, doi:10.1111/j.1523-1739.2007.00752.x.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., et al., 2008, 'a Global Map of Human Impact on Marine Ecosystems', *Science* 319(5865), 948–952, doi:10.1126/science.1149345.

Hanley, J. and Caballero, R., 2012, 'The role of large-scale atmospheric flow and Rossby wave breaking in the evolution of extreme windstorms over Europe', *Geophysical Research Letters* 39(21), n/a–n/a, doi:10.1029/2012GL053408.

Hansen, J., Josefson, A.B. and Pedersen, T.M., 2004, *Genindvandring af bundfauna efter iltsvindet 2002 i de indre danske farvande.* Faglig rapport fra DMU. Danmarks Miljøundersøgelser, http://www2.dmu.dk/1_Viden/2_Publikationer/3_Fagrapporter/rapporter/fr506.pdf (accessed 18 October 2013).

HELCOM, 2004, *Dioxins in the Baltic Sea*. HELCOM — Environmental Focal Point Information. HELCOM, Helsinki, http://www.helcom.fi/stc/files/Publications/OtherPublications/Dioxins_in_BS-2004.pdf (accessed 18 October 2013).

HELCOM, 2009, *Eutrophication in the Baltic Sea An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region* (Report No. 115B). Baltic Sea Environment Proceedings. HELCOM, Helsinki, http://www.helcom.fi/stc/files/Publications/Proceedings/bsep115A.pdf (accessed 18 October 2013).

HELCOM, 2010a, *Maritime Activities in the Baltic Sea An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea region* (Report No. 123). Baltic Sea Environment Proceedings. HELCOM, Helsinki, http://www.helcom.fi/stc/files/Publications/Proceedings/bsep123.pdf (accessed 18 October 2013).

HELCOM, 2010b, *Hazardous substances in the Baltic Sea — An integrated thematic assessment of hazardous substances in the Baltic Sea* (Report No. 120B). Baltic Sea Environment Proceedings. HELCOM, Helsinki, http://www.helcom.fi/stc/files/Publications/Proceedings/bsep120B.pdf (accessed 18 October 2013).

HELCOM, 2010c, *Ecosystem health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment* (Report No. 122). Baltic Sea Environment Proceedings. HELCOM, Helsinki.

HELCOM, 2013, Maritime Group (HELCOM MARITIME), http://www.helcom.fi/groups/maritime/en_GB/main (accessed 21 September 2013).

Hinkel, J., 2005, 'DIVA: an iterative method for building modular integrated models', *Advances in Geosciences* 4, 45–50.

Hinkel, J., Nicholls, R.J., Vafeidis, A.T., Tol, R.S.J. and Avagianou, T., 2010, 'Assessing risk of and adaptation to sea-level rise in the European Union: an application of DIVA', *Mitigation and Adaptation Strategies for Global Change* 15(7), 703–719, doi:10.1007/s11027-010-9237-y.

Hodgson, N., Harley, M., van Minnen, J., Schrander, J., Voigt, T. and Celikyilmaz-Aydemir, G., 2010, *European Coastal Climate Change Impacts, Vulnerability and Adaptation: a review of evidence* (Technical Paper No. 2010/7). ETC/ACC Technical Paper, 174. ETC/CCA, http://acm.eionet.europa.eu/reports/ETCACC_TP_2010_7_Coastal_IVA (accessed 18 October 2013).

Hof, A.F., 2013, *Sea-level rise damage and adaptation costs*. Impacts World 2013. Impacts World Conference, Potsdam, http://www.climate-impacts-2013.org/files/hdwb_hof.pdf (accessed 18 October 2013).

Holman, I.P., Berry, P.M., Mokrech, M., Richards, J. A., Audsley, E., Harrison, P.A., Rounsevell, M.D.A., Nicholls, R.J., Shackley, S. and Henriques, C., 2007, *Simulating the effects of future climate and socio-economic change in East Anglia and North West England: the RegIS2 project. Summary Report.* UKCIP, Oxford, http://www.ukcip.org.uk/wordpress/wp-content/PDFs/ReGIS2_summary.pdf (accessed 18 October 2013).

ICES, 2012a, *Report of the Joint EIFAAC/ICES Working Group on Eels (WGEEL), 3–9 September 2012* (Report No. 2012/ACOM:18). ICES CM. ICES, Copenhagen.

ICES, 2012b, *Report of the ICES Advisory Committee 2012* (No. 2012 Book 6). ICES Advice. ICES, Copenhagen.

Iglesias-Campos, A., Simon-Colina, A. and Fraile-Jurado, P., 2010, *Methods for assessing current and future coastal vulnerability to climate change* (Report No. 2010/8). ETC/ACC Technical Paper. ETC ACC, http://acm.eionet.europa.eu/reports/ETCACC_TP_2010_8_Coastal_vuln_methods (accessed 18 October 2013).

IMSA Amsterdam, 2013, *Plastic Marine Litter: One Big Market Failure. Systemic look at plastic waste in the light of plastic marine litter*. Report of the Plastic Marine Waste Project. IMSA Amsterdam, Amsterdam, http://www.plasticmarinelitter.eu/wp-content/uploads/2011/10/PMW023_Plastic-Marine-Litter_One-big-market-failure_D03.pdf (accessed 18 October 2013).

IPCC, 2007, *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds). Cambridge University Press, Cambridge, http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html (accessed 18 October 2013).

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T. P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., et al., 2001, 'Historical Overfishing and the Recent Collapse of Coastal Ecosystems', *Science* 293(5530), 629–637, doi:10.1126/science.1059199.

Katsanevakis, S., Gatto, F., Zenetos, A. and Cardoso, A.C., 2013, 'How many marine aliens in Europe?' *Management of Biological Invasions* 4(1), 37–42.

Knights, A.M., Koss, R.S., Papadopoulou, N., Cooper, L.H. and Robinson, L.A., 2011, 'Sustainable use of European regional seas and the role of the Marine Strategy Framework Directive'. Deliverable 1, EC FP7 Project (244273) 'Options for Delivering Ecosystem-based Marine Management' (Deliverable No. 1), 165. University of Liverpool, Liverpool, http://www.liv.ac.uk/media/livacuk/odemm/docs/ODEMM,Deliverable,1.pdf (accessed 18 October 2013).

Kont, A., Jaagus, J., Orviku, K., Palginõmm, V., Ratas, U., Rivis, R., Suursaar, Ü. and Tõnisson, H., 2011, 'Natural Development and Human Activities on Saaremaa Island (Estonia) in the Context of Climate Change and Integrated Coastal Zone Management'. In: *Global Change and Baltic Coastal Zones* Coastal Research Library (G. Schernewski, J. Hofstede and T. Neumann, eds.), 117–134. Springer Netherlands, http://link.springer.com/chapter/10.1007/978-94-007-0400-8_8 (accessed 18 October 2013).

Korpinen, S., Meski, L., Andersen, J.H. and Laamanen, M., 2012, 'Human pressures and their potential impact on the Baltic Sea ecosystem', *Ecological Indicators* 15(1), 105–114, doi:10.1016/j.ecolind.2011.09.023.

Lavalle, C., Gomes, C.R., Baranzelli, C. and Batista e Silva, F., 2011, *Coastal Zones Policy alternatives impacts on European Coastal Zones 2000–2050*. JRC Technical Notes. JRC-IES, Ispra, http://ec.europa.eu/environment/enveco/impact_studies/pdf/land_use_modelling%20adaptation_activities_coastal.pdf (accessed 18 October 2013).

Leslie, H.M., Meulen, van der, M.D., Kleissen, F.M. and Vethaak, A.D., 2011, *Microplastic Litter in the Dutch Marine Environment — Providing facts and analysis for Dutch policymakers concerned with marine microplastic litter (Final Report)*. Deltares, http://193.166.21.102:9091/servlet/com.trend.iwss.user.servlet.sendfile?downloadfile=IRES-1566525382-ACE7820-30473-30442-59 (accessed 18 October 2013).

Liquete, C., Zulian, G., Delgado, I., Stips, A. and Maes, J., 2013, 'Assessment of coastal protection as an ecosystem service in Europe', *Ecological Indicators* 30, 205–217, doi:10.1016/j.ecolind.2013.02.013.

Lusher, A.L., McHugh, M. and Thompson, R.C., 2013, 'Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel', *Marine Pollution Bulletin* 67(1–2), 94–99, doi:10.1016/j.marpolbul.2012.11.028.

Marchand, M. (Ed.), 2010, *Concepts and Science for Coastal Erosion Management. Concise report for policy makers*. Deltares, Delft, http://www.conscience-eu.net/documents/concise-report-final.pdf (accessed 18 October 2013).

Marine Scotland, 2013, *Sectoral Marine Plans for Offshore Wind, Wave and Tidal Energy in Scottish Waters Pre-statutory Consultation — Draft Analysis Report*. Marine Scotland, http://www.scotland.gov.uk/Resource/0042/00423960.pdf (accessed 18 October 2013).

Martin, J.F., Reyes, E., Kemp, G.P., Mashriqui, H. and Day, J.W., 2002, 'Landscape Modeling of the Mississippi Delta. *BioScience* 52(4), 357–365, doi:http://dx.doi.org/10.1641/0006-3568(2002)052[0357:LMOTMD]2.0.CO;2.

McLaughlin, S. and Cooper, J.A.G., 2010, A multi-scale coastal vulnerability index: a tool for coastal managers?', *Environmental Hazards* 9(3), 233–248, doi:10.3763/ehaz.2010.0052.

Mcleod, E., Poulter, B., Hinkel, J., Reyes, E. and Salm, R., 2010, 'Sea-level rise impact models and environmental conservation: a review of models and their applications', *Ocean & Coastal Management* 53(9), 507–517, doi:10.1016/j.ocecoaman.2010.06.009.

Meiner, A., 2010, 'Integrated maritime policy for the European Union — consolidating coastal and marine information to support maritime spatial planning', *Journal of Coastal Conservation* 14(1), 1–11, doi:10.1007/s11852-009-0077-4.

Meiner, A., 2013, 'Spatial data management priorities for assessment of Europe's coasts and seas', *Journal of Coastal Conservation* 17(2), 271–277, doi:10.1007/s11852-011-0173-0.

Mills, E., 2005, 'Insurance in a Climate of Change', *Science* 309(5737), 1 040–1 044, doi:10.1126/science.1112121.

Mokrech, M., Nicholls, R.J., Richards, J.A., Henriques, C., Holman, I.P. and Shackley, S., 2008, 'Regional impact assessment of flooding under future climate and socio-economic scenarios for East Anglia and North West England', *Climatic Change* 90(1-2), 31–55, doi:10.1007/s10584-008-9449-2.

Mouat, J., Lozano, R.L. and Bateson, H., 2010, *Economic Impacts of Marine Litter. KIMO*, http://www.kimointernational.org/WebData/Files/Marine%20Litter/Economic%20Impacts%20of%20Marine%20Litter%20Low%20Res.pdf (accessed 18 October 2013).

Naturvårdsverket, 2013, *Managing the dioxin problem in the Baltic region with focus on sources to air and fish*. Final report from the research project BalticPOPs (No. 6 566). Swedish Environmental Protection Agency report. Swedish Environmental Protection Agency, Stockholm, http://www.swedishepa.se/Documents/publikationer6400/978-91-620-6566-9.pdf (accessed 18 October 2013).

Nicholls, R.J. and Cazenave, A., 2010, 'Sea-Level Rise and Its Impact on Coastal Zones', *Science* 328(5985), 1517–1520, doi:10.1126/science.1185782.

Nicholls, R.J. and Klein, R.J.T., 2005, 'Climate change and coastal management on Europe's coast'. In: *Managing European Coasts* Environmental Science (J. Vermaat, W. Salomons, L. Bouwer and K. Turner, eds.), 199–226. Springer, Berlin, Heidelberg, http://link.springer.com/chapter/10.1007/3-540-27150-3_11 (accessed 18 October 2013).

Nicholls, R.J., Wong, P.P., Burkett, V., Codignotto, J., Hay, J., McLean, R., Ragoonaden, S. and Woodroffe, C.D., 2007, 'Coastal systems and low-lying areas'. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds.), 351–356. Cambridge University Press, Cambridge, United Kingdom.

OECD, 2012, *OECD Environmental Outlook to 2050: The Consequences of Inaction*. Organisation for Economic Co-operation and Development, Paris, http://www.oecd-ilibrary.org/content/book/9789264122246-en (accessed 18 October 2013).

OSPAR, 2010, *Quality Status Report 2010*. OSPAR Commission, London, http://qsr2010.ospar.org/en/downloads.html (accessed 18 October 2013).

Park, R.A., Clough, J.S., Jones, R. and Galbraith, H., 2003, 'Modelling the impacts of sea-level rise'. In: *NOAA Proceedings of the XIII Biennial Coastal Zone Conference*. NOAA, Baltimore, MD.

Park, R.A., Trehan, M.S., Mausel, P.W. and Howe, R.C., 1989, *The effects of sea-level rise on U.S. coastal wetlands and lowlands*, 48. Holcomb Research Institute, Butler University, Indianapolis, Indiana.

Pedersen, S.A., Fock, H.O. and Sell, A.F., 2009, 'Mapping fisheries in the German exclusive economic zone with special reference to offshore Natura 2000 sites', *Marine Policy* 33(4), 571–590, doi:10.1016/j.marpol.2008.12.007.

Petersen, J.K., Hansen, J.W., Laursen, M.B., Clausen, P., Carstensen, J. and Conley, D.J., 2008, 'Regime shift in a coastal marine ecosystem', *Ecological Applications* 18(2), 497–510, doi:10.1890/07-0752.1.

Petroleumtilsynet, 2012, *Risikonivå i petroleumsvirksomheten — Akutte utslipp Norsk sokkel 2001–2011*, 125. Petroleumtilsynet, http://www.ptil.no/getfile.php/PDF/RNNP-AU%202012/RNNP-%20Akutte%20utslipp%20-%20endelig%20rapport%202012.pdf (accessed 18 October 2013).

Philippart, C.J.M., Anadón, R., Danovaro, R., Dippner, J.W., Drinkwater, K.F., Hawkins, S.J., Oguz, T., O'Sullivan, G. and Reid, P.C., 2011, 'Impacts of climate change on European marine ecosystems: Observations, expectations and indicators', *Journal of Experimental Marine Biology and Ecology* 400(1–2), 52–69, doi:10.1016/j.jembe.2011.02.023.

Policy Research Corporation, 2011, *Study on the economic effects of Maritime Spatial Planning — Final report (Final Report)*. Legal and socio-economic studies in the field of the Integrated Maritime Policy for the European Union. European Commission, Luxembourg, http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/economic_effects_maritime_spatial_planning_en.pdf (accessed 18 October 2013).

Policy Research Corporation and MRAG, 2009, *The economics of climate change adaptation in EU coastal areas (Final Report)*, 153. Directorate-General for Maritime Affairs and Fisheries, Antwerp, http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/report_en.pdf (accessed 18 October 2013).

Proença, B., Oliveira, F.S.B.F. and Sancho, F., 2011, 'Coastal Erosion Management in Algarve (Portugal) — a Beach Nourishment Case Study', *Journal of Coastal Research* 328–334, doi:10.2112/SI61-001.33.

Ramieri, E., Hartley, A., Barbanti, A., Duarte Santos, F., Gomes, A., Hildén, M., Marinova, N. and Santini, M., 2011, *Methods for assessing coastal vulnerability to climate change,* Technical Paper No. 1/2011. ETC/CCA Technical Paper. ETC/CCA, Bologna.

Rapport, D.J. and Hildén, M., 2013, 'An evolving role for ecological indicators: From documenting ecological conditions to monitoring drivers and policy responses', *Ecological Indicators* 28, 10–15, doi:10.1016/j.ecolind.2012.05.015.

Reyes, E., White, M.L., Martin, J.F., Kemp, G.P., Day, J.W. and Aravamuthan, V., 2000, LANDSCAPE MODELING OF COASTAL HABITAT CHANGE IN THE MISSISSIPPI DELTA, *Ecology* 81(8), 2 331–2 349, doi:10.1890/0012-9658(2000)081[2331:LMOCHC]2.0.CO;2.

Richards, J.A., Mokrech, M., Berry, P.M. and Nicholls, R.J., 2008, 'Regional assessment of climate change impacts on coastal and fluvial ecosystems and the scope for adaptation', *Climatic Change* 90(1-2), 141–167, doi:10.1007/s10584-008-9451-8.

Richards, J.A. and Nicholls, R.J., 2009, *Impacts of climate change in coastal systems in Europe. PESETA-Coastal Systems study,* Report No. EUR 24130 EN. JRC Scientific and Technical Reports. JRC-IPTS, Seville, http://ftp.jrc.es/EURdoc/JRC55390.pdf (accessed 18 October 2013).

Selkoe, K.A., Halpern, B.S., Ebert, C.M., Franklin, E.C., Selig, E.R., Casey, K.S., Bruno, J. and Toonen, R.J., 2009, 'A map of human impacts to a 'pristine' coral reef ecosystem, the Papahānaumokuākea Marine National Monument', *Coral Reefs* 28(3), 635–650, doi:10.1007/s00338-009-0490-z.

SimCLIM, 2012, SimCLIM Essentials, http://simclim.climsystems.com/downloads.php (accessed 20 August 2013).

Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huq, S., Klein, R.J.T. and Yohe, G., 2001, 'Adaptation to climate change in the context of sustainable development and equity'. In: *Climate Change 2001: Impacts, Adaptation and Vulnerability* (J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, eds.), 877–912. Cambridge University Press, Cambridge, United Kingdom.

Smith, A.D., Taymaz, T., Oktay, F., Yüce, H., Alpar, B., Başaran, H., Jackson, J.A., Kara, S. and Şimşek, M., 1995, 'High-resolution seismic profiling in the Sea of Marmara (northwest Turkey): Late Quaternary sedimentation and sea-level changes', *Geological Society of America Bulletin* 107(8), 923–936, doi:10.1130/0016-7606(1995)107<0923:HRSPIT>2.3.CO;2.

SUSTAIN, 2012, DeCyDe for sustainability (Report). Interreg IVC, 16. Coastal & Marine Union, The Netherlands, http://www.sustain-eu.net/news/sustain-brochure.pdf (accessed 18 October 2013).

Swedish EPA, 2009, *What's in the sea for me — Ecosystem services provided by the Baltic Sea and Skagerrak,* Report No. 5872. SEPA Report. Swedish Environment Protection Agency, Stockholm.

Szlafsztein, C. and Sterr, H., 2007, 'A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil', *Journal of Coastal Conservation* 11(1), 53–66, doi:10.1007/s11852-007-0003-6.

Tetraplan, Institute for Transport Studies, Leeds, ISIS, Mcrit, BMT Transport Solutions, DTU-Transport, Institute for Regional Research, Kiel and Systema, Athens, 2009, *TRANSvisions — Report on Transport Scenarios with a 20 and 40 Year Horizon* (Final Report No. Contract A2/78-2007). Tetraplan, Copenhagen, http://ec.europa.eu/transport/themes/strategies/doc/2009_future_of_transport/20090324_transvisions_final_report.pdf (accessed 18 October 2013).

Thomas, J.A., Telfer, M.G., Roy, D.B., Preston, C.D., Greenwood, J.J.D., Asher, J., Fox, R., Clarke, R.T. and Lawton, J.H., 2004, 'Comparative Losses of British Butterflies, Birds, and Plants and the Global Extinction Crisis', *Science* 303(5665), 1 879–1 881, doi:10.1126/science.1095046.

Thompson, R.C., Moore, C.J., Saal, F.S. vom and Swan, S.H., 2009, 'Plastics, the environment and human health: current consensus and future trends', *Philosophical Transactions of the Royal Society B: Biological Sciences* 364(1526), 2 153–2 166, doi:10.1098/rstb.2009.0053.

Tol, R.S.J., 2006a, 'Multi-Gas Emission Reduction for Climate Change Policy: An Application of Fund', *The Energy Journal* Multi-Greenhouse Gas Mitigation and Climate Policy (Special Issue #3), 235–250.

Tol, R.S.J., 2006b, 'Exchange Rates and Climate Change: An Application of Fund', *Climatic Change* 75(1-2), 59–80, doi:10.1007/s10584-005-9003-4.

Tol, R.S.J., Klein, R.J.T. and Nicholls, R.J., 2008, 'Towards Successful Adaptation to Sea-Level Rise along Europe's Coasts', *Journal of Coastal Research* 432–442, doi:10.2112/07A-0016.1.

Tõnisson, H., Suursaar, Ü., Orviku, K., Jaagus, J., Kont, A., Willis, D. A. and Rivis, R., 2011, 'Changes in coastal processes in relation to changes in large-scale atmospheric circulation, wave parameters and sea levels in Estonia', *J. Coast. Res* 27, 701–705.

Torresan, S., Zabeo, A., Rizzi, J., Critto, A., Pizzol, L., Giove, S. and Marcomini, A., 2010, 'Risk assessment and decision support tools for the integrated evaluation of climate change impacts on coastal zones'. In: *International Environmental Modelling and Software Society (iEMSs) 2010 International Congress on Environmental Modelling and Software Modelling for Environment's Sake, Fifth Biennial Meeting, Ottawa, Canada* (D.A. Swayne, W. Yang, A.A. Voinov, A. Rizzoli and T. Filatova, eds.), 1–8, http://www.iemss.org/iemss2010/papers/W01/W.01.03.Risk%20assessment%20and%20decision%20support%20tools%20for%20the%20integrated%20evaluation%20of%20climate%20change%20impacts%20on%20coastal%20zones%20-%20SILVIA%20TORRESAN.pdf (accessed 18 October 2013).

Tweehuysen, G., 2013, *River litter — serious business*, http://wastefreewaters.wordpress.com (accessed 23 September 2013).

UNEP, 2005, *Marine Litter, an analytical overview*. UNEP, Nairobi, http://www.unep.org/regionalseas/marinelitter/publications/docs/anl_oview.pdf (accessed 18 October 2013).

UNEP, 2009, *Marine Litter: a Global Challenge*, 232. UNEP, Nairobi.

UNEP, 2012, *State of the Mediterranean marine and coastal environment — highlights for policymakers*, 12. UNEP, http://www.grida.no/publications/soemediterranean (accessed 18 October 2013).

UNEP/MAP-Plan Bleu, 2009, *State of the Environment and Development in the Mediterranean*. UNEP/MAP-Plan Bleu, Athens, http://planbleu.org/sites/default/files/publications/soed2009_en.pdf (accessed 18 October 2013).

Van Cauwenberghe, L., Claessens, M., Vandegehuchte, M. and Janssen, C.R., 2012, Occurrence of microplastics in mussels (*Mytilus edulis*) and lugworms (*Arenicola marina*) collected along the French-Belgian-Dutch coast. *VLIZ Special Publication* 55, http://bio.emodnet.eu/component/imis/?module=ref&refid=213327 (accessed 18 October 2013).

Vandenbruwaene, W., Maris, T., Cox, T.J.S., Cahoon, D.R., Meire, P. and Temmerman, S., 2011, 'Sedimentation and response to sea-level rise of a restored marsh with reduced tidal exchange: Comparison with a natural tidal marsh', *Geomorphology* 130(3-4), 115–126, doi:10.1016/j.geomorph.2011.03.004 (accessed 18 October 2013).

Warren Pinnacle Consulting, Inc., 2013, SLAMM: Sea Level Affecting Marshes Model, http://warrenpinnacle.com/prof/SLAMM/index.html (accessed 15 August 2013).

Warrick, R.A., Kenny, G.J. and Harman, J.J. (Eds), 2001, *The effects of climate change and variation in New Zealand: an assessment using the CLIMPACTS System*. International Global Change Institute, University of Waikato, Hamilton, http://docs.niwa.co.nz/library/public/0473079887.pdf (accessed 18 October 2013).

Warrick, R.A., Ye, W., Kouwenhoven, P., Hay, J.E. and Cheatham, C., 2005, 'New developments of the SimCLIM model for simulating adaptation to risks arising from climate variability and change'. In: *MODSIM 2005: International congress on modelling and simulation: advances and applications for management and decision making*, 551–558. Modelling and Simulation Society of Australia and New Zealand, Waikato, http://researchcommons.waikato.ac.nz/handle/10289/5486 (accessed 18 October 2013).

Özyurt, G. and Ergin, A., 2010, 'Improving Coastal Vulnerability Assessments to Sea-Level Rise: a New Indicator-Based Methodology for Decision Makers', *Journal of Coastal Research* 26(2), 265–273.

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