Sea Level Rise in Europe: Governance Context and Challenges

Bisaro, Alexander; Galluccio, Giulia; Fiorini Beckhauser, Elisa; Romagnoli, Claudia; McEvoy, Sadie; Sini, Eugenio; Biddau, Fulvio; David, Ruben; d'Hont, Floortje; Le Cozannet, Gonéri

DOI
10.5194/sp-3-slre1-7-2024

Publication date
2024

Document Version
Final published version

Published in
State of the Planet Discussions

State Planet, 3-slre1, 7, 2024
https://doi.org/10.5194/sp-3-slre1-7-2024

Sea Level Rise in Europe: Governance context and challenges

Alexander Bisaro[1], Giulia Galluccio[2], Elisa Fiorini Beckhauser[2,3], Fulvio Biddau[2], Ruben David[2], Floortje d'Hont[6], Antonio Góngora Zurro[8], Gonéri Le Cozannet[7], Sadie McEvoy[5], Begoña Pérez Gómez[8], Claudia Romagnoli[4], Eugenio Sini[2], and Jill Slinger[6,9]

[1]Adapt 3E, Berlin, Germany
[2]CMCC Foundation – Euro-Mediterranean Center on Climate Change, Milan, Italy
[3]Department of Legal Sciences, University of Salento, Lecce, Italy
[4]Department of Biological, Geological, and Environmental Sciences, University of Bologna, Bologna, Italy
[5]Climate Adaptation and Disaster Risk Management, Deltares, Delft, the Netherlands
[6]Multi-Actor Systems Department, Faculty of Technology, Policy and Management, Delft University of Technology, Delft, the Netherlands
[7]BRGM, Orléans, France
[8]Puertos del Estado, Madrid, Spain
[9]Institute for Water Research, Rhodes University, Makhanda, South Africa

Correspondence: Alexander Bisaro (bisaro@adapt3e.org) and Giulia Galluccio (giulia.galluccio@cmcc.it)

Received: 1 December 2023 – Discussion started: 9 January 2024
Revised: 19 April 2024 – Accepted: 9 May 2024 – Published: 29 October 2024

Abstract. Sea level rise (SLR) will affect Europe's coasts over the coming decades and beyond, giving rise to ongoing challenges in governing coastal and marine areas. Progress is being made in adapting to and addressing these challenges at both national and sub-national levels across all major European sea basins. This paper assesses progress in coastal adaptation governance in Europe by, first, characterising the socio-economic and political contexts in European sea basins and then by reviewing coastal-adaptation-relevant policy frameworks in place at regional and national levels within each of these sea basins. The regional frameworks reviewed are derived from regional sea conventions and are assessed for their legal status and their inclusion of SLR information. The national coastal policy frameworks reviewed include national adaptation plans focusing on coastal areas and marine spatial planning instruments for all European member states, as well as public financing arrangements for coastal adaptation, focusing on flood risk reduction measures. Key national policies for coastal adaptation are assessed for which coastal hazards they address, the extent to which they incorporate sea level rise information and their inclusion of SLR-specific adaptation measures. Finally, the paper presents governance challenges that arise due to the complexity of adaptation to SLR, i.e. time horizon and uncertainty, cross-scale and cross-domain coordination, and equity and social vulnerability, and discusses examples illustrating how each of these challenges is being addressed in different European sea basins. The paper finds that for all basins, regional policy frameworks generally do not include specific provisions for SLR or coastal adaptation, while at the national level, significant progress on SLR governance is being made. For all basins except for the Black Sea, all countries have reported observed and future SLR hazards and have adopted adaptation strategies. The inclusion of adaptation measures specific to SLR is less advanced, as most sea basins have at least one country that does not include specific SLR adaptation measures in either their adaptation strategies or their marine spatial plans. Regarding SLR governance challenges, key examples of how these are being addressed include approaches for incorporating flexibility into coastal planning, e.g. dynamic adaptation pathways in the Netherlands or dike crest widening in Germany, as well as co-development of nature-based adaptation solutions in Italy. Examples of addressing equity and social vulnerability challenges include the emerging issue of climate ligation illustrated through several court cases on liability for SLR-related damage.

Published by Copernicus Publications.

1 Introduction

Sea level rise (SLR) will affect Europe's coasts over the coming decades and beyond, giving rise to ongoing challenges for governing coastal and marine areas. Sea level rise will increase the frequency and intensity of coastal flood hazards; alter shoreline dynamics, potentially increasing coastal erosion; and increase saltwater intrusion, altering risk profiles in European coastal and marine areas (cf. van de Wal et al., 2024, for a comprehensive review). These impacts must be integrated into coastal governance approaches in order to ensure resilience, equity and sustainability over the long term.

Coastal governance can be defined as a comprehensive framework comprising institutional, structural and legal arrangements – primarily policies, regulations and economic activities, as well as social and cultural institutions established through processes of assessment, consultation and decision-making in a multiscale structure ranging from the local to the global level (Stephenson et al., 2019). Coastal governance thus involves heterogeneous subjects, such as coastal management, land-use planning, environmental law and policies, and environmental science, that interact within coastal governance structures. As an arena where the effects of many land-based and sea activities intersect, coastal governance is thus complex and can be characterised by not only conflict but also policy integration (Van Assche et al., 2020). The latter requires in-depth knowledge of coordination mechanisms, governance planning and related challenges. In this context, the challenges of managing Europe's sea basins in a healthy, productive, safe and resilient manner (Ocean governance) have emerged and are exacerbated by the cumulative nature of the impacts of activities carried out in coastal areas and of sea level rise. Thus, coastal governance challenges under SLR involve increasing complexity due to the long time horizons and uncertainty involved in planning for SLR, cross-scale and cross-domain coordination needed to deal with the scale of the challenge, and ensuring equity and addressing social vulnerability in adaptation to SLR. This paper set outs to assess progress in Europe in addressing these challenge by both reviewing the regional and national policy contexts in which coastal governance takes place and examining specific examples of approaches.

In order to do so, the paper focuses on six European sea basins: the north-east Atlantic Ocean, Mediterranean Sea, Black Sea, Baltic Sea, North Sea and Arctic Ocean. For each basin, the paper reviews (i) key intersections between geopolitics and socio-economics of the basin and SLR; (ii) coastal governance policies in force to clarify the enabling and constraining conditions of the institutional frameworks relevant to the European Union; and (iii) financial arrangements for coastal adaptation, decision-making under uncertainty, and cross-cutting and cross-domain coordination. Further, the paper then (iv) analyses approaches to governance challenges related to SLR in a fair, equal and democratic way in Europe. Finally, the concluding section discusses how governance challenges caused by SLR are being addressed within each of the basins. Throughout the paper, specific examples of approaches to addressing these governance challenges have been highlighted in text boxes in the relevant sections.

2 Geopolitical and socio-economic context of SLR governance

2.1 Geopolitical context in European sea basins

SLR may exacerbate geopolitical conflicts and act as a risk multiplier (Stephenson et al., 2019). It has relevant socio-economic, environmental and cultural consequences for European daily lives (European Environment Agency, 2024a), threatening livelihoods and industry, food and water security, health, infrastructure, critical services, and cultural heritage. Low-lying areas and coastal zones are particularly vulnerable (Horton et al., 2018), which poses substantial challenges to many European countries where millions of people live in coastal settlements (European Environment Agency, 2024b).

European sea basins have become geopolitical hotspots in recent years, and against this background, addressing SLR-related challenges will require a high degree of cooperation and joint action across sea basin boundaries, with specific and tailored strategies. In this respect the EU has been employing great efforts to foster positive cooperation and promote further connectivity in these regions, which can be challenging, especially in contexts where there is a mix of EU member states and associated countries, as in the case of the Mediterranean and Black seas (see "Key multilateral policy frameworks governing coastal adaptation" under the "Coastal governance" section).

SLR and the challenges it poses comprise a geopolitical issue for all European sea basins. Some of the sea basins have already experienced clear geopolitical issues related to sea level rise, and these have been reported in the literature. The following paragraphs elaborate on these specific examples that have already been tracked, and although some of the sea basins do not yet have specific examples, the geopolitical challenges that have emerged in one sea basin can easily be verified in the others in the future.

The Mediterranean Sea basin is a non-homogeneous area that has witnessed the emergence of state fragility, conflicts and security threats in countries that will be unevenly affected by the impacts of SLR. In northern Africa, for instance, saltwater intrusion is contaminating land and freshwater resources, destroying crops and livelihoods alike. Southern Europe and low-lying coastal regions, including many densely populated cities, are hotspots for risks such as erosion and saltwater intrusion aggravated by SLR (European Environment Agency, 2024a). Despite these effects

of SLR in southern Europe, the European shore has better tools and levels of resilience against such impacts than other bordering countries of the Mediterranean Sea basin, which demonstrates that overcoming geopolitical and socioeconomic challenges will require a high level of cooperation and joint action across borders (de Marignan, 2023). Hence, priorities in this sea basin include promoting conflict prevention and peacebuilding, counter-piracy, maritime security, counterterrorism, and the management of migration flows. This signals that strengthening partnerships with all neighbouring countries is a strategic imperative for the EU (European Commission, 2021b).

SLR also poses challenges for infrastructural security in the sea basins, as it can affect vessel navigation, critical waterways, transportation routes and berthing with ports. Damage to lighthouses and erosion of coastal roads are also risks. In addition to coastal facilities, low-lying military installations, especially in naval bases in the Black Sea, are also particularly susceptible to SLR (Mihailov et al., 2023). In this sea basin, therefore, the key issues are long-term stability, conflict management and the consolidation of a stable energy supply.

Critical maritime infrastructure is a salient issue for the Baltic Sea countries due to their role in energy security, underwater security and military planning (Swistek and Paul, 2023). Two elements are central to the SLR in the Baltic Sea basin: while the relative increase in SLR may be counteracted by land uplift in the northern areas, the ice cover situation will further decrease with a lowering of the maximum sea ice extent. Besides, SLR could also affect oil and gas operations, competition for energy resources, and potentially strategic positions on global trade routes (Thangaraj and Chowdhury, 2022). Hence, the strategic interests in this sea basin are energy security, trade and business, transnational crime, and targeted influence on societies in terms of information and cyberspace.

As a major transport hub in Europe, the North Sea basin hosts a strong transport and logistics industry (CPMR North Sea Commission, 2020). It is an attractive setting for offshore wind farms, with renewable-energy potential expected to increase as new technologies emerge and Europe's electricity networks are modernised (Mjahed, 2023). Sea-based energy supplies and maritime energy infrastructure are becoming increasingly relevant within European infrastructural decoupling from land-based supplies, and offshore wind farms and undersea power cables are likely to cover a relevant part of the electricity demand of Europe in the maritime region (Just Climate, 2022). Over the next decades, therefore, the North Sea is likely to play a key role in Europe's energy transition for net-zero emissions and in achieving the EU's climate targets, which require further policies and investment in green energy sources, technologies and grid infrastructure (CPMR North Sea Commission, 2020).

The Atlantic Ocean basin is the largest in terms of gross value added (GVA) and plays an important role in the blue economy of the EU (EU Blue Economy Observatory, 2024). Its countries play a vital role in maintaining international stability and security to balance the power distribution within the region (Adhitama, 2019), with regard to key issues such as maritime surveillance, the exercise of sovereignty at sea and the sustainable exploitation of natural resources (see Sect. 2.2). Further, international cooperation on aspects of communication systems such as submarine cables or cooperation between islands and Atlantic spaces is also important geopolitically and for security in the basin (Instituto de Defesa Nacional, 2022).

In the Arctic Ocean, as permafrost melts and coastlines erode, there is likely to be competition over land claims for oil and gas reserves, natural minerals, hydrocarbon, and rare earth elements useful for modern technology, also making the region a site of increasing global competition for profitable trade routes (Gross, 2020). The EU's engagement in the Arctic Ocean is crucial for European security, given the interest in resources and transport routes (European Commission, 2021b).

This overview signals that the European Union faces the challenge of aligning long-term climate goals with short-term supply chain security and managing energy independence with geopolitical risks and uncertainties.

2.2 Economic context in European sea basins

The EU economy significantly relies on service sectors, which accounted for more than 70 % of the value added to the economy in 2020, while importing about two-thirds of its energy, especially natural gas and crude oil. In 2020, the total weight of goods transported through EU ports by short sea shipping was 1.7×10^9 t (Eurostat, 2022). The European Climate Risk Assessment observes that SLR will increase the frequency and severity of coastal flooding in Europe, with potentially devastating impacts on Europe's population, infrastructure and economic activities (European Environment Agency, 2024a, c). In this sense, SLR may have relevant economic consequences for GDP at regional and sectoral levels in Europe. Predictions demonstrate that damage caused by SLR could amount to EUR 871.8 billion for the continent by the end of the century, a GDP loss of 1.26 % for the whole of the European Union (Cortés Arbués et al., 2024).

EU policy relevant to coastal and marine areas is guided by the European Commission's Sustainable Blue Economy Partnership, which stipulates that activities such as fisheries, coastal tourism and maritime transport reduce their environmental and climate impacts, tackle biodiversity loss and create alternatives to fossil fuels. Investment in new technologies is also a priority, with special attention given to wave and tidal energies, development of innovative fishing gear, and restoration of marine ecosystems, each of which may also create green jobs and business (Eurostat, 2022). The *EU Blue Economy Report 2023* shows that most of the sectors have increased their economic development since 2020.

For instance, from 2010 to 2020, GDP has increased +25 % for living resources, +25 % in port activities, +1762 % in offshore wind energy, and +22 % in ship building and repair. Notably, employment in the offshore wind energy sector surged by 20 times over the last decade (European Commission, 2023b).

Table 1 describes, for each sea basin, the currently significant economic sectors in coastal and marine areas as well as emerging sectors relevant to the EU sustainable blue economy approach.

3 Coastal governance

The governance of SLR involves a broad range of institutions, actors and stakeholders. In addition to the affected countries and their governmental agencies, commercial entities – mainly of manufacturing, transport, fisheries and tourism; fossil fuel users and producers; and international, non-governmental and also scientific organisations make up the key actors in play (Douglas and Kaspari, 2019). Regarding the norms, policy frameworks relevant to SLR governance at European sea basin spheres are in place at two levels: the regional level through multilateral agreements between states and the national level. The latter remains the key level for the management of coastal and marine areas because national policy-makers maintain decision-making authority for the planning as well as design, implementation and financing of measures in coastal and marine areas in Europe. A further key dimension of governance is the financing of coastal adaptation and approaches to public finance of coastal adaptation, which are also reviewed below.

3.1 Key multilateral policy frameworks governing coastal adaptation

The policy and governance frameworks currently in place to tackle the impacts of climate change on coastal areas include diverse and cross-cutting instruments. At the international level, these mainly include the UN 2030 Agenda for Sustainable Development, the United Nations Convention on the Law of the Sea (UNCLOS), other regional sea conventions (RSCs) and the integrated coastal zone management (ICZM) process. At the European level, while the European Green Deal generally targets the protection of oceans and coasts, it does not include specific instruments or measures concerning SLR. However, other policies have previously addressed issues related to SLR, as in the case of specific directives such as the Maritime Spatial Planning Directive (European Commission, 2014b), the Floods Directive (European Commission, 2007) and the Marine Strategy Framework Directive (European Commission, 2008), which are relevant policies for climate resilience in coastal zones.

Furthermore, aiming to make the adaptation process more systemic, the 2021 EU Strategy on Adaptation to Climate Change recognises the importance of addressing climate impacts and resilience in all sectors and areas, including coastal zones.

The 2030 Agenda for Sustainable Development is a global action programme aimed at guiding the action of individual states and the international community in the different areas of sustainable development. The 2030 Agenda for Sustainable Development and its sustainable development goals (SDGs) have become an international reference framework for sustainable development, understood in its three dimensions of economic growth, social inclusion and environmental protection. The "fight against climate change" is goal number 13 of the agenda and is composed of five targets, among which are those that call for "strengthening resilience and adaptation to climate-related risks and natural disasters in all countries" (13.1) and for "integrating climate change measures into national policies, strategies and planning" (13.2). Besides, for the first time, the conservation and sustainable use of the oceans were addressed in an overarching global policy agenda. SDG 14 – Life Below Water – brings ocean governance to the forefront of the dialogue on sustainable development, enabling a structure that can benefit ecosystems as well as people and their livelihoods (Vierros, 2017).

UNCLOS is the international agreement which sets forth the legal framework for all activities on the oceans and seas. UNCLOS defines the rights and responsibilities of states with respect to their use of the oceans and establishes principles of protection of the marine environment, including the ecosystem-based approach, the precautionary principle and sustainable development. UNCLOS provisions approach the limits of maritime zones and the rights of passage and navigation through them, establishing principles on how states should determine the breadth of the maritime zones.

Regarding climate change and SLR, this legal framework is mainly relevant due to legal implications of SLR on baselines from which the outer limits and boundaries of maritime zones are determined (e.g. some parts of the world may witness a substantial shift in the configuration of the coasts, which can consequently affect base points and baselines). UNCLOS is one of the most widely ratified treaties under the international law framework and is currently a legally binding instrument for 168 signatories, including the EU. Under this treaty, the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ) was adopted in 2023. This international legally binding treaty aims at ensuring the responsible use of the marine environment, maintaining the integrity of ocean ecosystems and conserving marine biological diversity. While countries' exclusive economic zones are legally separate entities from the BBNJ, they have an ecological and biological connection. Thus, governance in this context would benefit from an ecosystem approach that considers species that cross political boundaries. This approach would be positive for fishery resources; migratory species; and coastal communities for which ecosystems have economic, social and cultural im-

Table 1. Key economic sectors and developments in coastal and marine areas in European sea basins (see all the references in the table footnotes).

Sea basin	Current economic sectors	Emerging sectors
Mediterranean Sea[a]	*Coastal and maritime tourism.* This is the world's leading tourism area with 35 % of all international tourist arrivals. It accounts for 13 % of Mediterranean countries' exports. In 2018, 2.3 million businesses employed 12.3 million individuals in tourism-related sectors. *Fishing and aquaculture.* This sector accounts for a workforce and employment of 1 million people. The total revenue from marine capture fisheries for the Mediterranean area was estimated at USD 2.7 billion, while the total employment on board fishing vessels was 166 000 in 2020. USD 12 billion is the estimated combined output of fisheries and aquaculture, and 112 % is the increase in aquaculture production in the EU Mediterranean countries expected in 2030 in comparison to 2010.	*Desalination.* This is a blue economy emerging sector with more than 2300 operational desalination plants in the EU producing about 9.2×10^6 m^3 d^{-1} of desalinated water. *Floating offshore wind.* This is a viable option for deep waters, possibly opening new markets, as the highest resource potential for ocean energy. *Offshore green energy development.* Italy, Spain and Albania have signed a memorandum of understanding for the development of five green hydrogen projects in the Mediterranean Basin (three in Italy, one in Albania and one in Morocco). In Spain, Naturgy and Energas have announced a plan for a green hydrogen project off the coast of Asturias.
Black Sea[b]	*Fishing.* The total revenue from marine capture fisheries was estimated at USD 241 million in 2020, with a total employment on board fishing vessels of 28 000. *Aquaculture.* Production has grown from over 500 000 t of farmed seafood in 2017 to over 700 000 t in 2019, helping to boost food security and providing jobs and incomes.	*Ocean energy.* The potential for wave energy and floating offshore wind may open new markets in this basin, fostering EU competitiveness.
Baltic Sea[c]	*Shipping and port activities.* These account for 15 % of the world's cargo traffic in 2017. *Fishing.* In 2018, the fleets numbered 290 vessels and employed 4265 full-time-equivalent workers. The revenue generated amounted to EUR 215 million, 74 % of which came from Poland, Sweden, Finland and Denmark.	*Offshore wind energy.* Currently only 2.8 GW of total capacity is installed, and the Baltic's eight border countries are committed to increasing that to 19.6 GW by 2030. Offshore energy is projected to multiply 5-fold by 2030 and 30-fold by 2050 on an EU-wide level. *Wave energy.* This is a renewable source with localised exploitable potential. *Offshore green hydrogen.* Its development has an important source through the wind energy of the sea.
North Sea[d]	*Shipping and port activities.* This is one of the world's busiest shipping grounds with over 7600 ships passing through hotspot areas of this sea basin. *Oil and gas.* This is western Europe's most important oil and gas production area that yields high-quality crude oil with a low sulfur content. *Fishing.* This is one of the world's most important fishing grounds, with around 6600 active fishing vessels.	*Wave energy, wind energy and floating solar photovoltaic energy.* Regarding the potential of floating photovoltaics, the Dutch government aims to develop pilot projects in the North Sea in the period 2021–2026 to monitor the efficiency and environmental impact of such installations. *Offshore wind energy.* Germany, France, Belgium and the Netherlands intend to jointly build 150 GW of offshore wind energy by 2050. The states also plan to collaborate on joint offshore wind projects, energy islands and offshore grid infrastructure, as well as strengthening renewable hydrogen production.
North-east Atlantic Ocean[e]	*Coastal and maritime tourism.* This area offers high-quality tourism, and in 2019, Lisbon was the most visited port of call for cruise ships along the Atlantic coast of Europe, with 310 port calls. *Shipping and ports.* Shipping activities have increased by 34 % since 2019, including in 73 % of marine protected areas, and western Scotland experienced the largest increase in vessel density. *EU blue economy.* This is the largest sea basin in terms of GVA (36 % of the EU blue economy GVA). In 2017, the blue economy in the Atlantic Ocean employed 1.20 million people.	*Ocean energy.* At the European level, the Atlantic coast has notably the highest resource potential for wave and tidal energies, which are expected to be further developed up to 2030 with new EU resources and projects such as EnergyMare and the improvement of technologies. Deep-sea mining, environmental monitoring, desalination and offshore wind are also relevant sectors for the future.

Table 1. Continued.

Sea basin	Current economic sectors	Emerging sectors
Arctic Ocean[f]	*Oil and natural gas.* Important resources of minerals, notably hydrocarbons, and two of the world's major producing areas for oil and natural gas lie in the Arctic, namely north-western Siberia and the North Slope of Alaska. *Fishing, shipping and manufacturing.* These are strong industries in these sectors at the macroeconomic level. In 2016, the Arctic provided about USD 281 billion per year in terms of food, mineral extraction, oil production, tourism, hunting, existence values and climate regulation.	*Fibre cables and data centres.* Strategically located for global connectivity, the melting Arctic ice creates new opportunities for the tech industry. Technologies can benefit from the cold climate and abundant hydropower, and some of the largest data centres are scheduled to be built in the region. *Raw materials underground.* A warmer climate will enable mining in previous inaccessible zones. The region is rich in raw materials that are relevant to green technologies, e.g. used in batteries for electric cars and wind turbines.

[a] Plan Bleu (2022), FAO (2020), European Commission (2021c), Interreg Sudoe (ECCLIPSE: Assessment of Climate change in Ports of Southwest Europe), ISPI (2023). [b] FAO (2020, 2022), Kakachia et al. (2022). [c] Just Climate (2022), Krūmiòš and Kïaviòš (2022), Swistek and Paul (2023). [d] Chirosca et al. (2022), CPMR North Sea Commission (2020), Mjahed (2023). [e] UNCTAD (2022), O'Garra (2017), European Commission (2014–2020). [f] Mancebo Silva (2022), Gross (2020), European Commission (2021d).

portance. Marine areas beyond national jurisdiction present particular challenges, since they need integrated approaches but there is no organisation or institution in charge of the overall management responsibility. Besides, except for UNCLOS, current international regulation and institutional arrangements are all sectoral in nature (Vierros, 2017).

The regional sea conventions (RSCs) are cooperation structures set up to bring together states and neighbouring countries that share marine waters to protect the marine environment of a specific region. Some of these instruments are part of the United Nations Environment Programme (UNEP) Regional Seas Programme,[1] and they provide inter-governmental frameworks to address the ecological degradation of the oceans and seas at a regional level. While in an initial phase they focused on sea pollution, they are currently embracing the ecosystem approach to managing marine resources. There are also different protocols annexed to these treaties, including those on integrated coastal zone management (ICZM) through which one can address disaster reduction and climate change adaptation issues.

The European Commission has adopted initiatives such as the EU Maritime Security Strategy (EUMSS), which since 2014 has aimed to protect the EU's economic and infrastructure interests at sea; safeguard the marine environment; uphold international law – in particular the United Nations Convention on the Law of the Sea; and ensure training against growing cyber and hybrid threats. In 2023, the European Commission enacted an update of the EU Maritime Security Strategy and its action plan. The document approaches SLR as a climate-related challenge with a long-term and rolling-basis time frame for actions that are mainly related to developing awareness and preparedness for the phenomenon. In this sense, the management of risks and threats involves increasing "knowledge on the effects of climate change, SLR, storm surges, and environmental degradation on maritime security and addressing related risks and threats" (European Commission, 2023a). Besides, the Marine Strategy Framework Directive (MSFD) is the EU's main tool to protect and conserve the health of coasts and seas, aiming to achieve a good environmental status of the EU's marine waters and sustainably protect the resource base upon which marine-related economic and social activities depend. Adopted in 2008, the MSFD made the ecosystem-based approach legally binding for managing the EU's marine environment and maintaining resilient ecosystems while securing a sustainable use of marine resources.

The European regional sea conventions are the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR); the HELCOM Convention on the Protection of the Marine Environment of the Baltic Sea (Helsinki Convention); the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention or BAR-

[1] UNEP's Regional Seas Programme has three types of regional sea conventions, namely (a) UNEP-administered – established and directly administered by UNEP, who provides secretariat functions, managing of finances and technical assistance – comprising five regional sea conventions and two action plans (Wider Caribbean, East Asian seas, East Africa region, Mediterranean, Northwest Pacific, West and Central Africa; the Regional Office for Europe administers the Tehran Convention (Caspian Sea)); (b) non-UNEP administered – established under the auspices of UNEP, but another regional body provides the secretariat and administrative functions (Black Sea region, North-East Pacific region, Red Sea and Gulf of Aden region, ROPME Sea Area, South Asian Seas, South-East Pacific Region, Pacific Region); and (c) independent – not established by UNEP but cooperates with the Regional Seas Programme and attends regular meetings (Arctic Region, Antarctic Region, Baltic Sea, North-East Atlantic region). Details on the UNEP Regional Seas Programme are available at https://www.unep.org/topics/ocean-seas-and-coasts/regional-seas-programme/regional-seas-programme (last access: 15 January 2024).

CON), including, for example, the UN Environment Programme Mediterranean Action Plan (UNEP/MAP); and the Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention, under the Black Sea Commission, BSC). These policy mechanisms support regional sea protection and play an important role in achieving consistent marine assessments. Although the RSCs are not part of the EU system, the European Commission is a contracting party to three of them (HELCOM, OSPAR and UNEP/MAP). In HELCOM and OSPAR, most contracting parties are also members of the EU, whereas this is not the case for BARCON and the Bucharest Convention (Black Sea Commission, 1992). Besides the policies, the regional organisations for Europe's seas that have been establishing a regional cooperation are the Baltic Marine Environment Protection Commission (HELCOM), OSPAR, BARCON, the BSC and the Arctic Council (European Environment Agency, 2022; Ocean Governance, 2024).

There are also other important initiatives at the level of sea basins as well. Regarding the Mediterranean Sea basin, in 2014 the European Council adopted the EU Strategy for the Adriatic and Ionian Region (EUSAIR), which is a macro-regional strategic instrument aimed at supporting the integration of the western Balkans, providing political and financial support to enhance economic development, security, and sustainable tourism. This multilevel governance structure adopts a flexible, non-regulatory cooperation framework and helps to promote political and economic stability, thus fostering a solid foundation for European integration (European Commission, 2014a). Its 2020 Action Plan, however, does not mention SLR (European Commission, 2020a).

In 2017, the European Council adopted the Initiative for the sustainable development of the Blue Economy in the Western Mediterranean (WestMED Initiative; WESTMED Blue Economy Initiative, 2023). As a sea basin strategy (Kos and Štoka, 2021),[2] the WestMED Initiative focuses on generating growth, creating jobs and providing a better living environment for the population while preserving the services performed by the Mediterranean ecosystem (WestMED Initiative). Its framework for action mentions SLR only once, as part of the "sustainable fisheries and coastal community development" objective. The text highlights the critical role of knowledge for informing decision-making processes and investments that should fully consider climate change effects such as rising sea levels and coastal erosion (European Commission, 2017). These policies demonstrate that strengthening a Mediterranean partnership is a strategic imperative for the EU (European Commission, 2021b). In this path, the 2021 European Neighbourhood Policy (European Commission, 2021b) aims to enhance cooperation with Southern Neighbourhood countries[3] and promote conflict prevention and peacebuilding, counter-piracy, maritime security, and counterterrorism. The policy approaches environmental issues through a strategic priority of actively supporting measures to conserve, protect and restore the biodiversity of the Mediterranean (European Commission, 2021b). In the Black Sea basin, the Black Sea Synergy is a key EU initiative. In force since 2007, it has established sectors of cooperation such as (i) blue growth and economy; (ii) fisheries; (iii) environmental protection and climate change; (iv) cross-border cooperation; (v) civil society engagement, democracy and human rights; and (vi) energy and transport (European Commission, 2019b). The broader framework of the Black Sea Synergy also involves the Common Maritime Agenda (CMA) for the Black Sea, which is a bottom-up and EU sea basin strategy to enhance regional cooperation for achieving a sustainable blue economy. Besides engaging with bordering countries from inside and outside the EU, the CMA also involves a scientific pillar, the Strategic Research and Innovation Agenda (SRIA) for the Black Sea, which provides inputs for science-based decision-making (European Commission, 2019a).

As far as the Baltic Sea basin is concerned, the European Union Strategy for the Baltic Sea Region (EUSBSR) is the first internal EU strategy for a European macro-region. Based on an integrated long-term approach, this initiative has, since 2009, been pursuing the three pillars of saving the sea, connecting the region and increasing prosperity in the sea basin. Its sub-objectives include the promotion of clean and safe shipping; reliable energy markets; and climate change adaptation, risk prevention and management.

Regarding the North Sea basin, there is currently no formal strategy in force. However, the North Sea Region 2030 Strategy – a non-European Commission-steered strategy and voluntary initiative[4] – focuses on four priority areas: a productive and sustainable sea and a region that is climate-neutral, connected and smart.[5] The strategy sets goals in environmental, economic, infrastructure and socio-economic targets and builds on the strong industrial and research clusters already present in the North Sea basin countries (CPMR North Sea Commission, 2020). Environmental and climate

[2] EU sea basin strategies are established between member states and non-EU countries; the regional level is less involved – they target only sea basin neighbouring countries and have a higher policy coordination potential (European Commission, states and regions).

[3] Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia.

[4] "Non-EC-steered strategies" do not involve the European Commission; they are established between regional authorities and members of the CPMR (Conference of Peripheral Maritime Regions) and involve only the regional level, and thus there is lower policy coordination potential (only regions) (Kos and Štoka, 2021). For details, see https://blueair.adrioninterreg.eu/wp-content/uploads/2021/11/Technology-Park-Ljubljana.pdf (last access: 15 January 2024).

[5] A "smart" region refers to fostering economic diversification to ensure viable jobs and also developing innovative industries based on sustainable energy and tourism, a circular economy, and digitalisation.

objectives for 2030 include the creation of a healthy marine environment with the enhancement of blue economy sectors and sustainable aquaculture and fisheries, the production of more renewable energy, the increasing restoration of degraded ecosystems, and the fostering of climate adaptation measures (cf. Galluccio et al., 2024) to become climate-resilient (CPMR North Sea Commission, 2020). In terms of marine infrastructure, the region seeks to develop clean shipping and accessible transnational transport affordable for all social groups. For the socio-economic sphere, the region is focusing on smart specialisation strategies by fostering new industries based on marine resources, sustainable energy and tourism, a circular economy, and digitalisation which can increase employment rates with a more skilled workforce and seeks to include migrants in this process.

As for the Atlantic Ocean basin, the Atlantic Maritime Strategy (European Commission, 2011) is an EU sea basin policy adopted in 2011 that identifies challenges and opportunities under five thematic headings, namely implementing an ecosystem approach, reducing Europe's carbon footprint, sustainably exploiting the natural resources of the Atlantic seabed, responding to threats and emergencies, and promoting socially inclusive growth (European Commission, 2011). The strategy was updated in 2020 with an action plan (European Commission, 2020b) which does not mention SLR but focuses on four key thematic pillars: (i) Atlantic ports as gateways and hubs for the blue economy; (ii) promotion of blue skills of the future and ocean literacy; (iii) research, development and innovation and the exploitation of marine renewable energy; and (iv) healthy and resilient coasts. Promoting the role of ports in the sustainable development of sectors such as coastal tourism, aquaculture and shipbuilding is of key political and socio-economic interest to the transition to a carbon-free economy. Finally, the Atlantic Maritime Strategy also focuses on climate risk management and adaptation measures (see Galluccio et al., 2024) to protect coastal habitats and biodiversity and make Atlantic coastal areas more resilient. Subsequently, the circular economy, zero pollution and energy efficiency could contribute to the development of more sustainable practices, benefiting local economies and employment rates (European Commission, 2020b).

As for the Arctic Ocean, the EU's updated Arctic policy of 2021 focuses on three main issues, namely (i) maintaining peaceful cooperation in the region and developing strategic foresight on emerging security challenges; (ii) addressing climate-change-related challenges and making the Arctic more resilient with concerted action on black carbon and permafrost thaw; and (iii) supporting the sustainable development of the region with a focus on vulnerable groups such as Indigenous peoples, women and future generations. Another EU priority in the Arctic is to promote a precautionary and science-based approach to Arctic fisheries. Indeed, the EU is a party to the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, which entered into force in 2021 (European Commission, 2021b) and which has financed several scientific initiatives in the region. Finally, the EU intends to further strengthen Arctic marine governance and to further develop relations with partners in the region to ensure clean and sustainably managed seas (European Commission, 2021b).

The overview of international, regional and sea basin policies shows that integrating various management approaches undertaken by sectors into a comprehensive and cohesive plan is a challenge that remains in coastal governance.

Table 2 summarises the existing global, European and regional conventions and treaties that are directly or indirectly related to SLR and climate change management. Note that "soft law" refers to non-binding norms, principles, standards or guidelines that are used in international law and international relations.

Table 2. Key coastal policy frameworks: main objectives and relevance for SLR.

Instrument	Type of instrument		Objective		
	International or regional jurisdiction? Which sea basin?	Legally binding or soft law?	Main objectives	Specific measures on coastal adaptation?	Specific information on SLR
UN Convention on the Law of the Sea (UNCLOS – 1982)[a]	International, all	Legally binding	Define the rights and responsibilities of states in their use of the seas and oceans	No	Legal implications for baselines from which the outer limits and boundaries of maritime zones are determined
Agreement under UNCLOS on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction – BBNJ Agreement (High Seas Treaty)[b]	International, all	Legally binding	Conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction	No	No
UN 2030 Agenda for Sustainable Development[c]	International, all	Soft law	A global plan that sets out to achieve prosperity that is respectful of the planet and its inhabitants (based on five dimensions: people, planet, prosperity, peace and partnership)	No	No
Helsinki Convention (HELCOM – 1992)[d]	Regional, Baltic Sea	Legally binding	Protect from all sources of pollution, preserve biological diversity and promote the sustainable use of marine resources	No	No
Barcelona Convention (1995)[e]	Regional, Mediterranean Sea	Legally binding	Ensure sustainable management of marine and coastal natural resources, prevention of and reduction in pollution	Partially (Integrated Coastal Zone Management Protocol – ICZM Protocol)	No
Bucharest Convention (1992)[f]	Regional, Black Sea	Legally binding	Cooperation to protect the coastal and marine environment in the Black Sea; prevent, reduce and control the pollution	No	No
EU Strategy for the Baltic Sea Region (2009)[g]	Regional, Baltic Sea	Soft law	Improve sea basin governance, ensure a good environmental and ecological status of the marine and coastal areas	No	No
EU Strategy for the Adriatic and Ionian Region (EUSAIR – 2014)[h]	Regional, Mediterranean Sea	Soft law	Improve sea basin governance, ensure a good environmental and ecological status of the marine and coastal areas	No	No

https://doi.org/10.5194/sp-3-slre1-7-2024

Table 2. Continued.

Instrument	Type of instrument		Objective		
	International or regional jurisdiction? Which sea basin?	Legally binding or soft law?	Main objectives	Specific measures on coastal adaptation?	Specific information on SLR
Initiative for the sustainable development of the Blue Economy in the Western Mediterranean (WestMED Initiative, 2017)[i]	Regional, Mediterranean Sea	Soft law	Help public institutions, academia, local communities, and small- and medium-sized enterprises to develop maritime projects to strengthen the blue economy	General mention of adaptation to climate change in coastal cities	SLR is a major threat to coastal ecosystems and economies
European Neighbourhood Policy – 2021 Renewed partnership with the Southern Neighbourhood – A new agenda for the Mediterranean[j]	Regional, Mediterranean Sea	Soft law	Foster stability, security and prosperity in the EU's south and east neighbouring regions; set out a renewed agenda for the relaunching and strengthening of the strategic partnership between the EU and its Southern Neighbourhood partners	Yes	No
Black Sea Synergy initiative (2007)[k]	Regional, Black Sea	Soft law	Strengthen cooperation on good governance, environment, maritime policy and fisheries	No	No
The Common Maritime Agenda for the Black Sea[l]	Regional, Black Sea	Soft law	Support regional cooperation for a more sustainable blue economy in the Black Sea (developed in the broader framework of the Black Sea Strategy)	Yes	SLR is considered a major climate change effect, putting coastal and marine ecosystems at risk
The European Union Strategy for the Baltic Sea Region (EUSBSR)[m]	Regional, Baltic Sea	Soft law	The first macro-regional strategy in Europe aimed at saving the sea, connecting the region and increasing prosperity	No	SLR would affect at least 16 million people that live on the coast
North Sea Region 2030 Strategy[n]	Regional, North Sea	Soft law	Define four priority areas for cooperation: productive and sustainable, climate-neutral, connected, and smart North Sea region	Yes	Developing new methods to adapt to SLR sea temperatures and extreme weather events; the regions that will be affected by SLR, heavy rain showers, and long hot and dry summers should anticipate these events

Table 2. Continued.

Instrument	Type of instrument		Objective		
	International or regional jurisdiction? Which sea basin?	Legally binding or soft law?	Main objectives	Specific measures on coastal adaptation?	Specific information on SLR
Atlantic Maritime Strategy (2014)[o]	Regional, north-east Atlantic Ocean	Soft law	Unlock the potential of the blue economy while preserving marine ecosystems and addressing climate change, protect and enhance the marine and coastal environment, create a socially inclusive and sustainable model of regional development	No	No
The EU's Arctic policy (updated in 2021)[p]	Regional, Arctic Ocean	Soft law	Help preserve the Arctic as a region of peaceful cooperation to slow the effects of climate change and to support the sustainable development of Arctic regions	Yes	Arctic changes cause SLR; disturb weather systems; and lead to coastal erosion, biodiversity loss and the destruction of ecosystems
Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2018)[q]	Regional, Arctic Ocean	Legally binding	Ban unregulated fishing activities in the central Arctic Ocean and set up a joint scientific programme to improve parties' understanding of the ecosystems and potential fisheries	No	No
Trilateral Wadden Sea Cooperation (1978)[r]	Regional, North Sea	Soft law	Protect and conserve this sea as an ecological entity through common policies and management, monitor and assess the quality of the sea ecosystem in collaboration with national and regional authorities	Despite SLR being recognised as a major challenge, no specific adaptation measures are addressed	No
Marine Strategy Framework Directive (MSFD – 2008/56/EC)[s]	Regional, all	Legally binding	Require each coastal maritime strategy (MS) to prevent and restore damaged ecosystems to good environmental status (GES)	No	No
Marine Spatial Planning Directive (2014/89/EU)[t]	Regional, all	Legally binding	Make maritime spatial planning mandatory for all coastal MSs, promote the sustainable growth of maritime economies and areas	No	No

https://doi.org/10.5194/sp-3-slre1-7-2024

Table 2. Continued.

Instrument	Type of instrument		Objective		
	International or regional jurisdiction? Which sea basin?	Legally binding or soft law?	Main objectives	Specific measures on coastal adaptation?	Specific information on SLR
Bologna Charter (2012)[u]	Regional, Mediterranean Sea	Soft law	Promote a common framework for strategic actions aimed at the protection and sustainable development of Mediterranean coastal areas	Yes – a joint action plan (BC-JAP) proposing a strategy for assisting adaptation	BC-JAP includes the design of structural works for coastal protection and adaptation to climate change, fostering adaptive management solutions for the resilience of coastal systems and the efficient use of funding frameworks from the European to national and regional scales
EU Strategy on Adaptation to Climate Change (2021)[v]	Regional, all	Soft law	Reinforce the adaptive capacity of the EU and minimise vulnerability to the impacts of climate change, step up adaptation planning and climate risk assessments	Yes (importance of closing the gap on climate impacts in coastal areas) – promotion of blue–green nature-based solutions for coastal adaptation	SLR is an increasing worry for coastal areas, which produce 40 % of the EU GDP and are home to about 40 % of its population.

[a] UN Convention on the Law of the Sea (UNCLOS): https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (last access: 15 January 2024). [b] Agreement under UNCLOS on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (i.e. the High Seas Treaty or BBNJ Agreement): https://www.un.org/bbnj/sites/www.un.org.bbnj/files/draft_agreement_advanced_unedited_for_posting_v1.pdf (last access: 15 January 2024) and https://undocs.org/Home/Mobile?FinalSymbol=a%2Fconf.232%2F2023%2F4&Language=E&DeviceType=Desktop&LangRequested=False (last access: 15 January 2024). The agreement is open for signature by all states and regional economic integration organisations from 20 September 2023 to 20 September 2025 and will enter into force 120 d after the date of deposit of the 60th instrument of ratification, approval, and acceptance or accession. [c] UN 2030 Agenda for Sustainable Development: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (last access: 15 January 2024). [d] Helsinki Convention (HELCOM): https://helcom.fi/wp-content/uploads/2019/06/Helsinki-Convention_July-2014.pdf (last access: 15 January 2024). [e] Barcelona Convention: https://wedocs.unep.org/bitstream/handle/20.500.11822/31970/bcp2019_web_eng.pdf (last access: 15 January 2024). [f] Bucharest Convention: https://cil.nus.edu.sg/wp-content/uploads/2019/02/1992-Bucharest-Convention-for-the-Protection-of-the-Black-Sea-Against-Pollution-1.pdf (last access: 15 January 2024). [g] EU Strategy for the Baltic Sea Region: https://ec.europa.eu/regional_policy/sources/policy/cooperation/macro-regional-strategies/baltic/council_concl_30102009.pdf (last access: 15 January 2024). [h] EU Strategy for the Adriatic and Ionian Region (EUSAIR): https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733584/EPRS_BRI(2022)733584_EN.pdf (last access: 15 January 2024) and https://www.adriatic-ionian.eu/wp-content/uploads/2018/02/com_357_en.pdf (last access: 15 January 2024). [i] Initiative for the sustainable development of the Blue Economy in the Western Mediterranean (WestMED Initiative: https://maritime-spatial-planning.ec.europa.eu/practices/westmed-initiative-towards-initiative-sustainable-development-blue-economy-western (last access: 15 January 2024). [j] European Neighbourhood Policy – 2021 Renewed partnership with the Southern Neighbourhood – A new agenda for the Mediterranean: https://www.eeas.europa.eu/sites/default/files/joint_communication_renewed_partnership_southern_neighbourhood.pdf (last access: 15 January 2024). [k] Black Sea Synergy initiative: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0160&from=SV (last access: 15 January 2024). [l] The Common Maritime Agenda for the Black Sea: https://black-sea-maritime-agenda.ec.europa.eu/about/our-mission (last access: 15 January 2024). [m] The European Union Strategy for the Baltic Sea Region (EUSBSR): https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733703/EPRS_BRI(2022)733703_EN.pdf (last access: 15 January 2024). [n] North Sea Region 2030 Strategy: https://cpmr-northsea.org/policy-work/north-sea-region-2030-strategy/ (last access: 15 January 2024). [o] Atlantic Maritime Strategy: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0782 (last access: 15 January 2024) [p] The EU's Arctic policy (updated in 2021): https://www.eeas.europa.eu/eeas/joint-communication-stronger-eu-engagement-peaceful-sustainable-and-prosperous-arctic_en (last access: 15 January 2024). [q] Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean: https://oceans-and-fisheries.ec.europa.eu/news/arctic-agreement-prevent-unregulated-fishing-enters-force-2021-06-25_en (last access: 15 January 2024) and https://www.mofa.go.jp/files/000449233.pdf (last access: 15 January 2024). [r] Trilateral Wadden Sea Cooperation: https://www.waddensea-worldheritage.org/trilateral-wadden-sea-cooperation (last access: 15 January 2024). [s] Marine Strategy Framework Directive (MSFD – 2008/56/EC): https://eur-lex.europa.eu/eli/dir/2008/56/oj (last access: 15 January 2024). [t] Marine Spatial Planning Directive (2014/89/EU): https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0089 (last access: 15 January 2024). [u] Bologna Charter: https://bur.regione.emilia-romagna.it/bur/area-bollettini/bollettini-pubblicati/2013/luglio-periodico-parte-seconda-1a-quindicina.2013-07-03.6371477984/approvazione-dello-schema-della-carta-delle-regioni-europee-per-la-promozione-di-un-quadro-comune-di-azioni-strategiche-dirette-alla-protezione-e-sviluppo-sostenibile-delle-aree-costiere-del-mediterraneo-denominata-carta-di-bologna-2012/bologna-charter-2012 (last access: 15 January 2024) and https://maritime-spatial-planning.ec.europa.eu/practices/bologna-charter-2012 (last access: 15 January 2024). [v] EU Strategy on Adaptation to Climate Change: https://climate-adapt.eea.europa.eu/en/eu-adaptation-policy/strategy (last access: 15 January 2024).

Box 1: Emerging challenges of sea level rise for international law

The International Law Commission of the United Nations General Assembly A/CN.4/761 (UNGA, 2023) signals some relevant upcoming challenges related to sea level rise, such as the legal stability regarding baselines and maritime zone delimitation; effects of the situation whereby an agreed land boundary terminus ends up being located out at sea; and the consequences of when overlapping areas of the exclusive economic zones of opposite coastal states, delimited by bilateral agreements, no longer overlap. The exercise of sovereign rights and jurisdictions of coastal states is also of note, since historic waters, titles and rights and the permanent sovereignty over natural resources can be impacted by SLR with possible loss or gain of benefits by third states. Within statehood issues, sea level rise stresses concern about the practice on the requirements for the configuration of a State as a subject of international law and for the continuance of its existence, as is the case of the status of submerged islands, for instance. Regarding the protection of individuals, impacts of sea level rise point to issues of nationality, international security, forced migration and human rights violations. In this sense, the regulation of displacement and statelessness, as well as international cooperation on humanitarian assistance, encompasses concerns which will require further elaboration under international law.

Furthermore, SLR has the potential to significantly impact the spatial extent of national claims to maritime jurisdiction and change to the low-water line along the coast. This physical shift poses fundamental legal questions of how to deal with the jurisdictions of territories losing their lands and the pushback of the limits of the maritime zones and of how to react if the current baseline moves inland as a consequence of sea level rise, if water previously under national jurisdiction could become part of the high seas, and finally if the changes to the baselines should impact maritime boundaries between states with opposite or adjacent coasts.

Aiming to anticipate the challenges ahead, the current legal international regime must address gaps in the frameworks in force. This implies the need to elaborate on innovative and practical solutions to address SLR impacts, notably on forced human displacement and on the very existence of the land territory of some states (“Stressing Rising Seas Already Creating Instability, Conflict, Secretary-General Says Security Council Has Critical Role in Addressing Devastating Challenges”, United Nations, 2023). No single agreed solution to address these issues has been achieved so far. However, tools such as the further development of customary international law; protocols for the United Nations Framework Convention on Climate Change (UNFCCC); amendments of the provisions of UNCLOS; interpretations of the new High Seas Treaty, namely the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ) adopted in 2023; and advisory proceedings on climate change may guide international legal responses to rising sea levels in the future.

3.2 Key national policy frameworks governing coastal adaptation

Climate adaptation has become a policy theme for national governments in the last few decades[6]. In Europe, already in 2013, the EU Strategy on Adaptation to Climate Change had moved adaptation up the policy agenda for member states. Although non-binding, the strategy prompted member states to develop their own adaptation policies, and to date, all member states have approved a national adaptation strategy, a national adaptation plan or both. The United Kingdom provides a good example of climate adaptation policy with the Climate Change Act 2008. The act does not contain a specific long-term goal for adapting to climate change but requires an assessment of the risks of climate change on a 5-year cycle. Through the National Adaptation Programme, the act obliges the government to set out objectives for adaptation and a programme to meet them, publishing policy programmes to address the risks identified in the latest climate change risk assessment. In addition, the Climate Change Committee – an independent advisory body – monitors progress on adaptation targets every 2 years (Climate Change Committee, 2020).

However, while there are concrete policy outputs at the national level for climate adaptation in general in all European members states, assessing the state of coastal adaptation in particular in the 22 maritime member states[7] remains challenging. The approaches that countries take to coastal adaptation policy differ between them according to the institutional arrangements and specific geographical and social circumstances. For example, coastal adaptation may be embedded in general climate adaptation policies or strategies as well as in sectoral or location-specific (i.e. sub-national) policies, strategies and plans.

In order to assess progress at the national level on coastal adaptation, we therefore focused on two reporting mechanisms for climate adaptation and planning in marine areas that make available comparable information on coastal adaptation governance across different countries at the national level. These mechanisms are, first, the EU governance monitoring framework, which makes available country progress on climate adaptation policies through the Climate-ADAPT platform, and second, the European Maritime Spatial Planning Platform, which reports on the country progress of member states in implementing the Maritime Spatial Planning Directive (European Commission, 2014b), which explicitly calls for planning to consider the impacts from climate change and to design interventions that are "resilient" to its effects.

Table 3 shows the results of this analysis reporting on the observations and future projections of SLR hazards in each country, the status of its coastal adaptation policy, and the status and context of its MSP policies with respect to SLR. Generally, the information reported by the countries shows that sea level rise already affects and is expected to impact almost all EU coastal countries. Indeed, many member states identified sea level rise and coastal erosion as a major hazard currently and in the future, with only Bulgaria and Cyprus not reporting future hazards associated with SLR. Despite this, not all coastal adaptation plans or MSPs include measures to adapt to sea level rise. Indeed, only 5 countries include specific measures to adapt to SLR in their coastal adaptation policies. Slightly more, 10 out of 22 countries, include SLR adaptation measures in their MSPs, indicating the significance of MSPs as a coastal adaptation policy instrument; however this number remains relatively low (less than half of countries) in terms of overall inclusion of SLR adaptation measures. Out of 22 countries, 9 do not yet include SLR adaptation measures at all in coastal adaptation policies and MSPs. Table 3 thus shows an observed lag between recognising the risk of SLR and taking adaptation action at the national level. These results are consistent with recent analysis of OECD countries' coastal adaptation policies, which found that states often first adopt an information provision strategy regarding coastal risks, while policies that allocate funds for protection and SLR risk reduction are slower to emerge (OECD, 2019).

Beyond the overview presented in Table 3, more granular content analysis of the national coastal adaptation and MSP policies in EU member states provides the following further insights into progress in coastal adaptation policy frameworks at the national level.

First, although many member states have initiated coastal adaptation actions, most measures address the consolidation of knowledge and reducing uncertainty, as well as measures for improving governance and institutional capacity; a good example is provided by the National Climate Change Adaptation Plan of Spain, which highlights the necessity of improving the regulatory framework to facilitate adaptation on coasts and at sea (see Galluccio et al., 2024). There are however some examples of member states that are already implementing concrete SLR adaptation measures. For example, Belgium issued a royal decree establishing marine spatial planning for the period 2020 to 2026 in the Belgian sea areas. The decree stipulates that an entire island is dedicated to testing innovative solutions for coastal defence, such as

[6]The following mechanisms were used to collect data for the analysis conducted in Sect. 3.2: (a) the Governance of the Energy Union and Climate Action monitoring framework (Regulation (EU) 2018/1999 and its implementing regulation), which requires member states to report information every 2 years about the observed and future climate change impacts and the status of climate adaptation policies (the first round of reporting was carried out in 2021, and the information is available via Climate-ADAPT country profiles), and (b) the framework of the Maritime Spatial Planning Directive (Directive 2014/89/EU), which explicitly calls for planning to consider the impacts from climate change and to design interventions that are "resilient" to its effects (the European Commission constantly monitors the implementation of the MSP Directive in member states).

[7]We consider the 27 EU member states, with the exclusion of Austria, the Czech Republic, Hungary, Luxembourg and Slovakia.

Table 3. Assessment of national policies for coastal adaptation and maritime spatial planning policies in Europe. Note: n/a – not applicable.

Country	Sea basin	Reported chronic hazards		Coastal adaptation policy			Maritime spatial planning	
		Observed	Future	Strategy adopted?	List of measures?	Measure addressing SLR?	Enforced?	Addresses SLR?
Belgium	North Sea and Arctic	SLR, coastal erosion	SLR	Yes	Yes	No	Yes	Yes
Bulgaria	Black Sea	Coastal erosion	–	Yes	Yes	No	No	n/a
Croatia	Mediterranean Sea	SLR	SLR	Yes	No	No	No	n/a
Cyprus	Mediterranean Sea	Coastal erosion	–	Yes	No	No	No	n/a
Denmark	North Sea and Arctic and Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	No	No	Yes	No
Estonia	Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	Yes	Yes	Yes
Finland	Baltic Sea	SLR	SLR	Yes	Yes	No	Yes	No
France	Atlantic coast and Mediterranean Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	No	Yes	Yes
Germany	North Sea and Arctic and Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	Yes	Yes	No
Greece	Mediterranean Sea	Coastal erosion	SLR, coastal erosion	Yes	No	No	No	n/a
Ireland	Atlantic coast	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	Yes	Yes	Yes
Italy	Mediterranean Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	No	No	n/a
Latvia	Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	No	Yes	Yes
Lithuania	Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	No	Yes	Yes
Malta	Mediterranean Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	No	No	Yes	Yes

Table 3. Continued.

Country	Sea basin	Reported chronic hazards		Coastal adaptation policy			Maritime spatial planning	
		Observed	Future	Strategy adopted?	List of measures?	Measure addressing SLR?	Enforced?	Addresses SLR?
The Netherlands	North Sea and Arctic	SLR, coastal erosion	SLR	Yes	Yes	Yes	Yes	Yes
Poland	Baltic Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	No	No	Yes	Yes
Portugal	Atlantic Coast	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	Yes	Yes	No
Romania	Black Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	No	No	Yes	Yes
Slovenia	Mediterranean Sea	SLR	SLR	Yes	No	No	Yes	No
Spain	Atlantic Coast and Mediterranean Sea	SLR, coastal erosion	SLR, coastal erosion	Yes	Yes	Yes	Yes	Yes
Sweden	Baltic Sea	Coastal erosion	SLR, coastal erosion	Yes	No	No	Yes	No

Sources: table developed by the authors based on Climate-ADAPT and the European MSP Platform. This table is a summary of adaptation and maritime spatial planning policies in Europe with a focus on SLR-related issues. Its sources are Climate-ADAPT (https://climate-adapt.eea.europa.eu/#t-countries, last access: 15 January 2024) and the European MSP Platform (https://maritime-spatial-planning.ec.europa.eu/msp-practice/countries, last access: 15 January 2024). The European MSP Platform is available at https://maritime-spatial-planning.ec.europa.eu/msp-practice/countries (last access: 15 January 2024). As for the specific countries, see Belgium (Belgian National Climate Change Adaptation Strategy: https://www.cnc-nkc.be/sites/default/files/report/file/be_nas_2010_0.pdf, last access: 15 January 2024; Belgian National Adaptation Plan 2017–2020: https://www.cnc-nkc.be/sites/default/files/report/file/nap_en.pdf, last access: 15 January 2024), Croatia (Climate Change Adaptation Strategy for the period to 2040 with a view to 2070: https://prilagodba-klimi.hr/, last access: 15 January 2024), Denmark (How to manage cloudburst and rain water – Action plan for a climate-proof Denmark: https://en.klimatilpasning.dk/media/590075/action_plan.pdf, last access: 15 January 2024), Estonia (Climate Change Adaptation Development Plan until 2030: https://envir.ee/media/912/download, last access: 15 January 2024), Finland (Finland's National Strategy for Adaptation to Climate Change: http://urn.fi/URN:ISBN:952-453-231-X, last access: 15 January 2024; Finland's National Climate Change Adaptation Plan 2030: https://mmm.fi/paatokset/paatos?decisionId=0900908f807fc600, last access: 15 January 2024), France (Stratégie nationale d'adaptation au changement climatique: https://www.ecologie.gouv.fr/sites/default/files/ONERC_Rapport_2006_Strategie_Nationale_WEB.pdf, last access: 15 January 2024; 2e Plan national d'adaptation au changement climatique (PNACC-2): https://www.ecologie.gouv.fr/sites/default/files/2018.12.20_PNACC2.pdf, last access: 15 January 2024), Germany (Deutsche Anpassungsstrategie an den Klimawandel: https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaanpassung/das_gesamt_bf.pdf, last access: 15 January 2024), Greece (National Strategy for Adaptation to Climate Change: https://ypen.gov.gr/wp-content/uploads/legacy/Files/Klimatiki%20Allagi/Prosarmogi/20160406_ESPKA_teliko.pdf, last access: 15 January 2024), Ireland (National Adaptation Framework: https://www.gov.ie/en/publication/fbe331-national-adaptation-framework/, last access: 15 January 2024), Italy (National Adaptation Strategy to climate change: https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/documento_SNAC.pdf, last access: 15 January 2024; Piano Nazionale di Adattamento ai Cambiamenti Climatici: https://www.mase.gov.it/sites/default/files/PNACC_DOCUMENTO_DI_PIANO.pdf, last access: 15 January 2024), Latvia (Latvian National Plan for Adaptation to Climate Change until 2030: https://www.varam.gov.lv/en/media/32915/download?attachment, last access: 15 January 2024), Lithuania (National Climate Change Management Agenda: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/219a2632a6b311ecaf79c2120caf5094?jfwid=-56ckr0gcc, last access: 15 January 2024; National Energy and Climate Plan: https://energy.ec.europa.eu/system/files/2022-08/lt_final_necp_main_en.pdf, last access: 15 January 2024), the Netherlands (Adapting with ambition – National climate adaptation strategy 2016 (NAS): https://www.atachcommunity.com/fileadmin/uploads/atach/Documents/Country_documents/Netherlands_Strategy_VA_2016.pdf, last access: 15 January 2024; Nationaal Uitvoeringsprogramma Klimaatadaptatie: https://open.overheid.nl/documenten/dpc-2f1a2258b86c19919999b03a927ca9e3ba0498af/pdf, last access: 15 January 2024; Nationaal Uitvoeringsprogramma Klimaatadaptatie, 2023), Poland (Polish National Strategy for Adaptation to Climate Change by 2020 with the perspective by 2030: https://bip.mos.gov.pl/fileadmin/user_upload/bip/strategie_plany_programy/Strategiczny_plan_adaptacji_2020.pdf, last access: 15 January 2024), Portugal (National Adaptation to Climate Change Strategy (ENAAC 2020): https://files.dre.pt/1s/2015/07/14700/0511405168.pdf, last access: 15 January 2024; Action Plan for Adaptation to Climate Change (P-3AC): https://dre.pt/application/conteudo/123666112, last access: 15 January 2024), Romania (National Climate Change and Low Carbon Green Growth Strategy: http://www.mmediu.ro/categorie/cadrul-national/408, last access: 15 January 2024), Spain (National Climate Change Adaptation Plan 2021–2030: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pnacc-2021-2030-en_tcm30-530300.pdf, last access: 15 January 2024; Climate Change Adaptation: Work Programme 2021–2025: https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pt1-pnacc_tcm30-535273.pdf, last access: 15 January 2024) and Sweden (Nationell strategi för klimatanpassning: https://www.regeringen.se/contentassets/8c1f4fe980ec4fcb8448251acde6bd08/171816300_webb.pdf, last access: 15 January 2024).

Table 4. Coastal adaptation decision-making and fiscal arrangements in multilevel governance systems in Europe.

	Set strategic goal	Set coastal flood safety rules	Design measure	Fiscal control	
				Set public investment budget	Set tax base and rates
The Netherlands	National	National (regulate)	National	National	National
United Kingdom	National–regional–local	National (incentivise)	Local	National–local	National–local
Germany (Schleswig-Holstein)	Regional (state dikes)	Regional (regulate)	Regional	National–regional	Regional
Spain	National	National	National–local	National	National
Italy	Regional	Regional	Regional	Regional	National Regional
	Hybrid national–regional bodies (basin authorities)	Hybrid national–regional bodies (basin authorities)	Hybrid national–regional bodies (basin authorities)	National	National

seawalls, to contain future rising sea levels (Belgian Government, 2020).

Second, concerning the coastal adaptation governance modes in place for coastal adaptation, member states differ substantially in governance modes according to their different institutional architectures. Coastal adaptation requires coordination, both vertically between central governments and sub-national bodies such as regions or municipalities and horizontally between adjacent regions and central authorities with specific sectoral competencies, and this plays out differently according to the institutional arrangements in member states. Vertical coordination modes occur in several member states. In Belgium, for example, the federal government delegates the three regions to draw up specific local adaptation plans. Denmark also adopts a form of vertical coordination but with a direct relationship between the state and municipalities. The 2012 Danish national adaptation plan does not include direct action to address sea level rise, but it stipulates that municipalities develop a local adaptation plan that requires coastal municipalities to manage SLR risks. The central government provides support in terms of information such as the web portal http://klimatilpasning.dk (last access: 15 January 2024) and the yearly State of the Environment report (CMCC, 2021; https://miljotilstand.dk, last access: 27 June 2024) by the Danish Environmental Protection Agency, which includes a chapter on climate change and SLR. Italy provides another example of vertical coordination between the central state and regions for coastal adaptation. The Italian constitution recognises the legally binding competencies of Italian regions regarding spatial and territorial management. However, the Italian National Adaptation Strategy (Ministero dell'Ambiente e della tutela del territorio e del mare, 2015) does not prescribe specific actions for the regions, and thus there remains some lack of clarity regarding adaptation competencies between different levels of government. The National Climate Change Adaptation Plan (Ministero dell'Ambiente e della tutela del territorio e del mare, 2023) aims to set out these responsibilities; however it is not yet approved. Despite these barriers, the constitutional legal structure has provided a sufficient basis for fruitful cooperation between the central state and the regions in coastal erosion management (see Box 2). Further, a set of regional coastal adaptation plans have been developed both as part of this collaboration and under the ICZM Protocol adopted by the Barcelona Convention (CMCC, 2021).

For horizontal coordination modes, the Netherlands provides an example of horizontal coordination. The Dutch climate adaptation action is based on two pillars, the 2016 National Adaptation Strategy (The Netherlands, 2016) and the Delta Programme (Alphen, 2015). Important for horizontal coordination, the Delta Programme, which focuses on flood risk management and adapting the Netherlands to SLR over the long term, has mainstreamed adaptation to SLR into all its decision-making process and measures. For instance, in 2019, the Dutch government launched the Sea Level Rise Knowledge Programme as part of the Delta Programme, which is an extensive research and development agenda on SLR seeking to both improve forecasting capacity and identify adaptation solutions, thus involving coordination across multiple sectors of society. France addresses coastal adaptation through two parallel systems: one provides a coastal risk management framework with coastal adaptation measures, while the other deals specifically with adaptation to climate change – with policies that include coastal issues as well. The coastal governance structure includes different administrative authorities with responsibilities and competencies for

coastal adaptation measures to address SLR. While the national adaptation plan does not include specific SLR adaptation measures, the national strategy includes some recommendations for adaptation in coastal areas, such as to carefully study and plan strategic retreat, taking into account the foreseeable consequences of SLR. The country also has specific regional and local documents dealing with climate adaptation and SLR, such as "plans de prévention des risques littoraux" and strategic sea basin documents.

Finally, Sweden provides an example of hybrid horizontal and vertical coordination modes. Collaboration among the county administrative boards (CABs) of Skåne and Halland, the Swedish Geotechnical Institute (SGI), and the Geological Survey of Sweden (SGU) involves four public bodies working together with the different coastal municipalities in the counties of Skåne and Halland to address the problems of coastal erosion and rising sea levels in these areas.

Governance structures play a key role in coping with the short- and long-term effects of climate change and guaranteeing populations' safety. However, in a changing climate scenario, fragmented institutional power and a lack of communication across different levels of the management framework hinder the adoption of cross-cutting and coordinated preventive measures, ultimately reducing the adaptive capacity of societies. Moreover, to scale up defences in a planned manner and to mobilise resources towards climate-resilient territories, institutions and governmental infrastructures should align with the most up-to-date scientific knowledge on climate change. In turn, calibrating governance instruments could significantly influence a country's ability to manage climate challenges, which reveals that political–institutional structures may interfere in the level of vulnerability of society (see Sect. 3.1).

In summary, national governments are crucial in supporting coastal adaptation to SLR, notably by ensuring the relevant actors have the correct incentives and tools to adapt, as well as by removing potential distortions. Governments should take a proactive approach to improve the coordination, efficiency and effectiveness of actions implemented at lower levels of governance. Key areas for improving coastal adaptation involve enhancing access to information and guidance, ensuring that regulations and economic instruments are coherent, considering climate risks in funding decisions, and monitoring the effectiveness of policy interventions (OECD, 2019).

Box 2: Vertical collaboration scheme without legally binding policies for coastal adaptation – the case of Italy

In Italy, the management of coastal areas is a shared competence between all levels of government (national, regional and local) and different sectors of the public administration, resulting in fragmentation and poor coordination in coastal management (Buono et al., 2015). Further, coastal erosion is a salient issue with a recent study of Italian coasts' exposure to sea level rise finding that expected damage from erosion without adaptation was EUR 219 million per year, with beach loss of ca. 500 000 m^2 yr^{-1}. With relevant adaptation costs estimated as EUR 37.9 million per year, EUR 7.9 million of which is for nourishment interventions, resulting in a reduction in expected damage to less than EUR 7 million per year, for each million euros invested in adaptation, about EUR 5 million could be saved through avoided damage (MATTM-Regioni, 2018).

In this context, the Ministry of Environment and Energy Security has initiated coordinated management of coastal erosion risk, through the national board on coastal erosion (MATTM-Regioni, 2018), involving the Italian coastal regions. One output of the board is the Italian guidelines for coastal protection from erosion and climate change impacts (MATTM-Regioni, 2018). The document offers an overview of all possible options for managing coastal erosion and provides recommendations for technicians and experts tasked to design interventions to combat erosion. The guidelines consider previous similar initiatives at the European, national and local level that represent good practices from the last few decades, in line with EU Directive 2007/60/EC on the assessment and management of flooding and submersion risks.

3.3 Coastal adaptation financing arrangements

A major component of coastal adaptation governance is the financing of measures to address SLR. Coastal adaptation presents major coastal adaptation financing needs in Europe. Current estimates of investments needed globally to raise current coastal protection up to standards of the most flood-risk-intolerant countries are up to USD 4 trillion (Nicholls et al., 2019). Moreover, investment needs will increase with socio-economic development and sea level rise (SLR) and could lead to up to USD 70 billion in annual protection costs globally by 2100, a significant share of which will be in Europe (Hinkel et al., 2014). Further, investments needed to adapt to other sea-level-rise-related risks, such as salinity intrusion and coastal erosion, will increase these investment needs further (Bisaro et al., 2020).

Meeting these needs is largely a public funding challenge, as governments often have statutory requirements to provide coastal protection and are otherwise either explicit or implicit insurers of last resort (Bisaro et al., 2020). Meeting coastal adaptation funding needs is challenging because many coastal adaptation measures generally have high upfront investment costs with benefits from avoided damage materialising over the medium to long term. Various fiscal instruments are available to fund such measures, including taxation; public debt instruments, e.g. "green bonds" (Keenan, 2019); and cost-sharing arrangements with the private sector, e.g. public–private partnerships (Bisaro and Hinkel, 2018).

Funding challenges necessarily involve multiple levels of government because coastal adaptation measures often span multiple scales and jurisdictions beyond the immediate physical location where flooding or other SLR impacts may occur (Woodruff et al., 2020). This can give rise to distributional conflicts across different levels of government, e.g. over who pays for a given measure (Storbjörk and Hedrén, 2011), and between jurisdictions, e.g. over who receives funding for measures (Osberghaus et al., 2010), that can hinder public investments. Barriers to coastal adaptation financing also arise at the local level, where social acceptance of new taxes or levies to fund protection or beach nourishment measures may be low (Mullin et al., 2019), where low risk awareness may hinder support for local government finance instruments (Merrill et al., 2018), and where there may be a lack of capacity and misaligned performance incentives for local officials (Moser et al., 2019).

One potentially major source of funding for adaptation to SLR in Europe is the European Investment Bank (EIB) through their Blue Sustainable Ocean Strategy (Blue SOS), which aims to improve the health of oceans and coastal environments and increase sustainable economic activity. Through the strategy, the EIB committed to doubling lending to sustainable ocean projects to EUR 2.5 billion over the period 2019–2023. Further, the EIB aims to mobilise at least EUR 5 billion of investments that contribute to improving the health of oceans. In particular, the Blue SOS targets sustainable coastal development and protection and makes finance available through long-term loans and other instruments for governments and the private sector. Further, the facility provides technical assistance to support project promoters in preparing and implementing their sustainable ocean projects.

An example of EIB-funded coastal protection projects is the "Protection against coastal erosion – Phase II" project financed by the Cohesion Fund under the Large Infrastructure Operational Programme (LIOP) 2014–2020. The project has a significant positive environmental impact and contributes to the protection of the Romanian Black Sea coast from coastal erosion and floods exacerbated by climate change (Coastal Erosion Protection, 2023), enhancing compliance with EU environmental law, in particular the Water Framework Directive, the Floods Directive and the Marine Strategy Framework Directive. The project aims to generate substantial economic benefits, the most important of which are (i) environmental benefits from improved protection of marine habitats and species within Natura 2000 sites (wetlands) and of freshwater lakes against sea intrusion, (ii) benefits from improved recreational value of beaches, and (iii) avoided costs of damage to properties and infrastructure. In addition to the advisory support, favourable conditions of the EIB loan (i.e. longer maturity and below market interest rate) have a significant impact on the operation (Coastal Erosion Protection, 2023).

Countries take different public finance approaches to coastal adaptation. These approaches can be characterised in multilevel governance regimes along different public planning and fiscal dimensions and by their distribution between national (centralised) and local (decentralised levels; Hooghe et al., 2016). Key dimensions of characterising public finance approaches to coastal adaptation have been developed in Bisaro et al. (2020) and include the following dimensions:

- *Setting strategic goals.* Which levels of government (co-)determine the medium- to long-term goal for coastal risk management? Authority for such goal setting may be implicit or explicitly defined, e.g. through establishment of a statutory body for goal setting. Typical goals are to protect, accommodate, retreat and avoid.

- *Setting coastal flood safety rules.* Which levels of government (co-)determine rules for coastal flood safety? Typical types of rules are flood safety norms, funding rules and planning regulations.

- *Designing coastal adaptation measures.* Which levels of government (co-)determine the design of individual measures? Project design may be carried out by national-level implementing agencies; by designated local authorities; or by entities comprising several levels of government, often in consultation with citizens/stakeholders at the coast.

- *Enacting fiscal control.* Which levels of government (co-)determine the total budget for coastal adaptation

and dedicated tax revenues, i.e. tax base and rates? General revenue taxes and dedicated coastal flood risk reduction levies may be set by national, regional or local governments depending on tax legislation.

Table 4 shows several examples of coastal public finance arrangements within Europe. Even within this sub-set of examples, there are a range of approaches to financing coastal adaptation from centralised approaches, e.g. the Netherlands and Spain (López-Dóriga et al., 2020), to more decentralised approaches, e.g. the UK. Further, there are hybrid approaches, such as in Germany, where along some parts of the coast a centralised approach is taken at the federal state level, e.g. in Schleswig-Holstein at the Baltic Sea, while for other parts of the coast, financing and decision-making are devolved to the local level.

Italy represents another interesting case of a hybrid approach, which is somewhere between a centralised and federal system of government. The central state has devolved the competence of territorial management including coastal areas to the regions and the competence of flood risk management to the river basin authorities. These competencies are shared and sometimes overlapping, which can in some cases lead to fragmentation (see Table 4).

Beyond public finance arrangements for coastal protection and risk management in general, some countries have dedicated funds for addressing the increasing risks and associated costs of adaptation due to SLR. In France, the national government provided EUR 500 million to fund flood prevention measures, particularly in coastal areas, through the national flood plan ("plan submersions rapides"). The United Kingdom has established a GBP 2.6 billion 6-year capital investment programme (2015–2021) to reduce flood and coastal risk, which the second National Adaptation Programme estimated would provide over GBP 30 billion in overall economic benefits (e.g. reduced damage) and would benefit 300 000 households by 2021 (Department for Environment, Food & Rural Affairs, 2018). In Germany, a special instrument (Sonderrahmenplan) to accelerate implementation of coastal protection due to climate change risks was established in 2009, which provides EUR 25 million for all coastal federal states annually until 2025 (EUR 550 million total) (OECD, 2019). Further, in addition to public funding, innovative financing instruments for mobilising private finance, e.g. green bonds, are also emerging as a potentially important source of finance for coastal adaptation in Europe and are broadly supported by the EU (European Union, 2020). For instance, coastal protection activities are potentially aligned with the EU sustainability taxonomy (Alessi et al., 2019).

Managed retreat as an adaptation strategy is also receiving increasing attention. To date, in Europe, public financing for retreat or relocation measures, e.g. though buyouts or compensation of private property owners, has however been implemented only in a fragmented way through small-scale pilot projects, e.g. in the UK (Atoba et al., 2021) or Germany (de la Vega-Leinert et al., 2018). While public finance for such strategies can be rationalised on the basis of reducing overall costs of coastal protection to the public purse, it is important to consider the distributional implications of housing availability and affordability, employment opportunities, and facilitating collective relocation processes when implementing managed-retreat strategies (Braamskamp and Penning-Rowsell, 2018). Buyouts and managed-retreat programmes should be carefully designed to avoid creating or exacerbating existing socio-spatial inequalities, particularly by ensuring that retreat does not disproportionately affect already disadvantaged areas, in terms of both areas that are retreated from and areas that will receive immigration from retreat initiatives. Additionally, providing practical and psychological support during the relocation process is essential in alleviating feelings of loss and in addressing cultural and psychological impacts (Dannenbarg et al., 2019) (see Sect. 3.3).

Finally, several observations can be made regarding the outlook for coastal adaptation finance under future sea level rise. SLR is likely to increase the costs of maintaining current protection levels and coastal adaptation costs more broadly. This has several implications for coastal adaptation public finance arrangements. First, centralised public finance arrangements that exhibit little overlap between coastal adaptation beneficiaries and funders are likely to come under increasing pressure from SLR. For example, centralised funding arrangements in Germany entail a significant re-distribution of federal funds to coastal federal states for building and maintaining state dikes. As SLR increases the significance of this re-distribution in the national economy, these arrangements may be reconsidered. Relatedly, hazard-based flood safety standards as currently used in Schleswig-Holstein, which maintains state dikes that protect up to a 1-in-200-year flood hazard event, may also be reconsidered in favour of risk-based safety standards due to rising protection costs under SLR. Risk-based standards weigh the costs of protection against the value of protected assets and thus are more economically efficient. Second, under SLR, decentralised arrangements may lead coastal communities to be overwhelmed by the increasing financial burden from SLR due to budget and capacity constraints (Moser et al., 2019) and by resistance from local vested interests to raising new funds (Beatley, 2012). Finally, across all decentralised arrangements, coastal adaptation measures other than protection (such as retreat) are likely to become more important, as the costs of protecting the coast will outweigh the benefits, particularly in rural areas (Lincke and Hinkel, 2018).

4 Complexity and challenges

Despite the similarity in coastal issues in areas facing SLR, complexity in adaptation approaches derives from the great variety of the coastal settings considered, such as in physi-

cal (processes), socio-economic (development and activities) and administrative terms (governance), and from intrinsic uncertainties in sea level rise estimates.

A major source of uncertainty for long-term policies, in fact, is the assessment of SLR at the regional to local scale. Indeed, regional and local differences in changes in mean and extreme sea levels can be observed along the European coasts due to different processes (cf. Melet et al., 2024). Thus, despite IPCC being the most reported source of climate information in SLR planning in Europe (McEvoy et al., 2021) and recognising that global SLR information does contribute to advances in local agenda setting and awareness raising (Blankespoor et al., 2023), global projections are not suitable for all basins/sub-basins. The reconstruction of coastal vertical movements and of the local sea level variability at the sub-basin scale (see, for instance, Meli et al., 2023; Oelsmann et al., 2024) is crucial for supporting local/regional hazard assessment and related mitigation/adaptation policies. Addressing these challenges relies on the development of adaptive planning approaches, integrated with monitoring activities able to capture signals that may suggest updating or changing the plans and that allow the verification of their effectiveness (see Sect. 3.1). Cross-domain and cross-sectoral coordination is essential and should be based on the involvement of stakeholders and local communities in planning local adaptation, also through participatory processes (see Sect. 3.2). Furthermore, distributive and procedural justice challenges as well as vulnerability issues are also essential to address when designing and implementing the adaptation policy framework (see Sect. 3.3).

4.1 Time horizon and uncertainty

The rate, timing and amount of sea level rise over longer time horizons (roughly, beyond 2050) create deep uncertainty for decision-makers in coastal areas (van den Hurk et al., 2022). Traditional planning time frames and tools (e.g. economic assessments to compare alternative actions) and conventional political systems are typically not well suited to addressing long-term and uncertain risks when balancing clear, near-term policy objectives. Public support also tends to prioritise current needs while undervaluing long-term risks. For example, developing coastlines is an attractive proposition in many parts of Europe, where demand for housing in coastal areas is high. However, further development of vulnerable coastlines creates a lock-in to protect assets against increasing risks from sea level rise in the future. This challenge is illustrated in the case of nuclear reactors planned on the French coast.

Box 3: Case 1 nuclear reactors – lock-in and balancing near-term benefits and long-term risks

Long time horizons and uncertainties in the timing of sea level rise on local coastlines are especially relevant to long-lived infrastructure, such as new-generation nuclear plants. France is planning to add new nuclear reactors in two coastal plants: Penly, in Normandy, and Gravelines, close to the Belgian border. The expected lifetime of these nuclear reactors is at least 60 years, not including construction and dismantling. Hence, these plants will still be in place in 2100 and beyond, when scenarios well above 1 m of sea level rise cannot be excluded if a collapse of marine ice sheets in Antarctica is initiated. While the decision to implement these two reactors was announced by the national government in February 2022, the following year, the national chamber of accounts raised the issue that flood risks induced by sea level rise will be different in the two locations: in Penly, the nuclear reactors are located 11 m above sea level on the toe of a chalk cliff, whereas in Gravelines the plant is located in a polder area, largely below sea levels at high tide. In Gravelines, flood damage may not directly affect the plant itself but could compromise access through road damage, posing challenges to safe operation. There is currently no evidence that high-end scenarios involving ice sheet collapse are considered in territorial adaptation plans in the area of Gravelines, nor are there signals that the plans in Gravelines may be cancelled or amended due to consideration of high-end sea level rise. If the decision is confirmed, it will result in a long-term legacy that could lock in investments for coastal protections in the Gravelines area for several generations. However, a positive decision would also create immediate and near-term economic benefits for the territory via the construction and operation of the new reactors and support France's current energy and climate policy objectives.

Strategies for addressing uncertainty over long time horizons, such as dynamic adaptive policy pathways, link near-term actions with keeping long-term options open, to avoid maladaptation or lock-in under future climate or socio-economic conditions. The Dutch Delta Programme (Alphen, 2015) and the Thames Estuary 2100 Plan (Ranger et al., 2013) are two well-documented cases of adaptation pathways in practice. A challenge in implementing adaptive planning methods is establishing and operationalising a mechanism to monitor for locally relevant signals that indicate when it is time to consider a new action (Haasnoot et al., 2018). Existing governance and institutional structures are typically designed for "predict-and-act" planning and are less suited to adaptive planning, which requires trusted knowledge holders, a monitoring programme, a relatively stable political environment that respects established processes, and often the integration of different agencies (e.g. coastal authorities, spatial planning, environmental protection) (Hermans et al., 2017). The Dutch Delta Programme and the Thames Estuary have both implemented long-term, comprehensive monitoring programmes in their adaptive planning strategies.

Box 4: Dutch Delta – monitoring for signals in adaptive planning

The Dutch Delta Programme takes an adaptive approach that makes use of scenarios, adaptive strategies and a 6-year review period. The programme also relies on a signal group of independent, multidisciplinary experts who advise the Delta Commissioner annually on external scientific and societal trends and knowledge relevant to the programme. This *anticipatory* monitoring should signal when a change to the (adaptive) strategy may be needed. A separate *retrospective* monitoring group monitors the implementation and effectiveness of the plan.

In line with knowledge at the time, in 2014 the Delta Commissioner proposed adaptation to prepare for SLR of 0.3–1.0 m in 2100 (relative to 1990). In 2017, the signal group advised exploring the accelerated SLR scenarios and the implications for the Dutch Delta. This triggered a 2017 study on the topic, followed by an inventory of strategies to deal with accelerated SLR, in 2019. These strategies are currently elaborated upon in a dedicated programme, the SLR Knowledge Programme.

Accounting for potential long-term risks while making near-term decisions and keeping future options open are critical to avoiding lock-in and maladaptation. This can be achieved in different adaptation strategies. For example, protective measures, such as seawalls, can be built with a larger foundation than needed for the current protection height to allow the walls to be raised easily under higher amounts of sea level rise. By contrast, preventative actions, like restricting development of coastal zones, land buyouts and short-term land-use arrangements, can avoid lock-in (see Galluccio et al., 2024).

Most countries in Europe use 2100 as the long-term horizon for sea level rise planning (McEvoy et al., 2021). However, to plan and implement adaptation strategies often takes decades (Haasnoot et al., 2020). The MOSE barrier – Venice, Italy – timeline illustrates that it took over 50 years from an initiating event to a fully operational system, in 2020 (IPCC, 2022; see Fig. 1). Recent studies suggest that under high-emission scenarios, closures of the barrier for more than 2 months per year are virtually certain by the 2080s and closures of 6 months per year are likely by the end of the century (Lionello et al., 2021).

The long lead times required by especially large-scale adaptation may require taking decisions before there are clear signals. Accelerated sea level rise could further reduce the window to act (Haasnoot et al., 2020). In cases where retreat is a plausible future adaptation strategy, decision-makers often face the need to take preparatory action or decide whether to continue investment in the area long before public opinion may recognise the need for retreat. However, early action can allow more equitable and managed retreat in the long run (Haasnoot et al., 2021).

At the European level, preparedness and disparities in adaptation planning for SLR vary significantly across countries. Despite having significant populations living in low-lying coastal areas, many EU countries either are not planning for SLR (e.g. Bosnia and Herzegovina, Latvia, Malta, Montenegro, Romania, Slovenia, Ukraine) or are considering relatively low projections (i.e. less than 0.65 m by 2100, including countries like France, Italy and Spain). At the national level of planning, most countries are using SLR amounts that occur in all projections, independent of climate change and emission scenarios (between 0.15 and 0.35 m by 2050), including Albania, Croatia, Cyprus, Denmark, France, the Netherlands, Norway, Portugal, Spain and Ukraine. There are relatively few countries that consider high-end scenarios and time horizons beyond 2100 (McEvoy et al., 2021).

4.2 Cross-scale and cross-domain coordination

Both vertical (national to regional–local) and horizontal (intersectoral, cross-regional and interdisciplinary) coordination mechanisms are the base for integrating adaptation into sectoral policies and for shared management of responsibilities at multiple administrative levels. As indicated in Sect. 3.2, at the European level some member states have established national coordination bodies dealing with intersectoral policy coherence or regulatory mainstreaming of adaptation into sectoral policies. These coordination processes play an essential role in supporting local governments to develop and implement local adaptation strategies and action plans. Nonetheless, extensive effort is still required by local authorities to initiate, support and foster knowledge transfer and exchange of information within the area through consultations including academic institutions and stakeholders. Co-development processes are essential in these contexts. An example of a local adaptation plan developed in collaboration with the research community is the case of the municipality of Ravenna (see Box 5). To be effective, such plans require a strong commitment to co-creation processes with the wider community of stakeholders at the coast.

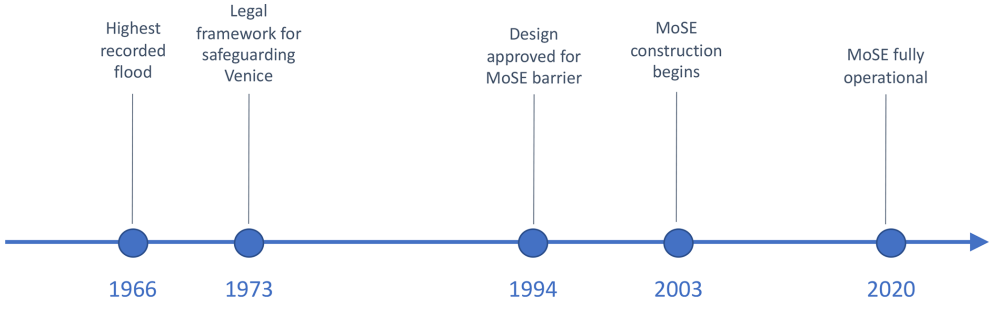

Figure 1. The timeline of milestones in the lead, design, construction and operationalisation of the MOSE barrier, in Venice, illustrates the significant time needed to implement large-scale adaptation to sea level rise.

Box 5: Ravenna municipality visions for 2100

In line with the EU initiatives "Covenant of Mayors" and "Mayors Adapt", aimed at promoting environmental policies for the mitigation of climate change impacts towards sustainable and resilient territories, a local adaptation plan has been developed by the municipality of Ravenna in the recent action plan PAESC (Comune di Ravenna, 2020). An effort was made to integrate different competencies and points of view (urbanistic, naturalistic, etc.) and to consider the different challenges involved in the coastal sector, such as natural areas and ecosystems and agricultural and touristic activities.

The timeline of the strategic scenario for the proposed adaptation strategies and for the realisation of a first "transition stage" is fixed to 2050. The adaptation strategies aim at enhancing the resilience potential of the territory and, besides the protection of coastal settlements, include the re-naturalisation and reinforcement of the dune and paleo-dune systems, the improvement of the hydraulic network in the internal area, and the creation of a "buffer" zone for flooding and salinisation processes. This mid-term scenario should allow for the identification of the main challenges and specific barriers to face and overcome in the longer term.

The SebD (scenarios' evaluation by design) method has been applied to evaluate the suitability of future adaptation strategies through the reconstruction of landscape transformation scenarios in 2100 by considering the high-end IPCC RCP8.5 scenario for SLR. In the plan, possible adaptation options are proposed for two particularly critical, low-lying coastal areas of the Ravenna territory, the ones most potentially exposed to marine ingression and local sea level rise. The two areas have high naturalistic environmental value (both include natural reserve areas) and are located in the southern and in the northern coastal sectors of the municipality of Ravenna. The effects of two different possible approaches have been tested, one more rigid–conservative using pre-existing structures and the other more dynamic and evolving. This enabled the evaluation of more suitable medium- to long-term adaptation strategies and related impacts. In the first case, the present setting and location of the territory are intended to be maintained in the future configuration, with a general stiffening of the present coastal defence structures (see, for instance, Fig. 2). In the second approach, the geomorphological characteristics of the natural systems should guide adaptive planning for future coastal land-use and ecosystem management. In this case, managed retreat of the coastline (apart from coastal settlements), a shift of transitional habitats and a partial transformation in land use (to wetland, marsh and forest areas) are foreseen (Fig. 3). This plan should support coastal adaptation decisions and the future selection of the most suitable adaptive strategies and related territorial transformative processes. Decisions and changes in planning will also be based on integrated, multidisciplinary monitoring activities in the territory, to be scheduled in the next stage of the PAESC with the involvement of academic institutions (University of Bologna).

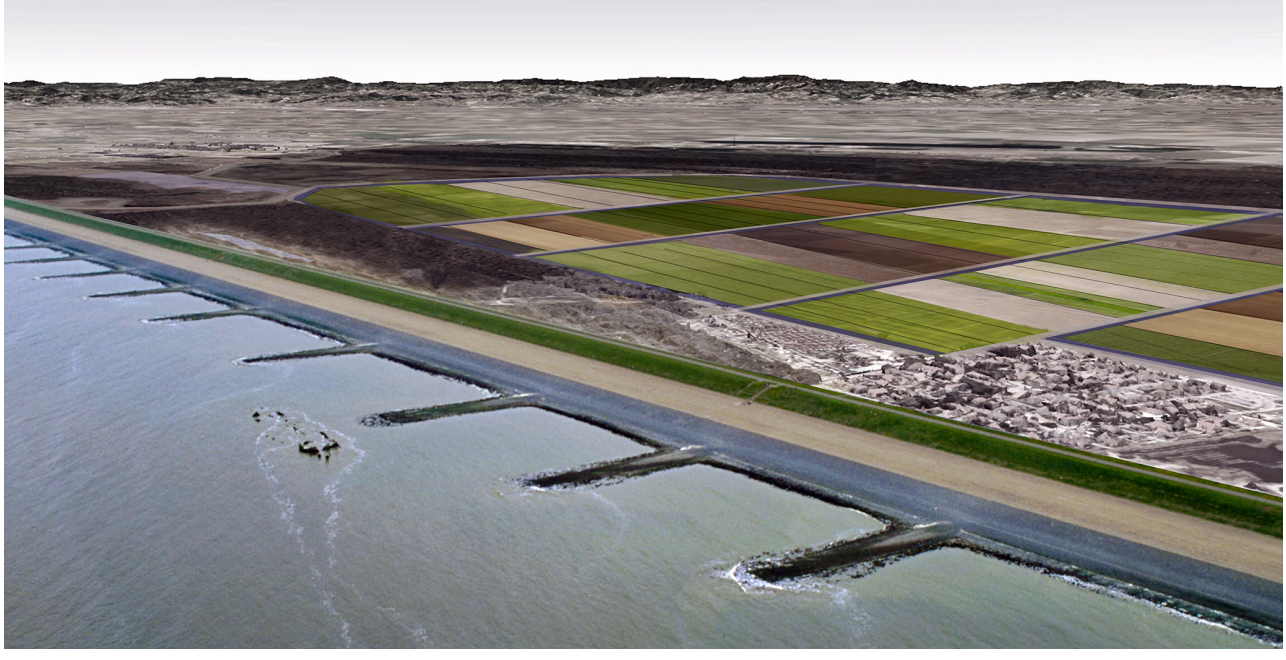

Figure 2. Computer-generated image of a possible configuration in 2100 (considering the IPCC RCP8.5 projections for SLR) in the southern coastal area of the municipality of Ravenna (Lido di Classe–Lido di Dante), according to a rigid–conservative approach, with maintenance of the coastal defence structures and the coastline position and prevalent agricultural land use in internal areas. The original source of this figure is Lobosco and Mencarini (2023).

Figure 3. Computer-generated image of possible configuration in 2100 (considering the IPCC RCP8.5 projections for SLR) in the southern coastal area of the municipality of Ravenna (Lido di Classe–Lido di Dante), according to a dynamic and evolutive approach, considering managed realignment of the coastline, the construction of a new dune line and the partial environmental transformation of the territory. The original source of this figure is Lobosco and Mencarini (2023).

Cross-cutting challenges also arise with respect to the involvement of stakeholders and local communities in the processes of planning local adaptation. Challenges include a lack of communication from local authorities to communities leading to a lack of knowledge and understanding and related negative perceptions of adaptation plans (Buono et al., 2015). Participatory methods (see also Galluccio et al., 2024) based on the involvement of stakeholders (citizens, local communities, public administration and companies, private companies, working activities, coastal users, local associations, and NGOs) can enhance communication and facilitate collaboration and consensus building. Communication, consultation and outreach are thus fundamental steps in the process of developing and implementing local coastal adaptation. The case of Texel, the Netherlands (Box 8), provides an example of the need for effective communication and co-development processes involving both coastal management experts and local communities.

Another aspect of cross-level and cross-domain challenges in coastal adaptation governance is the governance of critical infrastructure, such as ports, which plays a key role in the economic activity beyond the coast. Ports play a crucial role in a nation's economy by serving as vital gateways for international trade, facilitating the movement of goods and fostering economic growth (international shipping transports more than 80 % of global trade all over the world, according to the International Maritime Organization (IMO)). Due to their location on coasts, ports are particularly vulnerable to climate change, including rising sea levels combined with changes in the wave and wind regime or the frequency and intensity of storms. These changes may turn into an increased average time of operation disruption, potential damage to infrastructures and higher maintenance costs, impacting trade flows and the overall economy. An increase in the size of ships over the last few years may be aggravating these effects as greater draughts and construction of new and more exposed infrastructures are required.

Potential impacts of rising sea levels on port operations include the frequent interruption of low-lying coastal road and rail due to storm surges and flooding of terminal areas, more frequent flooding and potential damage of infrastructure in low-lying areas, erosion of infrastructure support, and changes in harbour facilities to accommodate higher tides and surges (UNCTAD, 2022). Further, changes in the tide and higher water level fluctuations are expected to cause periods of extremely low water levels on key inland waterways such as the Rhine in Europe or the Yangtze in China, with a negative effect on vessel loading and navigation planning.

It is therefore essential to enhance port resilience and minimise the adverse effects of climate change on ports' economic contributions. Individual risk analysis and adaptation measures must be considered for each port, depending on its oceanographic, meteorological and environmental conditions; coastal topography; relevant activities; and proximity to urban areas and other natural ecosystems. On the other hand, port governance systems are complex and vary around the world, from ports publicly owned and operated by government entities, allowing for direct control and coordination of port activities, to landlord models, where the government or port authority owns the land and infrastructure but contracts out operations to private companies, to fully privatised ports, where private companies own and manage all aspects of port operations. There are therefore scientific, technical, socio-economic and governance challenges, some of them shared with other economic sectors and others specific to the port activity, meaning adaptation strategies may differ significantly from one country to another. The effort made by Spain is a good example of such complexity and related cross-domain impacts of SLR.

Box 6: The Slufter on Texel, the North Sea – balancing stakeholder values with scientific information in seeking effective solutions for Texel's coastal problems

To maintain the coast, to protect land from flooding by the sea, and to build infrastructure that provides a desirable living environment now and in the future, Dutch coastal management has traditionally involved collaboration between different social actors and decision-makers (Avoyan and Meijerink, 2021; Lodder and Slinger, 2022). Indeed, decision-making along the coast has faced challenges in embracing local knowledge and moving towards innovative or potentially equitable solutions (Slinger et al., 2022). Given that inputs of professional experts are necessary in designing coastal solutions to fit the social, ecological and technical requirements of the local environment along the Dutch coast, the question of how to balance stakeholder perspectives with scientific information when seeking effective solutions becomes salient.

In two case studies on Texel, the westernmost island in the Wadden Sea, ongoing coastal management practice did not use locally crafted solutions – although local and regional authorities frequently organise participatory processes and multiple scientific research projects have been running and are ongoing on the island (de Vos et al., 2010). Both studies revealed the deep competence of local people, the knowledge that can be harvested to broaden and enrich the design space for coastal solutions, and a willingness on the part of the stakeholders to become involved in crafting such local solutions.

The first study was an innovative co-design process on Texel, in which local stakeholders and coastal experts were tasked with seeking an effective solution for the beach erosion problem on south-west Texel. The co-design collaborative process was configured according to theoretically founded principles for participatory design processes (D'Hont, 2020) and consisted of three main workshops between 2016–2017, involving local stakeholders and disciplinary experts (including engineers, geomorphologists, ecologists, coastal managers and governance specialists), to check the feasibility of envisioned solutions (cf. Cunningham et al., 2014; Klaassen et al., 2021; Slinger et al., 2014; Slinger and Kothuis, 2022).

While participants in the co-design process initially proposed innovations in the bio-geophysical system (e.g. nourishment programmes, dredging, relocation of the beach pavilion), later iterations increasingly considered potential adaptations in actor networks and institutions (e.g. remuneration schemes, coalition building). Overall, the co-design process facilitated an appreciation of the social–ecological system complexity inherent to flood defence on the island of Texel and revealed the potential to generate new types of solutions by bringing local knowledge to the foreground in the process.

These findings are consistent with a second case study, in which the role of system understanding in supporting integrated management of a small estuary was explored: the Slufter on Texel. The area includes a sand dike which forms a component of the primary flood defence of Texel, protecting the hinterland from flooding from the North Sea. The results of this study (D'Hont et al., 2014; D'Hont and Slinger, 2022) underline the close-knit and well-informed nature of the island community of Texel. For example, citizens know how to access and alert relevant authorities, and local citizens are well-organised and are vocal in stakeholder groups, such as village committees (D'Hont, 2020).

Overall, the need to create environments in which technical experts can engage local knowledge in developing better solutions through co-design was identified. Such environments support the search for environmentally just decisions in a coastal context, enhancing the distribution of benefits while employing inclusive decision-making practices.

Box 7: Ports' climate change impacts and adaptation – status and challenges for the Spanish port system

In Europe, the vast majority of port managing bodies in 2022 are publicly owned (ESPO, 2022). As an example, in Spain the Ministry of Transport, Mobility and Urban Agenda defines the port policy and development strategy of the state-owned port system. This is composed of 46 general-interest ports administered by 28 port authorities (PAs), organically dependent on this ministry through the state public agency Ports of the State.

In October 2022, a new strategic plant for Spanish ports was approved, including the development of a climate change adaptation plan for the ports, aiming to ensure the operability of physical elements and critical assets and to anticipate and react efficiently to downtime, disruption or operational delays. The plan identifies two goals, aligned with the second Spanish National Climate Change Adaptation (2021–2030): (i) the Spanish port system adaptation plans defined by 2025, with implementation completed by 2030, and (ii) a port climate change observatory including the monitoring of impacts implemented in 2025.

This ambitious plan requires the coordinated effort of Ports of the State and the 28 port authorities, both to implement the new measures and to continue those already initiated. As an example of an accommodation adaptation measure, Ports of the State has successfully implemented an advanced early warning system of essential climate variables in the last few decades. This system is composed of one of the most complete observational networks in the country, measuring sea level, waves, currents and other oceano-meteorological variables, with 30 years of data in some cases and more than 70 operational models forecasting sea level, waves, circulation and wind at regional, coastal and harbour scales. All these data are integrated in the Portus visualisation tool and Cuadro de Mando Ambiental (CMA, not to be confused with CMA for Common Maritime Agenda, used elsewhere in this paper) environmental management dashboard, which integrates additional tools and downstream services to support harbour decision-makers and operators. This activity will be continued and even enhanced, with possible densification of the observational network as required for the climate change observatory at each port. In addition, high-resolution models will be a key element for the development of climate projections at the scale required by the ports in the framework of the climate change adaptation strategy. This system will contribute to risk analysis and feed the climate component of the future port climate change observatory, which will link the oceano-meteorological data with the record of impacts in the ports.

The future roadmap builds on experiences of ports in Spain. In 2016 Ports of the State published, in collaboration with the Spanish State Meteorological Agency and other institutions, a vulnerability assessment of Spanish ports to climate change (Gomis Bosch and Álvarez Fanjul, 2016), analysing past trends and future projections of oceano-meteorological variables. Campos et al. (2019) proposed a downscaling modelling methodology for addressing local effects at the port scale, which was applied to the Port of Gijón, in the north of Spain. Several lessons have also been learnt from the Interreg Sudoe project ECCLIPSE (Assessment of Climate change in Ports of Southwest Europe, https://ecclipse.eu/, last access: 22 November 2023), led by the Valenciaport Foundation with the participation of Ports of the State and based on the World Association for Waterborne Transport Infrastructure (PIANC) methodology for port climate change adaptation (PIANC, 2020), applied to the ports of Valencia (Spain), Aveiro (Portugal) and Bordeaux (France). In 2022, the Balearic Islands Port Authority developed a first climate change adaptation plan for the ports of the Balearic Islands, with scientists and coastal engineers of the Universitat Politècnica de Catalunya (UPC; Sierra et al., 2022).

In the new roadmap to achieve the Spanish ports' strategic goals, Ports of the State will include the provision of relevant climate information, ensuring the use of common data and models, a link with the scientific community through the establishment of a group of experts and participation in research projects, and the development of a common methodology and best practices for implementation of high-resolution risk analysis and adaptation plans at the port level. The final adaptation measures, including consideration of economic, social and environmental impacts, will be approved and adopted by each individual Port Authority, relying on the risk analysis and the vulnerability assessment of an inventory of physical assets and port activities. A port community including public and private bodies will be established at each port for recording climate change impacts at the required spatial resolution, with a user-friendly application that should facilitate reporting to individual port actors. The record of damage to assets or impacts on operations can be sensitive information as it may negatively affect the interests of the affected party (ranging from economic to reputational interests). This element of the port climate change observatory will have to reconcile the principles of transparency and confidentiality of information, providing aggregated analysis that can inform decision-making while limiting the publication of individualised data, establishing restricted access based on the type of data or keeping information management within the scope of the port authority.

4.3 Equity and social vulnerability

The EU adaptation strategy introduced the concept of "just resilience" to acknowledge that the impacts of climate change are not evenly distributed across society and that benefits from climate adaptation need to be fairly distributed (European Commission, 2021b). This change builds on the rationale of "leaving no one behind" in climate mitigation and adaptation agendas. Achieving equal adaptation requires dealing with diverse levels and forms of social vulnerability throughout the adaptation process, ensuring both effective protection of communities and individuals from the adverse effects of climate impacts and the avoidance of disproportionate consequences of adaptation measures (Brisley et al., 2012; Reckien et al., 2018; Sayers et al., 2017).

Justice has been emerging as a key criterion for designing and implementing climate adaptation policies that recognise and address existing social vulnerabilities (Sayers, 2017). Environmental justice is widely acknowledged to encompass two main dimensions: distributive[8] and procedural justice (cf. Schlosberg, 2007).

i. *Distributive justice* focuses on the equitable allocation of burdens, disadvantages and benefits arising from climate impacts and adaptation efforts among individuals, places and generations.

ii. *Procedural justice* relates to the fairness of political procedures and decision-making processes related to adaptation, encompassing aspects such as representativeness, inclusion, openness, transparency and capacity to influence.

Further concepts have also been introduced in adaptation policies, namely recognition and restorative justices. While *recognition justice* focuses on recognising social differences, *restorative justice* highlights the need to identify and respond to the damage that has already occurred or to cases where mitigation actions are no longer possible or effective (Forsyth et al., 2021). Recently, the concept of *just resilience* in all its dimensions has been addressed by the European Environment Agency (EEA) in the report "Towards 'just resilience': leaving no one behind when adapting to climate change" (European Environment Agency, 2022).

Given the ever-increasing importance of justice issues for policy and decision-making, this section focuses on the challenges posed by ensuring distributive and procedural justice approaches when addressing sea level rise impacts, defining adaptation measures and designing decision-making processes. These aspects are discussed in-depth below, and Table 5 presents a summary of how adaptation responses and measures interact with vulnerability factors and (re)produce unequitable outcomes. Despite the relevance of justice issues, there is a significant gap for both research and concrete examples at the European level. For this reason, the section is somewhat lacking in regional differentiation and examples. Nonetheless the concepts addressed remain valid for all European sea basins.

Adaptation measures may also have positive justice impacts. In this regard, a recent literature review in Europe (see Riera-Spiegelhalder et al., 2023; Moraes et al., 2022) has shown support for nature-based solution (NbS) approaches as a cost-effective means for coastal adaptation, highlighting their multiple co-benefits, such as biodiversity enhancement, aesthetic values, carbon sequestration, water quality improvement and economic opportunities for livelihood diversification. Although NbS projects aim to deliver positive environmental and socio-economic outcomes, there is still limited understanding of how vulnerable and marginalised communities can benefit from them (Boyland et al., 2022). In this sense, NbS approaches are likely to be more effective when used in conjunction with other measures as part of a comprehensive climate change adaptation strategy (Riera-Spiegelhalder et al., 2023). Stakeholder participation in identifying co-benefits of NbS implementation is key to determining whether and how NbS projects can protect the coast and address the needs of coastal communities (Moraes et al., 2022; Davies et al., 2021). The case of Roggenplaat in the Netherlands (Kaufmann et al., 2021) shows that uncertainty related to the dynamic and unpredictable effects of NbS projects can cause new challenges to coast-dependent economic activities (e.g. oyster farming) and distributional trade-offs, where collective interests are put above individual economic livelihoods.

In addition, coastal contracts are a good example of a governance model that promotes participatory coastal planning and management (see Ernoul et al., 2021). Initially developed for rivers in the early 1980s, voluntary environmental contracts have been widely used for wetland management in Italy and France. These contracts consist in agreements negotiated between stakeholders through inclusive decision-making processes and multi-actor cooperation, involving both public and private entities. They aim to integrate expertise, perceptions and common concerns; facilitate coordination between institutions at different levels; and align policies and funding for joint actions. The experience of coastal contracts in the Gulf of Oristano (Sardinia, Italy) has shown that they can serve as a model for multilevel cooperation that stimulates economic growth and environmental sustainability, raises community awareness, and ensures that decisions are evidence-based and aligned with ecosystem and community needs (Puddu and Etzi, 2024).

[8] Distributive justice refers to the equitable distribution of income and wealth among the members of a given society. It is therefore concerned with the preferred framework for political processes and structures to fairly distribute benefits and burdens among the individual members of a community.

Table 5. Interaction of adaptation responses and vulnerability factors in (re)producing inequitable outcomes.

Type of adaptation response	Response description and examples	Justice implication	Vulnerability factors	References
Protect/ advance	Building hard (e.g. seawalls) and soft (e.g. beach nourishment and dune rehabilitation) protective structures to hold or advance the shoreline	– Coastal protection prioritises high-density areas, leading to property devaluation and limited land-use options in low-density and underprivileged areas (distributive justice). – Powerful stakeholders with economic interests at risk dominate decision-making, favouring options aligning with their interests (procedural justice).	– Income – Source of livelihood – Absence of access to services and infrastructures	McGinlay et al. (2021), Hinkel et al. (2018)
Accommodate	Implementing technological, architectural and urban planning solutions, such as elevating buildings and infrastructures, adapting drainage systems, and strengthening monitoring and early warning solutions and insurance schemes to promote safer behaviour	– Affordability challenges regarding insurance and proofing measures arise for low-income households, rented households and non-homeowners (distributive justice). – Elderly individuals and those with lower education levels face challenges in accessing information on coastal risks (procedural justice).	– Income – Home property – Age – Education – Digital literacy	Hudson et al. (2019), Tesselaar et al. (2020)
Retreat	Relocation of infrastructures and exposed houses, neighbourhoods or entire cities	– Relocation disproportionately affects low-income and rural communities, resulting in loss of social ties, negative mental-health impacts and housing challenges (distributive justice). – Lack of psychological and social support exacerbates the sense of loss in managed retreat/relocation (distributive justice). – Decision-making often disregards local priorities, place-specific cultures and livelihoods, leading to vertically imposed decisions (procedural justice).	– Physical isolation – Physical and mental health – Source of livelihood – Income	Kind et al. (2020), Ciullo et al. (2020), Siders et al. (2021), de la Vega-Leinert et al. (2018), Dannenbarg et al. (2019), Sayers et al. (2022)

4.3.1 Distributive aspects of coastal SLR impacts

Faced with sea level rise, communities and infrastructures located in coastal areas are expected to face increasing damage and losses due to increased erosion, flooding and storms (IPCC, 2022). The gradual rise in sea levels and associated impacts from the intensification of extreme weather events will manifest in the form of property devaluation and damage to material assets such as buildings, transport and energy infrastructures (Lager et al., 2023). Further, natural and infrastructural assets related to tourism, fishery, agriculture and cultural heritage will also be affected as well as there being intangible aspects with respect to, for example, place-based knowledge, memories, values and traditions (Breil et al., 2021).

Communities reliant on coastal resources and infrastructure for their livelihoods, such as coastal tourism-based or agriculture-based communities, may bear the brunt of the consequences of SLR, experiencing not only economic losses due to environmental change (e.g. reduction and changes in use of available land, disruption of coastal ecosystem functioning, soil and aquifer salinisation) but also adverse effects on mental well-being due to environmental stress and anxiety related to, for example, loss of income (Foudi et al., 2017; IPCC, 2022).

The distribution and severity of these impacts will be influenced not only by the level of hazard exposure but also by personal and social factors of vulnerability. The housing market often drives lower-income groups towards areas more susceptible to flooding, as these regions offer more affordable housing options (European Environment Agency, 2022). In the United Kingdom, coastal communities are frequently characterised by higher levels of deprivation, consisting of low-income groups and elderly populations who may experience declining income, property values and health because of increased risk (Buser, 2020).

4.3.2 Distributive aspects of adaptation measures

Regarding distributive aspects of SLR adaptation, areas with lower populations and asset density are often deemed unsuitable for costly private and public investments in protective infrastructure such as coastal defences, consequently increasing property devaluation and insurance pricing while decreasing land-use options in already-fragile areas (Landry et al., 2003; Hinkel et al., 2018; Sayers et al., 2022).

In this context, coastal defences are often perceived as socially inequitable, as they tend to prioritise the interests of coastal residents living in high-value areas over spatially distant groups regardless of their socio-economic differences (Cooper and Mckenna, 2008). There are notable disparities in the groups affected by SLR, and the loss of homes or decline in property values will vary among second-home owners and long-term residents. Impacts of declining property values also extend to the loss of social and family ties, negative effects on mental health, and challenges in accessing suitable alternative housing options (Hardy et al., 2017).

Despite adaptation options increasingly shifting from hazard protection to increasing coastal resilience (van den Hurk et al., 2022), this shift often leans towards a risk-based approach, favouring managed retreat and accommodate options that tend to more negatively affect low-income or marginalised groups (Dannenbarg et al., 2019). Without adequate compensation or support programmes, low-income households may face challenges in affording quality flood insurance or implementing flood-proofing measures (Hudson et al., 2019). The tension between increasing risks and insurance systems regarding financial recovery and vulnerable areas is further elaborated in Box 8, "Addressing distributive justice in insurance schemes". Moreover, adaptation measures and associated support tend to be available primarily to homeowners and not to those residing in rented or social housing, who often include the most vulnerable groups in many EU countries (cf. Tesselaar et al., 2020). Notably, only Belgium, France, Romania and Spain have implemented public-sector initiatives that cover flood risk through an equitable solidarity-based system (European Environment Agency, 2022). In addition, some areas at higher risk of flooding are inhabited by populations either unable or unwilling to move to safer locations (European Environment Agency, 2020; Filčák, 2012).

Among the factors leading to the unequitable distribution of *adaptation benefits*, scholars raise substantial criticism regarding the narrow use of cost–benefit analysis (CBA), e.g. focusing on the metric of money, as a decision-making tool for adaptation planning. Indeed, CBA is often legally prescribed to determine coastal adaptation options, and when applied narrowly, it can often result in favouring engineered solutions and prioritising areas with high population and asset density while disadvantaging poorer and rural areas with lower exposed values, which are often the key focus of managed-retreat programmes (Ciullo et al., 2020; Kind et al., 2020; Siders et al., 2021). Further, CBA, when narrowly applied, may fail to acknowledge interests and values that are challenging to monetise, neglecting ecological, socio-cultural and psychological impacts, such as mental stress from relocation or loss of social ties, place identity or cultural heritage (Maldonado, 2014; Tubridy et al., 2022). Moreover, managed retreat, nature-based solutions and ecosystem-based adaptation solutions may not fare well in CBA, particularly when high discount rates are applied, due to the initial high costs associated with them despite their potential long-term benefits (Bongarts Lebbe et al., 2021).

4.3.3 Procedural aspects of adaptation

Assessing and selecting adaptation measures can involve substantial conflict as adaptation can intensify inequalities and concentrate wealth in certain groups or hurt vulnerable members of society (Sovacool et al., 2015).

Failure to adequately acknowledge and involve vulnerable groups and diverse knowledge systems and interests poses a risk of excluding or not prioritising options that could benefit the less powerful segments of society. Often options benefitting less powerful segments of society do not reach the agenda, whilst more powerful groups might dominate the discussion and decision-making and prioritise options that align with their interests and minimise their expenses and losses (Breil et al., 2021). In this regard, some vulnerable groups have been using the courts to address violations of their rights and seek compensation for SLR-related damage in climate litigation cases. This topic is further detailed in Box 9, "Sea level rise as an emerging legal issue before the courts – catching the eye for climate litigation".

Therefore, if a "participatory parity" in decision-making is to be achieved, marginalised groups should be meaningfully engaged in these processes. This involves including and supporting the most disadvantaged individuals in understanding the issues at hand and contributing their knowledge to assessing and identifying solutions, enabling all groups to have a voice and influence on the assessment, design and implementation of measures while considering and addressing diverse capacities and power dynamics (Lager et al., 2023). This can be addressed through decision-making approaches that rely on joint fact-finding and co-creation processes to accommodate societal preferences, raise awareness and facilitate greater learning, and gain support (Bongarts Lebbe et al., 2021). Such approaches can enable greater consideration in decision-making of often-neglected social factors such as local priorities, place-specific cultures and livelihoods. Such inclusive decision-making aims to balance more technocratic approaches that can perpetuate procedural injustice and may lead to conflicts (Rocle et al., 2020; Tubridy et al., 2022).

Another challenge is for inclusive coastal management and adaptation to ensure that community involvement is initiated at the outset of coastal decision-making processes. Often co-production processes are limited to agenda setting and evaluation (Mees et al., 2018), while community consultations may solicit input only on pre-selected options, informed by coastal management professionals and experts' decisions about problem definition or solution finding (Blunkell, 2016; Few et al., 2007). Limiting stakeholder involvement, for example by inviting stakeholders only to select from predefined solutions rather than to contribute to scenario building, can risk reinforcing or recreating existing inequalities within new institutional frameworks (Schuerch et al., 2022).

Experiences on the German Baltic Sea coast show that managed retreat can be successfully negotiated to bring benefits to all major parties when conducted with inclusive participation. Stakeholders are prepared to trade some losses for individual and collective gains. In contrast, when such projects are implemented in a top-down manner without involving the affected parties, local opposition can arise (de la Vega-Leinert et al., 2018).

Box 8: Addressing distributive justice in insurance scheme

With increasing risks, the burden on public budgets and insurers to absorb impacts will rise drastically over the medium and long term (Ocean & Climate Platform, 2022). According to the "Commission Staff Working Document" of the European Commission, the existing insurance systems risks being inadequate in facilitating financial recovery and, at the same time, may inadvertently encourage the continuation of high-risk developments in vulnerable areas (European Commission Directorate-General for Climate Action, 2018). However, the expertise of the insurance industry in risk assessment and quantification can play a pivotal role in advancing the principles of "build back better" or even "build forward better". Insurers can contribute to strengthening risk information through assessment, communication and price signalling (European Commission, 2021a). Moreover, insurance systems covering risks separately tend to be less cost-effective compared to single insurance products that address multiple risks, which is crucial given that many cities face compound risks (Ocean & Climate Platform, 2022). However, not all risks are fully insurable by private providers or compensated by national funds, as is the case of the Fund for the Prevention of Major Natural Hazards in France that does not count erosion as eligible.

When private insurers can only partially cover or cannot cover relevant risks, governments can consider public–private partnerships, as illustrated by the Danish Storm Council (Paleari, 2019). Insurance and compensation systems that rely on collective solidarity, such as those based on shared responsibility in France and the Netherlands or universal flood coverage in the United Kingdom, offer extensive coverage and distribute risks more evenly (European Commission Directorate-General for Climate Action, 2018). Finally, governments can also act by providing tax incentives or subsidies. In this regard, the provision of subsidies and technical support to redevelopment can be planned through community-driven approaches to assessing vulnerability and needs (e.g. community profiling at the village or neighbourhood level) to identify vulnerable subjects and sites for redevelopment and have oversight of redevelopment in a bottom-up process (Breil et al., 2018).

Box 9: Sea level rise as an emerging legal issue before the courts – catching the eye for climate litigation

Climate change litigation is an emerging field that raises legal or factual issues relating to climate change before adjudicatory bodies (Sabin Center for Climate Change Law and Columbia Law School, 2023). These cases have spiked in recent years, and currently there are about 300 climate cases in around half of European countries, making European courtrooms increasingly relevant to addressing climate change (United Nations Environment Programme, 2020).[9] SLR has figured indirectly in European litigation so far, but disruptive scientific predictions for the future and the ever-growing robustness of attribution science[10] (IPCC, 2022; Ekwurzel et al., 2017) make litigation targeting SLR, both its causes and its consequences, likely to increase. To date, European climate litigation approaches to sea level rise include the violation of human rights, the breaching of (mainly) mitigation obligations by granting new licences for fossil fuel activities and liability of damage to investments in flood-prone areas.

Human rights to life, health, territory, and culture are highly threatened by sea level rise. A prominent vulnerable group in climate litigation comprises children, youth and future generations, since they will bear the burden of sea-level-rise-related harms far more and for longer than adults and have limited participation in political decisions. In the case *Sacchi et al. vs. Argentina et al.* (Sacchi et al. v. Argentina et al., 2019), 16 children discussed whether the respondent countries violated children's rights under international law by insufficiently cutting greenhouse gas emissions and failing to protect them from carbon pollution by the world's major emitters. The case has a strong transnational feature since it involves European Union members – France, Germany and Sweden – as well as a sea basin perspective, encompassing the Mediterranean-bordering countries of Tunisia and Türkiye. Sea level rise is only indirectly claimed as one of the climate-related events that violate human rights. However, the United Nations Committee on the Rights of the Child acknowledged extraterritorial responsibilities for transboundary harms. In this sense, not only the state where the event occurred or where the emissions were generated but also a state whose jurisdiction controlled the emissions if there is a causal link between the events can be held accountable for the damage. This understanding can lead to transnational liability for countries or companies with headquarters in Europe, even when their activities are carried out abroad.

In cases challenging environmental licences that grant permits for new fossil fuel projects, sea level rise is usually indirectly approached as a consequence of climate change potentiated by fossil fuel activities. The *Greenpeace vs. North Sea Transition Authority* case discussed approval for an oil and gas field in the North Sea, and the *Greenpeace Ltd vs. (1) Secretary of State for Business, Energy and Industrial Strategy and (2) the Oil and Gas Authority* and *Uplift vs. (1) SSBEIS and (2) the OGA (North Sea oil and gas licensing)* cases challenged the North Sea Transition Authority for granting the 33rd Offshore Licensing Round for oil and gas. Some cases combine both human rights and fossil fuel permit arguments. The *Greenpeace Nordic and Others vs. Norway* challenged the licence to develop deep-sea oil and gas extraction in the Barents Sea. Pending before the European Court of Human Rights (ECtHR) and discussing whether Norway has violated fundamental rights, this is a potential "impact case", since it may impact the effectiveness of the European convention system and national legal systems as well. Despite the transversal role of sea level rise, this case raises the issue of ECtHR possibly requiring countries to reconsider their oil and gas policies and strengthen their due diligence obligations to avoid climate harm (Setzer and Higham, 2022). Sea level rise appears as an associated climate impact in other cases around Europe[11] – most of them combining human rights claims as well. Although many lawsuits are filed against governments, one may observe that they can have indirect effects on financial institutions as they may result in stronger regulation for mitigation and adaptation and changes in licensing for specific sectors, which affects portfolio investments and involves financial costs to comply (Sarra and DeMarco, 2021).

Moreover, sea level rise may appear as *climate damage* in transnational lawsuits against the private sector. As an example, in *Asmania et al. vs. Holcim* (2022), inhabitants of an Indonesian island sued the Swiss company Holcim, requesting compensation for climate-change-related damage, such as flooding, reduction in carbon dioxide emissions and financial contributions to adaptation measures. The plaintiffs argue that sea level rise is destroying their livelihoods and the defendant bears a significant amount of responsibility due to its tremendously high emissions. This is a groundbreaking claim which engages the private sector on a transnational-level dispute. It may also highlight the insufficiency of monetary compensation in scenarios involving non-economic losses such as culture, traditional knowledge and displacement. The possibility of going beyond the remedies for ex post harms and asking for injunctive relief is also a relevant argument arising from this case.

[9] Regarding the European Union, the countries with the largest number of cases are Germany, France and Spain. Outside the EU but still in Europe, the United Kingdom is also of note.

[10] Regarding attribution science, the causal chain for slow-onset events such as sea level rise is scientifically clear in a condition sine qua non formula and in terms of contributory causation. Climate science can trace back sea level rise with Carbon Majors emissions and already shows that 26 %–32 % of sea level rise is attributable to historical emissions, while 11 %–14 % is related to recent emissions.

[11] *Milieudefensie et al. vs. Royal Dutch Shell plc*, *Armando Ferrão Carvalho and Others vs. The European Parliament and the Council of the European Union*, *Notre Affaire à Tous and Others vs. France*, and the remarkable *Urgenda Foundation vs. State of the Netherlands*.

Finally, sea level rise also appears as an emerging concern for the private sector due to the liability of damage to investments in flood-prone areas. The insurance industry is facing an increasing risk associated with sea level rise and climate litigation, both as an investor with shareholder obligations and as an underwriter to claims against its policyholders. Insurers will have to deal with the uncertainty and reach of liability exposure for climate-change-related claims, which can pose a threat to the industry itself. Besides, climate litigation cases have been increasingly targeting Carbon Majors (Heede, 2014) for their contribution to the crisis, which affects liability insurers, who have a duty to defend the policyholders challenged in these lawsuits. Since 2018, lawsuits have been strengthening the argument that Carbon Majors created a public nuisance and, as such, should be responsible for paying for the damage associated with climate change and for the costs of adaptation to, inter alia, rising sea levels (British Institute of International and Comparative Law, 2021).

In the governmental sphere, many industrialised countries have advocated insurance mechanisms as a principle and effective means to deal with climate-related damage (Vanhala and Hestbaek, 2016). This, in turn, raises questions for companies on embedding the management of climate-related risks as part of core business risk management to reduce litigation. The further development of such cases in European litigation is yet to be seen.

Table 6 synthesises formal aspects of the aforementioned cases.

Table 6. Climate litigation cases.

Case and status	Parties	Principal law	Year	Jurisdiction	Sea basin
Sacchi et al. vs. Argentina et al., decided	Individuals and government	United Nations Framework Convention on Climate Change, Paris Agreement, United Nations Convention on the Rights of the Child	2019	United Nations Committee on the Rights of the Child	Mediterranean Sea
Greenpeace vs. North Sea Transition Authority, pending	NGOs and government	Regulation 16 of the Offshore Petroleum and Pipelines (Assessment of Environmental Effects)	2022	England and Wales High Court of Justice	North Sea
Greenpeace Ltd vs. (1) Secretary of State for Business, Energy and Industrial Strategy and (2) the Oil and Gas Authority and *Uplift vs. (1) SSBEIS and (2) the OGA (North Sea oil and gas licensing)*, pending	NGOs and government	Petroleum Act 1998, Environmental Assessment of Plans and Programmes Regulations 2004	2022	England and Wales High Court of Justice	North Sea
Greenpeace Nordic and Others vs. Norway, pending	NGOs, individuals, and government	European Convention on Human Rights	2021	European Court of Human Rights	Arctic Ocean
Greenpeace Nordic Ass'n vs. Ministry of Petroleum and Energy (People vs. Arctic Oil), decided	NGOs and government	Norwegian constitution, European Convention on Human Rights	2016	Supreme Court of Norway	Arctic Ocean
Asmania et al. vs. Holcim, pending	Individuals and private company	–	2022	The Justice of the Peace of the Canton of Zug, Switzerland	–

5 Summary: key developments per basin

Regarding *policy frameworks* relevant to coastal adaptation (Sect. 3.1), the Mediterranean Sea basin has three regional instruments in force, only one of which is legally binding. Two of these instruments have statements on coastal adaptation, and only one – a soft-law charter – includes specific information on SLR. The Black Sea, east Atlantic Ocean and Baltic Sea basins each have two different regional instruments, one soft law and the other legally binding. However, for all three basins, none of the regional instruments address specific measures for coastal adaptation or sea level rise. The North Sea basin has one specific soft-law instrument that, while recognising SLR as a major challenge, does not, however, contain provisions or guidelines on coastal adaptation measures. No specific treaty was mapped concerning the Arctic Ocean. Further, there are international legally binding instruments that apply to all countries in Europe; however these also do not provide specific measures on coastal adaptation. Of the three EU policy instruments that apply to all European sea basins, only the soft-law EU Strategy on Adaptation to Climate Change acknowledges the risks of SLR and provides measures for coastal adaptation. The two legally binding directives on marine strategy and marine spatial planning do not make specific provisions for SLR or coastal adaptation measures.

Regarding the *state of coastal adaptation at national level* (Sect. 3.2), almost all countries in the Mediterranean Sea basin have reported SLR as an already-observed or future expected hazard with the exceptions of Cyprus, whose national policies do not mention SLR at all. All countries have adopted adaptation policy strategies, but only France and Spain provide a list of adaptation measures, the latter specifically to address SLR. Only four countries have enforced maritime spatial planning, and three of these instruments address SLR. Further, countries are taking different approaches to funding coastal adaptation measures, with Spain having a centralised national funding approach, whereas in Italy funding for measures is distributed across multiple levels of government. In terms of addressing cross-domain governance challenges, progress of the Ports of the State in Spain in advancing climate change monitoring systems and adaptation measures illustrates the potential positive spillovers of coastal adaptation to sectors and economic activities beyond the coast.

All North Sea basin countries have reported SLR as both an observed and a future chronic hazard. Adaptation policy strategies have been adopted by the four countries, but only half of them have a list of measures, and Germany is the only one that provides specific measures to address SLR. All countries include maritime spatial planning, but only Belgium and the Netherlands address SLR in theirs. Further, countries' approaches to funding coastal adaptation also differs substantially within the basin. The Netherlands' funding is highly centralised and concentrated at the national level, whereas the UK has decentralised both coastal adaptation and decisions to local authorities. Germany has a hybrid approach of centralised funding for some portions of the coast, with decentralised funding responsibilities at other locations. The North Sea basin also shows several examples of incorporating flexibility into governance processes and adaptation measures to address the challenges of uncertainty in long-term SLR. In the Netherlands, dynamic adaptation pathways explicitly incorporate flexibility into the approach of the Delta Programme, while in Germany, dike reinforcement includes additional widening of dike crests in order to reduce future costs of increasing dike heights should high-end SLR materialise. Finally, progress is being made on co-development processes that engage local communities on equal footing with experts and coastal managers, as illustrated in the case of Texel in the Netherlands.

Of EU Black Sea basin countries, only Romania reported SLR as both an observed and a future chronic hazard. Both Romania and Bulgaria have adopted adaptation policy strategies; however only Bulgaria lists adaptation measures, and neither country specifically addresses SLR. Neither country has maritime spatial planning in force.

All Baltic Sea basin countries have reported SLR as an observed and future chronic hazard, except for Sweden which reported it only as a future one. All have adopted adaptation policy strategies; five of them list measures, but only Estonia and Germany specifically address SLR. Maritime spatial planning has been enforced by all, but Estonia, Latvia and Lithuania are the only ones addressing SLR in their MSP documents.

SLR is an observed and future chronic hazard in all Atlantic Ocean basin countries. All countries have adopted adaptation policy strategies with a list of measures, and only France does not include measures specifically addressing SLR. Maritime spatial planning is also enforced by all countries, and only Portugal does not specifically address SLR in their MSP document. In terms of addressing the challenges of uncertainty in SLR and risks associated with lock-in of coastal planning decisions with long time horizons, in France, there is little evidence that high-end scenarios are being considered in the siting and design of new nuclear power plants at the coast.

In the Arctic Ocean basin, Norway is considering mid-range SLR scenario information in its planning approaches.

6 Conclusion

SLR may exacerbate geopolitical conflicts and acts as a potential risk multiplier with relevant socio-economic, environmental and cultural consequences for Europe. Addressing the challenges of SLR will therefore require a high degree of cooperation and joint action across sea basin boundaries and the engagement of multiple stakeholders. Such coordination and engagement will enable the European Union to address

the challenges of reconciling long-term climate goals with short-term supply chain security and managing energy independence in the context of geopolitical risks.

Relevant policy frameworks for SLR governance exist at regional and national levels. The latter remains the key level for coastal and marine management, as national policymakers retain the decision-making authority for planning and implementing measures in coastal and marine areas. Each sea basin has policy instruments aimed at safeguarding strategic interests related to the sea, in cooperation with different actors. Approaches to coastal adaptation policies vary among countries at the national level according to institutional arrangements and geographical and social circumstances. Although SLR is already affecting and is expected to affect almost all EU coastal countries and has been identified as a major hazard by almost all EU member states, only a few countries include specific measures to adapt to SLR in their coastal adaptation policies. This indicates that there is still a gap between the recognition of SLR risks and the adaptation measures to address them through policies at the national level. Further, as cumulative SLR impacts that often have a cross-boundary character are unlikely to be effectively managed in a fragmented way, the analysis points to the need for a more holistic and integrated approach to coastal governance in European sea basins.

In terms of public financing arrangements for coastal adaptation, a wide variety of approaches are observed across countries, particularly in addressing flood risk reduction. Highly centralised arrangements in which tax revenue is collected and distributed by the central government, which also determines flood safety levels, are observed, for instance, in the Netherlands. In contrast, decentralised models, where greater financing responsibility is borne by municipal or local governments, are observed in the UK and for parts of the German Baltic Sea coast. Further, there is an emerging emphasis, supported at the EU level, on innovative instruments for scaling up private finance for coastal adaptation (European Commission, 2019b).

Analyses of time horizons and uncertainty show that the rate, timing and amount of regional and local sea level rise over longer time horizons (roughly beyond 2050) are highly uncertain. This points to the governance challenge of implementing adaptive planning approaches that support decision-makers to act in the short term while avoiding lock-in and maladaptation in the longer term. This is particularly the case for planning and implementing adaptation strategies that include large-scale interventions, which often take decades, may require taking decisions before uncertainty is reduced or risk responding too late. In contrast, traditional planning time frames and tools, as well as conventional policy systems and decision-making, are often not well suited to addressing long-term and uncertain risks when balancing clear, short-term needs. The evidence on how countries in Europe take uncertainty and time horizons into account when planning for SLR offers a mixed picture. At the national level, many countries use 2050 and 2100 as planning horizons for SLR. Very few countries consider horizons beyond 2100, despite long-term commitments to SLR and the long life span of many interventions. Most countries report planning for ranges of SLR that occur in almost all emissions scenarios, suggesting that relatively few countries are addressing uncertain high-end or accelerated SLR.

Another key SLR governance challenge relates to the need for coordination approaches (national to regional–local, intersectoral and interdisciplinary) to integrate adaptation to SLR into sectoral policies and to share responsibilities across different levels of governance. In order to develop and implement local adaptation strategies and action plans, local authorities are encouraged to promote knowledge transfer through broad consultations involving coastal management experts and stakeholders, local coastal user communities, and local associations. To this end, participatory methods can improve communication and facilitate consultation and outreach. While there are emerging examples of such co-development processes for coastal adaptation across Europe, greater investment in such processes, including in awareness raising for coastal communities, will be key in ensuring that participation can be scaled up to meet SLR governance challenges across Europe. Further, it should be noted that this is already broadly supported at the EU level through initiatives such as EU science diplomacy, which could be leveraged to ensure the sharing of experiences and knowledge of coastal adaptation across disciplines and European regions (European Union Science Diplomacy Alliance, 2024).

Finally, it should be emphasised that participatory governance approaches also play a critical role in recognising and addressing social vulnerabilities and inequalities emerging from or exacerbated by SLR impacts and adaptation responses. Vulnerable communities, such as low-income and marginalised groups, often bear a disproportionate burden of climate impacts, yet they can be overlooked in decision-making processes, perpetuating existing socio-economic inequalities. Integrating social justice and vulnerability considerations into coastal management and adaptation strategies is therefore imperative to ensure equitable coastal adaptation. Achieving distributive justice and legitimacy in adaptation efforts requires decision-making processes that involve diverse stakeholders to develop viable pathways that address the needs of vulnerable groups. However, translating these principles into practice faces challenges around Europe due to dominant practices in adaptation planning and decision-making, in particular the reliance on cost–benefit analysis and non-inclusive sustained engagement processes. Considering other methods and governance approaches to vulnerability assessment and adaptation appraisal, such as multi-criteria analysis and coastal contracts, can facilitate European sea basins, countries and coastal communities in better addressing the justice and vulnerability challenges posed by SLR.

Data availability. No data sets were used in this article.

Author contributions. AB, GG and EFB acted as coordinating lead authors. Moreover, AB, GG and EFB wrote the paper with text contributions from CR, SM, ES, FB and RD. JS, Fd'H and GLC wrote Box 6 about the Slufter on Texel, and BPG and AGZ wrote Box 7 about the Spanish ports. All authors participated in the iterations and revisions of the paper.

Competing interests. The contact author has declared that none of the authors has any competing interests.

Disclaimer. Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims made in the text, published maps, institutional affiliations, or any other geographical representation in this paper. While Copernicus Publications makes every effort to include appropriate place names, the final responsibility lies with the authors.

Acknowledgements. We would like to acknowledge the guidance of Nadia Pinardi, who inspired the idea behind this chapter.

This paper is part of the 1st Assessment Report of the Knowledge Hub on Sea Level Rise (https://knowledgehubsealevelrise.org/, last access: 25 September 2024), a joint initiative by the Joint Programming Initiatives for Connecting Climate Knowledge for Europe (https://jpi-climate.eu/, last access: 25 September 2024) and Healthy and Productive Seas and Oceans (https://jpi-oceans.eu/en, last access: 25 September 2024), and is endorsed as a UN Ocean Decade project. This assessment report has been made possible through the dedicated efforts of the knowledge hub experts, authors, editors, reviewers, and contributors to scoping workshops and the Sea Level Rise Conference 2022 held in Venice in October 2022.

Review statement. This paper was edited by Kate Larkin and reviewed by Poppy Kalesi and three anonymous referees.

References

Adhitama, M. R.: Geopolitics of Portugal in Atlantic Sea, in: The 1st International Conference on Global Development – ICODEV, 19 November 2019, Surabaya, Indonesia, IPTEK Journal of Proceedings Series, No. 6, ISSN 2354-6026, 2019.

Alphen, J. V.: The Delta Programme and updated flood risk management policies in the Netherlands, J. Flood Risk Manag., 9, 310–319, https://doi.org/10.1111/jfr3.12183, 2015.

Asmania et al.: Asmania et al. vs Holcim, Justice of the Peace of the Canton of Zug, http://climatecasechart.com/non-us-case/four-islanders-of-pari-v-holcim/ (last access: 19 June 2023), 2022.

Atoba, K. O., Brody, S. D., Highfield, W. E., Shepard, C. C., and Verdone, L. N.: Strategic Property Buyouts to Enhance Flood Resilience: A Multi-Criteria Spatial Approach for Incorporating Ecological Values into the Selection Process, Environ. Hazards, 20, 229–247, https://doi.org/10.1080/17477891.2020.1771251, 2021.

Avoyan, E. and Meijerink, S.: Cross-sector Collaboration Within Dutch Flood Risk Governance: Historical Analysis of External Triggers, Int. J. Water Resour. D., 37, 24–47, https://doi.org/10.1080/07900627.2019.1707070, 2021.

Alessi, L., Battiston, S., and Melo, A.: The EU sustainability taxonomy – A financial impact assessment, European Commission, Luxembourg, https://doi.org/10.2760/347810, 2019.

Beatley, T.: Planning for Coastal Resilience: Best Practices for Calamitous Times, Island Press, United States of America, ISBN 978-1-59726-561-4, 2012.

Belgian Government: Royal Decree establishing the marine spatial planning for the period 2020 to 2026 in the Belgian sea-areas, https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/msp-2020-englishtranslation.pdf (last access: 12 April 2023), 2020.

Bisaro, A. and Hinkel, J.: Mobilizing private finance for coastal adaptation: A literature review, WIREs Climate Change, 9, e514, https://doi.org/10.1002/wcc.514, 2018.

Bisaro, A., de Bel, M., Hinkel, J., Kok, S., Stojanovic, T., and Ware, D.: Multilevel governance of coastal flood risk reduction: A public finance perspective, Environ. Sci. Policy, 112, 203–212, https://doi.org/10.1016/j.envsci.2020.05.018, 2020.

Black Sea Commission: Convention on the Protection of the Black Sea against Pollution (Bucharest Convention), http://www.blacksea-commission.org/Official%20Documents/The%20Convention/Full%20Text/ (last access: 20 June 2023), 1992.

Blankespoor, B., Dasgupta, S., Wheeler, D., Jeuken, A., van Ginkel, K., Hill, K., and Hirschfeld, D.: Linking sea-level research with local planning and adaptation needs, Nat. Clim. Change, 13, 760–763, https://doi.org/10.1038/s41558-023-01749-7, 2023.

Blunkell, C. T.: Local participation in coastal adaptation decisions in the UK: between promise and reality, Local Environment, 22, 492–507, https://doi.org/10.1080/13549839.2016.1233525, 2016.

Bongarts Lebbe, T., Rey-Valette, H., Chaumillon, É., Camus, G., Almar, R., Cazenave, A., Claudet, J., Rocle, N., Meur-Férec, C., Viard, F., Mercier, D., Dupuy, C., Ménard, F., Rossel, B. A., Mullineaux, L., Sicre, M.-A., Zivian, A., Gaill, F., and Euzen, A.: Designing Coastal Adaptation Strate-

gies to Tackle Sea Level Rise, Front. Mar. Sci., 8, 740602, https://doi.org/10.3389/fmars.2021.740602, 2021.

Boyland, M., Tuhkanen, H., Green, J., and Barquet, K.: Principles for just and equitable nature-based solutions, SEI discussion brief, Stockholm Environment Institute, https://doi.org/10.51414/sei2022.016, 2022.

Braamskamp, A. and Penning-Rowsell, E. C.: Managed Retreat: A Rare and Paradoxical Success, but Yielding a Dismal Prognosis, Environmental Management and Sustainable Development, 7, 108–136, https://doi.org/10.5296/emsd.v7i2.12851, 2018.

Breil, M., Downing, C., Kazmierczak, A., Mäkinen, K., and Romanovska, L.: Social vulnerability to climate change in European cities – state of play in policy and practice, European Topic Centre Climate Change Impacts, Vulnerability and Adaptation – European Environmental Agency, report, https://doi.org/10.25424/CMCC/SOCVUL_EUROPCITIES, 2018.

Breil, M., Zandersen, M., Pishmisheva, P., Pedersen, A. B., Romanovska, L., Coninx, I., Rogger, M., and Johnson, K.: "Leaving No One Behind" in Climate Resilience Policy and Practice in Europe Overview of Knowledge and Practice for Just Resilience, European Environment Agency, Italy, report, https://doi.org/10.25424/cmcc/justtrans_europe, 2021.

Brisley, R., Welstead, J., Hindle, R., and Paavola, J.: Socially just adaptation to climate change, Joseph Rowntree Foundation, United Kingdom, https://www.jrf.org.uk/sites/default/files/migrated/migrated/files/climate-change-adaptation-full_0.pdf (last access: 21 June 2023), 2012.

British Institute of International and Comparative Law: Rising Sea Levels: Promoting Climate Justice through International Law: Climate Change Litigation before Domestic Courts, British Institute of International and Comparative Law, United Kingdom, https://www.biicl.org/documents/10888_rising_sea_levels_episode4_report_-_final.pdf (last access: 18 June 2023), 2021.

Buono, F., Soriani, S., Camuffo, M., Tonino, M., and Bordin, A.: The difficult road to Integrated Coastal Zone Management implementation in Italy: Evidences from the Italian North Adriatic Regions, Ocean Coast. Manage., 114, 21–31, https://doi.org/10.1016/j.ocecoaman.2015.06.001, 2015.

Buser, M.: Coastal adaptation planning in Fairbourne, Wales: Lessons for climate change adaptation, Planning practice & Research, 35, 127–147, https://doi.org/10.1080/02697459.2019.1696145, 2020.

Campos, Á., García-Valdecasas, J. M., Molina, R., Castillo, C., Álvarez-Fanjul, E., and Staneva, J.: Addressing Long-Term Operational Risk Management in Port Docks under Climate Change Scenarios – A Spanish Case Study, Water, 11, 2153, https://doi.org/10.3390/w11102153, 2019.

Chirosca, A. M., Rusu, L., and Bleoju, A.: Study on wind farms in the North Sea area, Energy Reports, 8, Supplement 16, 162–168, https://doi.org/10.1016/j.egyr.2022.10.244, 2022.

Ciullo, A., Kwakkel, J. H., De Bruijn, K. M., Doorn, N., and Klijn, F.: Efficient or Fair? Operationalizing Ethical Principles in Flood Risk Management: A Case Study on the Dutch-German Rhine, Risk Anal., 40, 1844–1862, https://doi.org/10.1111/risa.13527, 2020.

Climate Change Committee: CCC Insights Briefing 1: The UK Climate Change Act, Climate Change Committee: The UK's independent adviser on tackling climate change, United Kingdom, https://www.theccc.org.uk/wp-content/uploads/2020/10/CCC-Insights-Briefing-1-The-UK-Climate-Change-Act.pdf (last access: 21 March 2024), 2020.

CMCC: Existing national, regional and local adaptation plan on coastal area of Italy and Croatia (Interreg project), Euro-Mediterranean Center on Climate Change, https://programming14-20.italy-croatia.eu/documents/2134091/0/D.5.1.1+Existing+adaptation+plan+on+coastal+area+of+Italy+and+Croatia.pdf/712250a3-65c5-2c85-029c-aea8ec8c1ad4?t=1698675590258 (last access: 19 June 2023), 2021.

Coastal Erosion Protection (FL 2015-0548): https://www.eib.org/en/projects/pipelines/all/20210631, last access: 21 July 2023.

Comune di Ravenna: Piani di Azione per l'Energia e il Clima: Resilienza e adattamento agli effetti del cambiamento climatico, https://www.comune.ra.it/aree-tematiche/ambiente-e-animali/ambiente-e-territorio/strumenti-di-gestione-ambientale/paes-piano-dazione-per-lenergia-sostenibile/ (last access: 26 June 2023), 2020.

Cooper, J. A. G. and Mckenna, J.: Working with Natural Processes: The Challenge for Coastal Protection Strategies, Geogr. J., 174, 315–331, https://doi.org/10.1111/j.1475-4959.2008.00302.x, 2008.

Cortés Arbués, I., Chatzivasileiadis, T., and Ivanova, O.: Distribution of economic damages due to climate-driven sea-level rise across European regions and sectors, Sci. Rep., 14, 126, https://doi.org/10.1038/s41598-023-48136-y, 2024.

CPMR North Sea Commission: North Sea Region 2030 Strategy, Conference of Peripheral Maritime Regions, Sweden, report, https://cpmr-northsea.org/download/north-sea-region-strategy-2030/?wpdmdl=3029&ind=1604574928659 (last access: 19 June 2023), 2020.

Cunningham, S. W., Hermans, L. M., and Slinger, J. H.: A review and participatory extension of game structuring methods, EURO J. Decis. Process., 2, 173–193, https://doi.org/10.1007/s40070-014-0035-8, 2014.

Dannenbarg, A. L., Frumkin, H., Hess, J. J., and Ebi, K. L.: Managed retreat as a strategy for climate change adaptation in small communities: public health implications, Climatic Change, 153, 1–14, https://doi.org/10.1007/s10584-019-02382-0, 2019.

Davies, C, Chen, W. Y., Sanesi, G., and Lafortezza, R: The European Union roadmap for implementing nature-based solutions: a review, Environ. Sci. Policy, 121, 49–67, https://doi.org/10.1016/j.envsci.2021.03.018, 2021.

de la Vega-Leinert, A. C., Stoll-Kleemann, S., and Wegener, E.: Managed Realignment (MR) along the Eastern German Baltic Sea: A Catalyst for Conflict or for a Coastal Zone Management Consensus, J. Coast. Res., 34, 586–601, https://doi.org/10.2112/JCOASTRES-D-15-00217.1, 2018.

de Marignan, C.: The Mediterranean Sea: Between Geopolitical Challenges and Climate Crisis, European Institute of the Mediterranean, https://www.iemed.org/publication/the-mediterranean-sea-between-geopolitical-challenges-and-climate-crisis/ (last access: 21 March 2024), 2023.

Department for Environment, Food & Rural Affairs: Central Government Funding for Flood and Coastal Erosion Risk Management in England, Department for Environment, Food & Rural

Affairs, United Kingdom, https://southerncoastalgroup-scopac.org.uk/wp-content/uploads/2018/11/Funding_for_flood_and_Costal_Erosion_in_England_Oct_2018.pdf (last access: 21 July 2023), 2018.

de Vos, A., Rozema, J., van Rijsselberghe, M., van Duin, W., and Brandenburg, W.: Zilte Landbouw Texel – een voorbeeld transitieproject – 2006–2010 eindrapport, Vrije Universiteit Amsterdam, Texelse Milieuvriendelijke Natuurprodukten B.V., Imares/Wageningen-UR, Hoogheemraadschap Noorderkwartier, Biosalien Innovatiecentrum Amsterdam, the Netherlands, https://edepot.wur.nl/159504 (last access: 20 June 2023), 2010.

D'Hont, F.: Co-design in the coastal context, Doctoral Thesis, Delft University of Technology, the Netherlands, https://pure.tudelft.nl/ws/portalfiles/portal/83650853/d_Hont_Co_design_in_the_coastal_context_dissertation.pdf (last access: 20 June 2023), 2020.

D'Hont, F., Slinger, J. H., and Goessen, P.: A knowledge intervention to explore stakeholders' understanding of a dynamic coastal nature reserve, in: Proceedings of the 32nd International conference of the system dynamics society, Delft, the Netherlands, 20–24 July 2014, s.l., the Netherlands, http://resolver.tudelft.nl/uuid:3bb7e69b-3f1a-42f9-b22d-74e4f742154d (last access: 19 June 2023), 2014.

D'Hont, F. M. and Slinger, J. H.: Including local knowledge in coastal policy innovation: comparing three Dutch case studies, Local Environment, 27, 897–914, https://doi.org/10.1080/13549839.2022.2084722, 2022.

Douglas, B. and Kaspari, S.: Unit 1: Climate Change and Sea Level: Who Are the Stakeholders?, GETSI – GEodesy Tools for Societal Issues, https://serc.carleton.edu/getsi/teaching_materials/climate_change/unit1.html (last access: 21 March 2024), 2019.

Ekwurzel, B., Boneham, J., and Dalton, M. W.: The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers, Climatic Change, 144, 579–590, https://doi.org/10.1007/s10584-017-1978-0, 2017.

Ernoul, L., Vera, P., Gusmaroli, G, Muccitelli, S, Pozzi, C., Magaudda, S., and Monti, F.: Use of voluntary environmental contracts for wetland governance in the European Mediterranean region, Mar. Freshwater Res., 73, 1–8, https://doi.org/10.1071/MF21109, 2021.

ESPO: Trends in EU Ports Governance 2022, European Sea Ports Organisation, Brussel, https://www.espo.be/media/ESPO%20Trends%20in%20EU%20ports%20governance%202022.pdf (last access: 21 July 2023), 2022.

EU Blue Economy Observatory: https://blue-economy-observatory.ec.europa.eu/index_en, last access: 21 March 2024.

European Commission: Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007/60/EC, 27–34, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0060 (last access: 21 November 2023), 2007.

European Commission: Marine Strategy Framework Directive (MSFD – 2008/56/EC, 22 pp., https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0056 (last access: 21 June 2023), 2008.

European Commission: Atlantic Maritime Strategy, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0782 (last access: 20 June 2023), 2011.

European Commission: EU Strategy for the Adriatic and Ionian Sea Region (EUSAIR), https://maritime-spatial-planning.ec.europa.eu/practices/eu-strategy-adriatic-and-ionian-region-eusair (last access: 20 June 2023), 2014a.

European Commission: Marine Spatial Planning European Directive (2014/89/EU), Official Journal of the European Union, 11 pp., https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0089 (last access: 21 June 2023), 2014b.

European Commission: Communication From The Commission To The European Paliament And The Council, The Committee Of The Regions And The European Economic And Social Committee Initiative For The Sustainable Development Of The Blue Economy In The Western Mediterranean, 52017SC0130, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017SC0130 (last access: 21 March 2024), 2017.

European Commission: Common Maritime Agenda for the Black Sea, https://black-sea-maritime-agenda.ec.europa.eu/206/common-maritime-agenda-black-sea (last access: 21 March 2024), 2019a.

European Commission: Joint Staff Working Document: Black Sea Synergy: review of a regional cooperation initiative – period 2015–2018, 53 pp., https://www.eeas.europa.eu/eeas/black-sea-synergy_en (last access: 20 June 2024), 2019b.

European Commission: Commission Staff Working Document Evaluation, Support instruments for the development of ocean energy policy, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0433 (last access: 3 February 2024), 2014–2020.

European Commission: Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Concerning The European Union Strategy For The Adriatic And Ionian Region, 74 pp., https://www.adriatic-ionian.eu/wp-content/uploads/2020/04/EUSAIR-SWD-2020.pdf (last access: 21 March 2024), 2020a.

European Commission: Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee of the Regions: A new approach to the Atlantic maritime strategy – Atlantic action plan 2.0 An updated action plan for a sustainable, resilient and competitive blue economy in the European Union Atlantic area, 52020DC0329, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:329:FIN (last access: 20 June 2023), 2020b.

European Commission: Closing the climate protection gap – Scoping policy and data gaps, Commission Staff Working Document, 113 pp., Cion doc.: SWD(2018) 461 final, https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vkti9g07t6xs (last access: 10 April 2023), 2021a.

European Commission: Joint Communication to the European Parliament, the Council, the European Economic and Social Committee of the Regions: Renewed Partnership With The Southern Neighbourhood – A New Agenda For The Mediterranean, SWD(2021) 23 final, https://www.eeas.europa.eu/sites/default/files/joint_communication_renewed_partnership_southern_neighbourhood.pdf (last access: 20 June 2023), 2021b.

European Commission: The EU Blue Economy Report, 2021, Publications Office of the European Union, Luxembourg, https://doi.org/10.2771/8217, 2021c.

European Commission: Joint Communication to the European Parliament, the Council, the European economic and social committee and the Committee of the regions a stronger EU engagement for a peaceful, sustainable and prosperous Arctic, JOIN(2021) 27 final, https://www.eeas.europa.eu/sites/default/files/2_en_act_part1_v7.pdf (last access: 20 June 2023), 2021d.

European Commission: Joint Communication To The European Parliament And The Council on the update of the EU Maritime Security Strategy and its Action Plan "An enhanced EU Maritime Security Strategy for evolving maritime threats", 52023JC0008, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52023JC0008 (last access: 21 March 2024), 2023a.

European Commission: The EU Blue Economy Report, https://doi.org/10.2771/7151, 2023b.

European Commission Directorate-General for Climate Action: Using insurance in adaptation to climate change. Publications Office, European Commission, Luxembourg, https://doi.org/10.2834/036674, 2018.

European Environment Agency: Urban adaptation in Europe: how cities and towns respond to climate change, European Environmental Agency, Luxembourg, https://doi.org/10.2800/324620, 2020.

European Environment Agency: Towards "just resilience": leaving no one behind when adapting to climate change, European Environment Agency, https://doi.org/10.2800/043692, 2022.

European Environment Agency: European climate risk assessment: Executive summary, European Environment Agency, Luxembourg, https://doi.org/10.2800/204249, 2024a.

European Environment Agency: Seas and coasts, European Environment Agency, https://www.eea.europa.eu/en/topics/in-depth/seas-and-coasts, last access: 21 March 2024b.

European Environment Agency: Climate change impacts, risks and adaptation, European Environment Agency, https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation?activeTab=07e50b68-8bf2-4641-ba6b-eda1afd544be&activeAccordion=dd2e16ef-4d34-48ae-bd38-31258544004d, last access: 21 March 2024c.

European Union: Opinion of the European Economic and Social Committee on "Financing the Transition to a Low-Carbon Economy and the Challenges in Financing Climate Change Adaptation", 52019AE4485, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019AE4485 (last access: 5 April 2024), 2020.

European Union Science Diplomacy Alliance: Strenghtening Science Diplomacy in and for Europe through Horizon Europe, European Union Science Diplomacy Alliance, https://www.science-diplomacy.eu/media/Policy-Brief_EU-SD-Alliance_Horizon-Europe_Feb-2024_Final-release1-1.pdf (last access: 28 June 2024), 2024.

Eurostat: Key figures on Europe, Publications Office of the European Union, https://doi.org/10.2785/851035, 2022.

FAO: The State of Mediterranean and Black Sea Fisheries 2020, General Fisheries Commission for the Mediterranean, Rome, https://doi.org/10.4060/cb2429en, 2020.

FAO: Aquaculture market in the Black Sea: country profiles, General Fisheries Commission for the Mediterranean, Rome, https://doi.org/10.4060/cb8551en, 2022.

Few, R., Brown, K., and Tompkins, E. L.: Climate change and coastal management decisions: insights from Christchurch Bay, UK, Coast. Manage., 35, 255–270, https://doi.org/10.1080/08920750601042328, 2007.

Filčák, R.: Environmental Justice and the Roma Settlements of Eastern Slovakia: Entitlements, Land and the Environmental Risks, JSTOR, 48, 537–562, http://www.jstor.org/stable/23535001 (last access: 22 June 2023), 2012.

Forsyth, M., Cleland, D., Tepper, F., Hollingworth, D., Soares, M., Nairn, A., and Wilkinson, C.: A future agenda for environmental restorative justice?, The International Journal of Restorative Justice, 4, 14–40, https://doi.org/10.5553/TIJRJ.000063, 2021.

Foudi, S., Osés-Eraso, N., and Galarraga, I.: The effect of flooding on mental health: Lessons learned for building resilience, Water Resour. Res., 53, 5831–5844, https://doi.org/10.1002/2017WR020435, 2017.

Galluccio, G., Hinkel, J., Fiorini Beckhauser, E., Bisaro, A., Biancardi Aleu, R., Campostrini, P., Casas, M. F., Espin, O., and Vafeidis, A. T.: Sea Level Rise in Europe: Adaptation measures and decision-making principles, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), edited by: van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K., Copernicus Publications, State Planet, 3-slre1, 6, https://doi.org/10.5194/sp-3-slre1-6-2024, 2024.

Gomis Bosch, D. and Alvarez Fanjul, E.: Vulnerabilidad de los Puertos Españoles ante el Cambio Climático, Vol. 1: Tendencias de variables físicas oceánicas y atmosféricas durante las últimas décadas y proyecciones para el siglo XXI, Organismo Público Puertos del Estado, M-43202-2016, https://www.puertos.es/es-es/BibliotecaV2/VULNERABILIDAD_completo_alta.pdf (last access: 20 July 2023), 2016.

Gross, M.: Geopolitical Competition in The Arctic Circle, Harvard International Review, https://hir.harvard.edu/the-arctic-circle/ (last access: 20 June 2023), 2020.

Haasnoot, M., van't Klooster, S., and van Alphen, J.: Designing a monitoring system to detect signals to adapt to uncertain climate change, Global Environ. Chang., 52, 273–285, https://doi.org/10.1016/j.gloenvcha.2018.08.003, 2018.

Haasnoot, M., Kwadijk, J., van Alphen, J., Le Bars, D., van den Hurk, B., Diermanse, F., van der Spek, A., Essink, G. O., Delsman, J., and Mens, M.: Adaptation to uncertain sea-level rise; how uncertainty in Antarctic mass-loss impacts the coastal adaptation strategy of the Netherlands, Environ. Res. Lett., 15, 034007, https://doi.org/10.1088/1748-9326/ab666c, 2020.

Haasnoot, M., Lawrence, J., and Magnan, A. K.: Pathways to coastal retreat: The shrinking solution space for adaptation calls for long-term dynamic planning starting now, Science, 372, 1287–1290, https://doi.org/10.1126/science.abi6594, 2021.

Hardy, R. D., Milligan, R. A., and Heynen, N.: Racial coastal formation: The environmental injustice of colorblind adaptation planning for sea-level rise, Geoforum, 87, 62–72, https://doi.org/10.1016/j.geoforum.2017.10.005, 2017.

Heede, R.: Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers 1854–2010,

Climatic Change, 122, 229–241, https://doi.org/10.1007/s10584-013-0986-y, 2014.

Hermans, L. M., Haasnoot, M., ter Maat, J., and Kwakkel, J. H.: Designing monitoring arrangements for collaborative learning about adaptation pathways, Environ. Sci. Policy, 69, 29–38, https://doi.org/10.1016/j.envsci.2016.12.005, 2017.

Hinkel, J., Lincke, D., Vafeidis, A. T., Perrette, M., Nicholls, R. J., Tol, R. S. J., Marzeion, B., Fettweis, X., Ionescu, C., and Levermann, A.: Coastal flood damage and adaptation costs under 21st century sea-level rise, P. Natl. Acad. Sci. USA, 111, 3292–3297, https://doi.org/10.1073/pnas.1222469111, 2014.

Hinkel, J., Aerts, J. C. J. H., Brown, S., Jiménez, J. A., Lincke, D., Nicholls, R. J., Scussolini, P., Sanchez-Arcilla, A., Vafeidis, A., and Addo, K. A.: The ability of societies to adapt to twenty-first-century sea-level rise, Nat. Clim. Change, 8, 570–578, https://doi.org/10.1038/s41558-018-0176-z, 2018.

Hooghe, L., Marks, G., Schakel, A. H., Chapman Osterkatz, S., Niedzwiecki, S., and Shair-Rosenfield, S.: Measuring regional authority: a postfunctionalist theory of governance, Volume I, Oxford University Press, United Kingdom, ISBN 9780198728870, https://hdl.handle.net/1814/44965 (last access: 20 June 2023), 2016.

Horton, B. P., Kopp, R. E., Garner, A. J., Hay, C. C., Khan, N. S., Roy, K., and Shaw, T.: Mapping Sea-Level Change in Time, Space, and Probability, Annu. Rev. Env. Resour., 481–521, https://doi.org/10.1146/annurev-environ-102017-025826, 2018.

Hudson, P., Botzen, W. J. W., and Aerts, J. C. J. H.: Flood insurance arrangements in the European Union for future flood risk under climate and socioeconomic change, Global Environ. Chang., 58, 101966, https://doi.org/10.1016/j.gloenvcha.2019.101966, 2019.

Instituto de Defesa Nacional: Shifts in World Geopolitics: Cooperation and Competition in the Atlantic, in: IDN E-Briefing Paper, International Seminar "Shifts in World Geopolitics: Cooperation and Competition in the Atlantic", 25 February 2022, Lisbon, Portugal, ISSN 2184-8246, 62 pp., 2022.

IPCC: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., and Rama, B., Cambridge University Press, https://doi.org/10.1017/9781009325844, 2022.

ISPI: Italy's "Wider Mediterranean": Is It Just About Energy?, https://www.ispionline.it/en/publication/italys-wider-mediterranean-is-it-just-about-energy-109073 (last access: 21 June 2023), 2023.

Just Climate: Geopolitics and Energy Security in Europe: how do we move forward?, FES Just Climate, Belgium, https://justclimate.fes.de/fileadmin/user_upload/images/publications/FES_Just_Climate_Study_19012023_Geopolitics_and_Energy_Security_in_Europe.pdf (last access: 20 June 2023), 2022.

Kakachia, K., Valiyev, A., Shelest, H., Lebanidze, B., Khylko, M., Alili, A., and Kandelaki, S.: Black Sea Security after the Russian invasion of Ukraine: Views from Ukraine, Georgia, and Azerbaijan, Policy Paper No. 31, Georgian Institute of Politics, http://prismua.org/wp-content/uploads/2022/09/Policy-Paper-31-ENG-Web.pdf (last access: 20 June 2023), 2022.

Kaufmann, M., Priest, S., Hudson, P., Löschner, L., Raška, P., Schindelegger, A., and Vleesenbeek, T.: Win–win for everyone? Reflecting on nature-based solutions for flood risk management from an environmental justice perspective, in: Nature-Based Solutions for Flood Mitigation: Environmental and Socio-Economic Aspects, Springer, vol. 107, 399–423, ISBN 978-3-030-77505-6, 2021.

Keenan, J. M.: Climate Adaptation Finance and Investment in California, Routledge, United Kingdom, 173 pp., ISBN 978-0-367-02607-3, ISBN 978-0-429-39875-9, 2019.

Kind, J., Botzen, W. J. W., and Aerts, J. C. J. H.: Social vulnerability in cost-benefit analysis for flood risk management, Environ. Dev. Econ., 25, 115–134, https://doi.org/10.1017/S1355770X19000275, 2020.

Klaassen, R., Kothuis, B., and Slinger, J.: Engineering roles in Building with Nature interdisciplinary design: Educational experiences, Research in Urbanism Series, 7, 73–98, https://doi.org/10.47982/rius.7.129, 2021.

Kos, E. and Štoka, A. M.: Blue Growth innovation policies in sea basins Best practice identification and benchmarking introduction, https://blueair.adrioninterreg.eu/wp-content/uploads/2021/11/Technology-Park-Ljubljana.pdf (last access: 21 March 2024), 2021.

Krūmiòš, J. and Kïaviòš, M.: The Baltic States' Move toward a Sustainable Energy Future, Energies, 15, 8230, https://doi.org/10.3390/en15218230, 2022.

Lager, F., Coninx, I., Breil, M., Bakhtaoui, I., Pedersen, A. B., Mattern, K., Berg, H. van den, Sini, E., Galluccio, G., Klein, R., and Vierikko, K.: Just Resilience for Europe: Towards measuring justice in climate change adaptation, European Environment Agency, https://doi.org/10.25424/CMCC-BATP-3M95, 2023.

Landry, C. E., Keeler, A. G., and Kriesel, W.: An Economic Evaluation of Beach Erosion Management Alternatives, Mar. Resour. Econ., 18, 105–127, 2003.

Lincke, D. and Hinkel, J.: Economically robust protection against 21st century sea-level rise, Global Environ. Chang., 51, 67–73, https://doi.org/10.1016/j.gloenvcha.2018.05.003, 2018.

Lionello, P., Barriopedro, D., Ferrarin, C., Nicholls, R. J., Orlić, M., Raicich, F., Reale, M., Umgiesser, G., Vousdoukas, M., and Zanchettin, D.: Extreme floods of Venice: characteristics, dynamics, past and future evolution (review article), Nat. Hazards Earth Syst. Sci., 21, 2705–2731, https://doi.org/10.5194/nhess-21-2705-2021, 2021.

Lobosco, G. and Mencarini, V.: Landscape and climate change: a resilient strategy for the adaptation plan of the Ravenna area in Italy, Convergences – Journal of Research and Arts Education, 13, no. 26, https://doi.org/10.53681/c1514225187514391s.26.39, 2023.

Lodder, Q. and Slinger, J.: The "Research for Policy" cycle in Dutch coastal flood risk management: The Coastal Genesis 2 research programme, Ocean Coast. Manage., 219, 106066, https://doi.org/10.1016/j.ocecoaman.2022.106066, 2022.

López-Dóriga, U., Jiménez, J. A., Bisaro, A., and Hinkel, J.: Financing and implementation of adaptation measures to climate change along the Spanish coast, Sci. Total Environ., 712, 135685, https://doi.org/10.1016/j.scitotenv.2019.135685, 2020.

Maldonado, J. K.: A multiple knowledge approach for adaptation to environmental change: lessons learned from coastal

Louisiana's tribal communities, J. Polit. Ecol., 21, 61–82, https://doi.org/10.2458/v21i1.21125, 2014.

Mancebo Silva, P.: The old colonialisms and the new ones: the Arctic Resource Boom as a new wave of settler-colonialism, The Arctic Institute, https://www.thearcticinstitute.org/old-colonialisms-new-ones-arctic-resource-boom-new-wave-settler-colonialism/ (last access: 19 June 2023), 2022.

MATTM-Regioni: Linee Guida per la Difesa della Costa dai fenomeni di Erosione e dagli effetti dei Cambiamenti climatici, Versione 2018 – Documento elaborato dal Tavolo Nazionale sull'Erosione Costiera, MATTM-Region, Italy, http://www.erosionecostiera.isprambiente.it/files/linee-guida-nazionali/TNEC_LineeGuidaerosionecostiera_2018.pdf (last access: 20 June 2023), 2018.

McEvoy, S., Haasnoot, M., and Biesbroek, R.: How are European countries planning for sea level rise?, Ocean Coast. Manage., 203, 105512, https://doi.org/10.1016/j.ocecoaman.2020.105512, 2021.

McGinlay, J., Jones, N., Clark, J., and Maguire-Rajpaul, V. A.: Retreating coastline, retreating government? Managing sea level rise in an age of austerity, Ocean Coast. Manage., 204, 105458, https://doi.org/10.1016/j.ocecoaman.2020.105458, 2021.

Mees, H., Alexander, M., Gralepois, M., and Matczak, P.: Typologies of citizen co-production in flood risk governance, Environ. Sci. Policy, 89, 330–339, https://doi.org/10.1016/j.envsci.2018.08.011, 2018.

Melet, A., van de Wal, R., Amores, A., Arns, A., Chaigneau, A. A., Dinu, I., Haigh, I. D., Hermans, T. H. J., Lionello, P., Marcos, M., Meier, H. E. M., Meyssignac, B., Palmer, M. D., Reese, R., Simpson, M. J. R., and Slangen, A. B. A.: Sea Level Rise in Europe: Observations and projections, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), edited by: van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K., Copernicus Publications, State Planet, 3-slre1, 4, https://doi.org/10.5194/sp-3-slre1-4-2024, 2024.

Meli, M., Camargo, C. M. L., Olivieri, M., Slangen, A. B. A., and Romagnoli, C.: Sea-level trend variability in the Mediterranean during the 1993–2019 period, Front. Mar. Sci., 10, 1150488, https://doi.org/10.3389/fmars.2023.1150488, 2023.

Merrill, S., Kartez, J., Langbehn, K., Muller-Karger, F. E., and Reynolds, C. J.: Who Should Pay for Climate Adaptation? Public Attitudes and the Financing of Flood Protection in Florida, Environ. Value., 5, 535–557, https://doi.org/10.3197/096327118X15321668325957, 2018.

Mihailov, M. E., Grigorescu, L., and Pera, R.: Climate change and security: the case for Black Sea, Strategic Impact, 88, 54–71, https://doi.org/10.53477/1842-9904-23-16, 2023.

Ministero dell'Ambiente e della tutela del territorio e del mare: Strategia Nazionale di Adattamento ai Cambiamenti Climatici, https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/documento_SNAC.pdf (last access: 21 June 2023), 2015.

Ministero dell'Ambiente e della tutela del territorio e del mare: Piano Nazionale di Adattamento ai Cambiamenti Climatici, https://www.mase.gov.it/pagina/piano-nazionale-di-adattamento-ai-cambiamenti-climatici (last access: 21 June 2023), 2023.

Mjahed, H.: The North Sea: Europe's Energy Powerhouse, Policy Center for the New South, Policy Brief no. 09/2023, 2023.

Moraes, R. P. L., Reguero, B. G., Mazarrasa, I., Ricker, M., and Juanes, J. A.: Nature-Based Solutions in Coastal and Estuarine Areas of Europe, Front. Environ. Sci., 10, 829526, https://doi.org/10.3389/fenvs.2022.829526, 2022.

Moser, S. C., Ekstrom, J. A., Kim, J., and Heitsch, S.: Adaptation finance archetypes: local governments' persistent challenges of funding adaptation to climate change and ways to overcome them, Ecol. Soc., 24, 28, https://doi.org/10.5751/ES-10980-240228, 2019.

Mullin, M., Smith, M. D., and McNamara, D. E.: Paying to save the beach: effects of local finance decisions on coastal management, Climatic Change, 152, 275–289, https://doi.org/10.1007/s10584-018-2191-5, 2019.

Nationaal Uitvoeringsprogramma Klimaatadaptatie: Slimmer, intensiever, voor en door iedereen, Nationaal Uitvoeringsprogramma Klimaatadaptatie, the Netherlands, https://open.overheid.nl/documenten/dpc-2f1a2258b86c19919999b03a927ca9e3ba0498af/pdf (last access: 2 July 2024), 2023.

Nicholls, R. J., Hinkel, J., Lincke, D., and van der Pol, T.: Global Investment Costs for Coastal Defense Through the 21st Century, World Bank Policy Research Working Paper No. 8745, https://ssrn.com/abstract=3338183 (last access: 21 June 2023), 2019.

Ocean & Climate Platform: Adapting Coastal Cities and Territories to Sea Level Rise in Northern Europe: Challenges and Best Practices, Ocean & Climate Platforme, https://ocean-climate.org/wp-content/uploads/2022/04/SEATIES_Report_Adaptation_SLR_Northern-Europe_V2.pdf (last access: 22 June 2023), 2022.

Ocean Governance: https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/ocean-governance, last access: 21 March 2024.

OECD: Responding to Rising Seas: OECD Country Approaches to Tackling Coastal Risks, https://doi.org/10.1787/9789264312487-en, 2019.

Oelsmann, J., Marcos, M., Passaro, M., Sanchez, L., Dettmering, D., Dangendorf, S., and Seitz, F.: Regional variations in relative sea-level changes influenced by nonlinear vertical land motion, Nat. Geosci., 17, 137–144, https://doi.org/10.1038/s41561-023-01357-2, 2024.

O'Garra, T.: Economic value of ecosystem services, minerals and oil in a melting Arctic: A preliminary assessment, Ecosystem Services, 24, 180–186, https://doi.org/10.1016/j.ecoser.2017.02.024, 2017.

Osberghaus, D., Dannenberg, A., Mennel, T., and Sturm, B.: The Role of the Government in Adaptation to Climate Change, Environ. Plann. C, 28, 834–850, https://doi.org/10.1068/c09179j, 2010.

Paleari, S.: Disaster risk insurance: A comparison of national schemes in the EU-28, Int. J. Disast. Risk Re., 35, 101059, https://doi.org/10.1016/j.ijdrr.2018.12.021, 2019.

PIANC: Climate Change Adaptation Planning for Ports and Inland Waterways, The World Association for Waterborne Transport Infrastructure, PIANC report no. 178/2020, 2020.

Plan Bleu: State of Play of Tourism in the Mediterranean, Interreg Med Sustainable Tourism Community project, https://planbleu.org/wp-content/uploads/2022/11/EN_VF_stateoftourism_PLANBLEU.pdf (last access: 27 June 2023), 2022.

Puddu, M. and Etzi, F.: Coastal Contract: A Governance Approach for Integrated Wetland Management Applied in the Gulf of Oristano, Sardinia, Italy, https://climate-adapt.eea.europa.eu/en/mission/solutions/mission-stories?size=n_10_n&filters%5B0%5D%5Bfield%5D=cluster_name&filters%5B0%5D%5Btype%5D=any&filters%5B0%5D%5Bvalues%5D%5B0%5D=cca&filters%5B1%5D%5Bfield%5D=objectProvides&filters%5B1%5D%5Btype%5D=any&filters%5B1%5D%5Bvalues%5D%5B0%5D=Mission%20story&filters%5B2%5D%5Bfield%5D=readingTime&filters%5B2%5D%5Btype%5D=any&filters%5B2%5D%5Bvalues%5D%5B0%5D%5Bname%5D=All&filters%5B2%5D%5Bvalues%5D%5B0%5D%5BrangeType%5D=fixed&filters%5B3%5D%5Bfield%5D=issued.date&filters%5B3%5D%5Btype%5D=any&filters%5B3%5D%5Bvalues%5D%5B0%5D=Last%205%20years&filters%5B4%5D%5Bfield%5D=language&filters%5B4%5D%5Btype%5D=any&filters%5B4%5D%5Bvalues%5D%5B0%5D=en (last access: 21 March 2024), 2024.

Ranger, N., Reeder, T., and Lowe, J.: Addressing "deep" uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project, EURO J. Decis. Process., 1, 233–262, https://doi.org/10.1007/s40070-013-0014-5, 2013.

Reckien, D., Salvia, M., Heidrich, O., Jon Marco, C., Piatrapertosa, F., De Gregorio-Hurtado, S., D'Alonzo, V., Foley, A., Simoes, S. G. S., Krkoška Lorencová, E., Orru, H., Orru, K., Wejs, A., Flacke, J., Olazabal, M., Geneletti, D., Feliu, E., Vasilie, S., Nador, C., and Dawson, R. J.: How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28, J. Clean. Prod., 191, 207–219, https://doi.org/10.1016/j.jclepro.2018.03.220, 2018.

Riera-Spiegelhalder, M., Campos-Rodrigues, L., Enseñado, E. M., Dekker-Arlain, J. den, Papadopoulou, O., Arampatzis, S., and Vervoort, K.: Socio-Economic Assessment of Ecosystem-Based and Other Adaptation Strategies in Coastal Areas: A Systematic Review, Journal of Marine Science and Engineering, 11, 319, https://doi.org/10.3390/jmse11020319, 2023.

Rocle, N., Rey-Valette, H., Bertrand, F., Becu, N., Long, N., Bazart, C., Vye, D., Beck, E., Amalric, M., and Lautrédou-Audouy, N.: Paving the way to coastal adaptation pathways: An interdisciplinary approach based on territorial archetypes, Environ. Sci. Policy, 110, 34–45, https://doi.org/10.1016/j.envsci.2020.05.003, 2020.

Sabin Center for Climate Change Law and Columbia Law School: Climate Change Litigation Database, http://climatecasechart.com (last access: 21 June 2023), 2023.

Sacchi et al. v. Argentina et al.: Sacchi et al. v. Argentina et al., Communication No. 104/2019 (Argentina), Communication No. 105/2019 (Brazil), Communication No. 106/2019 (France), Communication No. 107/2019 (Germany), Communication No. 108/2019 (Turkey), 2019.

Sarra, J. and DeMarco, E.: Climate-related legal risks for financial institutions: Executive Brief, Global Risk Institute, Executive Brief, https://ccli.ubc.ca/wp-content/uploads/2021/08/Climate-related-legal-risks-for-financial-institutions-Executive-brief.pdf (last access: 4 October 2023), 2021.

Sayers, P.: Evolution of Strategic Flood Risk Management in Support of Social Justice, Ecosystem Health, and Resilience, Oxford Research Encyclopedia of Natural Hazard Science, https://doi.org/10.1093/acrefore/9780199389407.013.85, 2017.

Sayers, P., Penning-Rowsell, E., and Horritt, M.: Flood vulnerability, risk and social disadvantage: Current and future patterns in the UK, Journal of Regional Environmental Change, 18, 339–352, https://doi.org/10.1007/s10113-017-1252-z, 2017.

Sayers, P., Moss, C., Carr, S., and Payo, A.: Responding to climate change around England's coast – The scale of the transformational challenge, Ocean Coast. Manage., 225, 106187, https://doi.org/10.1016/j.ocecoaman.2022.106187, 2022.

Schlosberg, D.: Defining Environmental Justice: Theories, Movements, and Nature, Online edition, Oxford University Press, United Kingdom, ISBN 978-0-19-171332-3, 2007.

Schuerch, M., Mossman, H. L., Moore, H. E., Christie, E., and Kiesel, J.: Invited perspectives: Managed realignment as a solution to mitigate coastal flood risks – optimizing success through knowledge co-production, Nat. Hazards Earth Syst. Sci., 22, 2879–2890, https://doi.org/10.5194/nhess-22-2879-2022, 2022.

Setzer, J. and Higham, C.: Global trends in climate second line goes here change litigation: 2022 snapshot, Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science, London, Policy report, June 2022, 2022.

Siders, A., Ajibade, I., and Casagrande, D.: Transformative potential of managed retreat as climate adaptation, Curr. Opin. Env. Sust., 50, 272–280, https://doi.org/10.1016/j.cosust.2021.06.007, 2021.

Sierra, J. P., Sánchez-Arcilla, A., Gironella, X., Gracia, V., Altomare, C., González-Marco, D., Sánchez-Artús, X., Gómez, J., Casals, C., Molero, J., Verger, E., and Gironella, X.: Plan de adaptación al cambio climático para los puertos de la Autoridad Portuaria de Baleares, Puertos del Estado, Ports de Balears, Barcelona, https://portsdebalears.com/sites/default/files/Presentaci%C3%B3n_Agust%C3%ADn_S%C3%A1nchez-Arcilla_0.pdf (last access: 20 July 2023), 2022.

Slinger, J. H. and Kothuis, B. B.: Chapter 28 – A specific transdisciplinary co-design workshop model to teach a multiple perspective problem approach for integrated nature-based design, edited by: Brody, S., Lee, Y., and Kothuis, B. B., Coastal Flood Risk Reduction, Elsevier, ISBN 9780323852517, 377–395, https://doi.org/10.1016/B978-0-323-85251-7.00028-7, 2022.

Slinger, J. H., Cunningham, S. W., Hermans, L. M., Linnane, S. M., and Palmer, C. G.: A game-structuring approach applied to estuary management in South Africa, Ocean Coast. Manage., 219, 106066, https://doi.org/10.1016/j.ocecoaman.2022.106066, 2014.

Slinger, J. H., Taljaard, S., and d'Hont, F. M.: Complex Coastal Systems: transdisciplinary learning on international case studies, OPEN Publishing, the Netherlands, 149 pp., https://doi.org/10.34641/mg.32, 2022.

Sovacool, B. K., Linnér, B.-O., and Goodsite, M. E.: The Political Economy of Climate Change Adaptation, Palgrave Macmillan UK, London, https://doi.org/10.1057/9781137496737, 2015.

Stephenson, R. L., Hobday, A. J., Cvitanovic, C., Alexander, K. A., Begg, G. A., Bustamante, R. H., Dunstan, P. K., Frusher, S., Fudge, M., Fulton, E. A., Haward, M., Macleod, C., Mc-

Donald, J., Nash, K. L., Ogier, E., Pecl, G., Plagányi, É. E., van Putten, I., Smith, T., and Ward, T. M.: A practical framework for implementing and evaluating integrated management of marine activities, Ocean Coast. Manage., 177, 127–138, https://doi.org/10.1016/j.ocecoaman.2019.04.008, 2019.

Storbjörk, S. and Hedrén, J.: Institutional capacity-building for targeting sea-level rise in the climate adaptation of Swedish coastal zone management. Lessons from Coastby, Ocean Coast. Manage., 54, 265–273, https://doi.org/10.1016/j.ocecoaman.2010.12.007, 2011.

Swistek, G. and Paul, M.: Geopolitics in the Baltic Sea Region: The "Zeitenwende" in the context of critical maritime infrastructure, escalation threats and the German willingness to lead, German Institute for International and Security Affairs, SWP Comment 2023/C 09, 16.02.2023, 8 pp., https://doi.org/10.18449/2023C09, 2023.

Tesselaar, M., Botzen, W. J. W., and Aerts, J. C. J. H.: Impacts of Climate Change and Remote Natural Catastrophes on EU Flood Insurance Markets: An Analysis of Soft and Hard Reinsurance Markets for Flood Coverage, Atmosphere, 11, 146, https://doi.org/10.3390/atmos11020146, 2020.

Thangaraj, A. and Chowdhury, A.: Energy, geopolitics and the dying arctic ice fields: an enviro- political perspective, IOP Conf. Ser.: Earth Environ. Sci., 1084, 012034, https://doi.org/10.1088/1755-1315/1084/1/012034, 2022.

The Netherlands: National Climate Adaptation Strategy 2016: Adapting with ambition, Ministry of Infrastructure and the Environment, the Netherlands, https://klimaatadaptatienederland.nl/publish/pages/125102/2016_12_02_nas_netherlands_4_5.pdf (last access: 20 June 2023), 2016.

Tubridy, F., Lennon, M., and Scott, M.: Managed retreat and coastal climate change adaptation: The environmental justice implications and value of a coproduction approach, Land Use Policy, 114, 105960, https://doi.org/10.1016/j.landusepol.2021.105960, 2022.

UNCTAD: Building Capacity to Manage Risks and Enhance Resilience: A Guidebook for Ports, United Nations Conference on Trade and Development, https://unctad.org/system/files/official-document/tcsdtlinf2022d3_en.pdf (last access: 21 July 2023), 2022.

United Nations: Stressing Rising Seas Already Creating Instability, Conflict, Secretary-General Says Security Council Has Critical Role in Addressing Devastating Challenges: https://press.un.org/en/2023/sgsm21688.doc.htm (last access: 21 March 2024), 2023.

United Nations Environment Programme: Global Climate Litigation Report: 2020 Status Review, United Nations Environment Programme, Kenya, https://wedocs.unep.org/bitstream/handle/20.500.11822/34818/GCLR.pdf?sequence=1&isAllowed=y (last access: 20 June 2023), 2020.

United Nations General Assembly (UNGA): Sea-level rise in relation to international law A/CN.4/761, United Nations General Assembly, International Court of Justice, document number 187-20230630-REQ-06-06-EN, https://documents.un.org/doc/undoc/gen/n23/044/38/pdf/n2304438.pdf?token=1CFwxAJHfls1hYKLyl&fe=true (last access: 7 March 2024), 2023.

Van Assche, K., Hornidge, A. K., Schlüter, A., and Vaidianu, N.: Governance and the coastal condition: Towards new modes of observation, adaptation and integration, Mar. Policy, 112, 103413, https://doi.org/10.1016/j.marpol.2019.01.002, 2020.

van den Hurk, B., Bisaro, A., Haasnoot, M., Nicholls, R. J., Rehdanz, K., and Stuparu, D.: Living with sea-level rise in North-West Europe: Science-policy challenges across scales, Climate Risk Management, 35, 100403, https://doi.org/10.1016/j.crm.2022.100403, 2022.

van de Wal, R., Melet, A., Bellafiore, D., Camus, P., Ferrarin, C., Oude Essink, G., Haigh, I. D., Lionello, P., Luijendijk, A., Toimil, A., Staneva, J., and Vousdoukas, M.: Sea Level Rise in Europe: Impacts and consequences, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), edited by: van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K., Copernicus Publications, State Planet, 3-slre1, 5, https://doi.org/10.5194/sp-3-slre1-5-2024, 2024.

Vanhala, L. and Hestbaek, C.: Framing Climate Change Loss and Damage in UNFCCC Negotiations, Global Environ. Polit., 16, 111–129, https://doi.org/10.1162/GLEP_a_00379, 2016.

Vierros, M.: Global Marine Governance and Oceans Management for the Achievement of SDG 14, United Nations, UN Chronicle, https://www.un.org/en/chronicle/article/global-marine-governance-and-oceans-management-achievement-sdg-14 (last access: 21 March 2024), 2017.

WESTMED Blue Economy Initiative: https://westmed-initiative.ec.europa.eu/westmed-initiative/, last access: 21 March 2023.

Woodruff, S., Mullin, M., and Roy, M.: Is coastal adaptation a public good? The financing implications of good characteristics in coastal adaptation, J. Environ. Plann. Man., 63, 2082–2101, https://doi.org/10.1080/09640568.2019.1703656, 2020.