**SP35 - Sea Level Rise in Europe: Adaptation measures and decision-making principles**

**KEY DEVELOPMENTS PER BASIN**

Adaptation to SLR in Europe has been approached through various types of measures to accommodate, protect, advance and retreat. Below, we summarise the main developments organised by the different sea basins.

In the Baltic Sea basin, for accommodate measures, progress has been made, with several Baltic nations incorporating SLR projections into their spatial planning and land use regulations. Notably, Estonia has implemented a Maritime Spatial Plan for 2022 that integrates SLR information. In terms of protect measures, upgrading coastal defences, e.g. with sea walls, embankments and dikes, has been implemented, while nature-based solution initiatives to re- store and create wetlands and coastal marshes that can act as buffer zones and reduce wave energy are also underway. For instance, the Danish Baltic coast provides the first large-scale example of successful managed realignment with the restored Gyldensteen Coastal Lagoon, which has to date enhanced ecological status and species richness in the project area (Thorsen et al., 2021). The Baltic Sea basin has also seen progress in marine environment conservation, which can potentially enhance living marine resources and related fishing activities. Key to furthering coastal adaptation in the basin is ensuring that solutions are also linked to financing mechanisms that can mobilise co-finance, e.g. from the private sector, to supplement national public funding.

In the North Sea basin, SLR information has been integrated into coastal planning at the national and sub-national levels in most countries, while North Sea basin countries are implementing different mixes of hard and soft protect measures. In the Netherlands, the Delta Programme includes a comprehensive mix of measures to maintain a healthy groundwater system, using spatial planning and other context-specific strategies while providing more space for water and enhancing urban and ecological values. Sand nourishment is also growing in importance as a coastal protect measure in the Netherlands, alongside dike upgrading and re- inforcement. In Germany, there is an emphasis on integrated coastal zone management and dike upgrading and widening that incorporates flexibility for future SLR. In the UK, a mix of protection, beach nourishment and managed retreat is being considered for different sections of the coastline. These countries each reflect different approaches to addressing uncertainty that should be iterated and revisited as more information on SLR becomes available in the future.

In the Mediterranean Sea basin, key developments include the mainstreaming of SLR information into planning through the development of national adaptation plans, e.g. in Spain and Italy. Furthermore, insurance is emerging as an accommodate measure to address SLR-related risks, e.g. in Spain and France. Soft protect measures, such as sand nourishment and nature-based solutions more broadly, are important in the Mediterranean Sea basin, with coastal reforestation and the restoration of dunes and marshes implemented in various regions to act as natural barriers. Other examples are cliff strengthening and stabilisation measures that include green and grey options focusing on reducing erosion and enhancing natural protection along coastal cliffs, e.g. in Croatia and Italy. Several major urban areas in the basin have initiated large-scale adaptation measures. For example, the Venice MOSE project is a system of mobile barriers constructed to protect Venice from high tides and flooding, while the city of Barcelona has introduced green infrastructure projects that focus on permeability and water retention to combat both SLR and increased rainfall. Such differentiated measures appropriate to the specific biophysical and socio-economic context at issue should be further supported through participatory co-development approaches for coastal decision-making (Bisaro et al., 2024).

In the Black Sea basin, there is an increased emphasis on developing monitoring and early-warning systems to help manage SLR and the associated flood risks. Furthermore, efforts have focused on upgrading and modernising existing coastal infrastructure to enhance resilience to rising sea levels. For example, in Romania, a major initiative combining sand nourishment and cliff stabilisation with marine measures including artificial reef building is being implemented to reduce coastal erosion risks exacerbated by SLR and to enhance resilience in the tourism sector. Furthermore, implementation of such nature-based solutions that also benefit local economies is promising and should be explored for scaling up coastal adaptation in the basin.

In the Atlantic Ocean basin, countries are implementing a range of adaptation measures, with an emerging focus on nature-based solutions and improved spatial planning to reduce risks to coastal development across the entire basin. Soft protect measures, such as cliff strengthening and sand nourishment, are being implemented in Portugal, while restoration measures, protecting against wave energy and therefore limiting erosion and sediment accumulation, are being implemented in Spain, Portugal and France. Advance strategies are also being implemented through nature-based solution approaches, as in Spain, where the national adaptation plan envisions the regeneration of beaches and artificial dune systems to reduce erosion and revitalise coastal ecosystems, e.g. in the restoration one of the largest dune sys- tems of the Cantabrian Sea. Furthermore, in France, coastal land in the south-west of the country has been advanced with the creation of a vegetated area with the specific intention of supporting natural accretion of land and surrounding low areas. Finally, retreat measures are also being implemented, such as in Portugal, where the progressive removal of constructions located in flood-critical territories along the coastline is being implemented through spatial planning instruments to manage the risk of SLR.

Common themes and general trends are further highlighted in the conclusion.

**CONCLUSION**

This paper has conducted a review of the literature on coastal adaptation. The main outcome of this process, which is summarised in Table 1, was the collection and categorisation of 17 adaptation measures to SLR, focusing on European sea basins and targeting four climate impacts, namely coastal flooding, saltwater intrusion, coastal erosion and impacts on ecosystems and estuaries. The table combines two categorisations regarding the responses to SLR: first, a top-level categorisation of adaptation measures according to the four main types of response identified by the IPCC, and a further elaboration taking into account the sub-Key Type of Measure (sub-KTM) to SLR developed by the EEA. By reviewing the relevant literature on European sea basins, the paper has shown that adaptation strategies on Europe’s coasts include a mix of hard and soft measures, planning measures, policy developments and stakeholder and community engagement. A common theme across all the basins is the shift towards a combination of traditional engineering solutions with soft measures, such as nature-based solutions.

The measures discussed in this paper are generally subject to trade-offs that should be considered when planning for coastal adaptation. In order to accurately analyse existing trade-offs, it is important to understand the effectiveness and feasibility of these measures. The paper identified a critical gap in the literature in this regard. In particular, there is a scientific need to assess the effectiveness and feasibility of individual measures and in context-specific cases. Such a research gap, if addressed, could advance knowledge and contribute to the field of coastal adaptation. Hence, these findings suggest that the literature review can be expanded to include more studies, and that more research is needed to learn about the trade-offs of implementing each of these measures.

In terms of decision making approaches, the paper has shown that coastal adaptation is a complex undertaking mainly because of five key common characteristics, namely the diversity of fundamentally different measures, the multiple objects and trade-offs, the multiple interests and social conflicts, the long time horizon, and the large and deep uncertainties involved in such decisions. To support decision-making processes, analytical tools are available, ranging from relatively straightforward tools such as adaptation pathway analysis and multi-criteria analysis to technically complex methods such as robust decision-making and real-option analysis.

Integrating local communities into decision-making processes and emphasising the importance of continuous monitoring and flexible management strategies are notable trends. Ensuring that these trends lead to appropriate mixes of coastal adaptation measures being found depends on the continued support and involvement of public and private sector stakeholders in effective multi-level governance. To this end, it should be noted that there is a large discrepancy between the normative and descriptive literature in the participatory approaches for supporting decisions, and more empirical work is therefore needed to understand the conditions under which participatory adaptation processes are delivered.