

June, 2026

# Climate, Ocean Acidification & Nature Governance in the Baltic-Black Sea Region

**Governance brief**

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**This report has been produced as part of the ECOADAPTOR project, funded by the Swedish Institute’s Baltic Sea Neighbourhood Programme.**

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**Published** in June 2026



## Main takeaways

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1. **The Baltic and Black Seas are facing interconnected environmental crises.**  
Climate change, acidification, eutrophication, hypoxia, and biodiversity loss are reinforcing one another, threatening marine ecosystems, water quality, fisheries, tourism, and coastal economies.
2. **Ocean acidification remains a major blind spot in climate policy.**  
Although acidification is a direct consequence of rising CO<sub>2</sub> emissions, it is still poorly integrated into global, EU, and national climate frameworks, including the SDGs and National Energy and Climate Plans (NECPs).
3. **Current governance is too fragmented to address these challenges effectively.**  
Climate policy, marine policy, river basin management, nature restoration and agricultural policy are often developed separately, despite the need for integrated “source-to-sea” and climate–ocean–nature approaches across the entire Baltic–Black Sea region.
4. **Stronger regional cooperation, monitoring, and financing are urgently needed.**  
Better coordination between countries and institutions, harmonized monitoring systems, integrated land–sea governance, stakeholder participation, and expanded blue finance mechanisms are essential to strengthen resilience and protect marine ecosystems.
5. **Nature-based solutions and marine spatial planning are key tools for building resilience.** The restoration of coastal and marine ecosystems, combined with ecosystem-based marine spatial planning, can simultaneously support climate adaptation, biodiversity recovery, water quality improvement, carbon sequestration, and sustainable blue economy development across the Baltic–Black Sea region. This should form an important component of National Restoration Plans (NRPs).

# 1. Executive Summary

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The region between the Baltic and Black Seas is one of the most climate-sensitive areas in Europe, characterized by both high anthropogenic pressure and fragmented management systems.

Marine waters globally absorb approximately 25% of anthropogenic CO<sub>2</sub> emissions, causing pH declines of approximately 0.02 units per decade. In the Baltic, however, local rates of acidification can be up to 2.5 times higher than the global average, as observed in some Danish estuaries. At the same time, the Baltic–Black Sea region is warming faster than the global average. In the Baltic Sea, surface temperatures has increased by as much as 1°C per decade between 1990 and 2008. The Black Sea is also warming rapidly, with surface temperatures rising by approximately 0.5–0.65°C per decade. While pH decline across the surface layer of the Black Sea shows a moderate overall trend, stronger local acidification may occur in coastal zones and intermediate waters.

Marine acidification remains an underestimated component of climate policy, and current management systems are fragmented and poorly integrated, limiting the effectiveness of mitigation, adaptation and nature restoration efforts. It is important to recognize the close interconnection between climate, oceans and biodiversity: climate change affects the oceans through warming, acidification and deoxygenation<sup>1</sup>, while marine ecosystems contribute to climate regulation through CO<sub>2</sub> uptake, carbon sequestration and temperature regulation. Restoring degraded marine and coastal ecosystems can enhance their resilience to climate impacts and strengthen the delivery of ecosystem services. These are not separate systems operating independently of one another, but a single interconnected and interdependent climate–ocean–nature nexus.

This briefing highlights the need to give greater attention to aspects related to ocean and sea acidification in climate and nature restoration policy documents. At the same time, policy frameworks addressing marine waters should more clearly acknowledge that acidification is closely linked to global CO<sub>2</sub> emissions. Greater integration of planning documents and management tools is therefore needed to address the interdependence between climate change and marine acidification and biodiversity more effectively. This briefing also proposes including acidification in the National Energy and Climate Plans (NECP) as well as National Restoration Plans (NRP) and establishing a “Baltic–Black Sea Climate & Ocean Initiative”. Nature-based solutions and ecosystem-based marine spatial planning should become key instruments for addressing the interconnected challenges of climate change, marine acidification, biodiversity loss, and coastal resilience across the Baltic–Black Sea region.

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<sup>1</sup> Marine **deoxygenation** refers to the reduction of dissolved oxygen levels in marine waters, leading to the expansion of hypoxic and anoxic zones that threaten marine biodiversity and ecosystem functioning.

## 2. Context and Significance of the Region

The region encompasses EU countries such as Poland, Lithuania, Latvia, Estonia, Sweden, Denmark, Finland, Romania, and Bulgaria, as well as Ukraine, a candidate country on its path toward EU membership. This intermarium area – Baltic–Black Sea region – includes major river basins such as the Vistula, Oder, Danube, and Dniro rivers, together with numerous smaller river catchments. Collectively, these river systems, contribute to environmental pressures through the transport of CO<sub>2</sub>, nutrients, and other pollutants. Key economic activities relevant for waters in the region includes fisheries and aquaculture, maritime transport (TEN-T corridors<sup>2</sup>), coastal tourism, and building energy security (offshore, LNG). Below is a map illustrating the intermarium area (Fig. 1).

Fig. 1. The area between the Baltic and Black Seas



Source: Wikipedia

- 2 **TEN-T corridors** (Trans-European Transport Network corridors) are the main transport routes that connect European countries and regions. They are part of the EU's strategy to create an integrated, efficient, and sustainable transport system by linking roads, railways, inland waterways, ports, airports, and logistics hubs across Europe.

### 3. Environmental Status and Trends

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#### Baltic Sea

According to the Helsinki Commission (HELCOM), the impacts of climate change in the Baltic Sea include rising water temperatures and a reduced sea ice cover, among other effects. Increased average annual precipitation has also been observed in the northern parts of the region. Together, these changes have a significant consequence for the ecosystems and the ecosystem services they provide. The direct and indirect effects of climate change are highly complex, and this complexity is further amplified by feedback mechanisms and interactions with other ongoing environmental changes.

Across many Baltic Sea sub-basins, declining pH levels and increasing CO<sub>2</sub> concentration have already been observed, accompanied with strong seasonal fluctuations, with pH levels occasionally dropping to around 7.9 during winter (according to HELCOM typically around 8.0–8.2). Forecasts indicate that CO<sub>2</sub> concentrations could increase from around 390 to more than 970  $\mu\text{atm}$  by 2100<sup>3</sup>. Given that these impacts are already occurring—and are expected to intensify even under the most optimistic climate scenarios—adaptive measures are urgently needed alongside continued mitigation efforts. Such adaptation strategies should be based not only on assessments of current conditions but also on projections of future environmental change.

Eutrophication is one of the most serious environmental challenges facing the Baltic Sea, with major impacts on its ecosystem, economy, and human health. The main drivers of eutrophication include agricultural nutrient runoff, wastewater discharges, air pollutant deposition, and industrial activities. The Baltic Sea is particularly vulnerable due to its semi-enclosed nature and limited water exchange with the open ocean. In addition, its large drainage basin encompasses 14 countries, making effective management highly dependent on international cooperation and coordinated action. As nutrient loads increase, phytoplankton growth accelerates, leading to extensive summer blooms of toxic cyanobacteria that pose risks to both human and animal health. The Baltic Sea also contains some of the world's largest “dead zones”—areas with hypoxia or anoxia<sup>4</sup>—with up to ~17% of the seabed impacted. These oxygen-depleted conditions cause widespread mortality among fish and benthic organisms, degraded habitats, and trigger the release of phosphorus from sediments, a process known as internal nutrient loading. This, in turn, reinforces eutrophication, and creates a self-perpetuating vicious cycle.

Biodiversity is declining, while opportunistic species increasingly dominate marine ecosystems. These organisms – including some plants, algae and invertebrates – rapidly

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3 **The unit  $\mu\text{atm}$**  (microatmosphere) refers to a unit of partial pressure of a gas—in this case, CO<sub>2</sub> dissolved in seawater. It represents a measure of the “activity” of CO<sub>2</sub>, rather than its direct concentration expressed in mg/L.

4 **Hypoxia and anoxia** refer to conditions of extremely low or absent dissolved oxygen in aquatic environments. **Hypoxia** occurs when oxygen levels are too low to support healthy aquatic life, while **anoxia** describes a complete lack of oxygen, leading to severe ecosystem degradation and the death of most oxygen-dependent organisms.

exploit favourable, often disturbed, environmental conditions created by human pressures such as eutrophication, warming and pollution. As a result, significant changes in food chains are occurring. Increased water turbidity reduces light penetration, leading to the growth of submerged vegetation and contributing to the loss of underwater meadows, including eelgrass (*Zostera*) habitats. At the same time, chemical changes associated with oxygen depletion, such as the formation of hydrogen sulfide under anoxic conditions, further degrade marine ecosystems.

In the Baltic Sea, eutrophication contributed to a doubling of primary production in the 20th century. Under a “business as usual” scenario hypoxic conditions are expected to persist, potentially leading more than a doubling of anoxic areas. At the same time, climate change is projected to increase regional temperatures by 2–5°C by 2100, while salinity is expected to decrease due to higher precipitation and increased river inflow.

## **Black Sea**

The Black Sea is an inland body of water, which is part of the Mediterranean basin and is connected to it via the Sea of Marmara and the Bosphorus and Dardanelles straits. The Kerch strait connects the Black Sea with the Sea of Azov. The Black Sea is locked between Europe and Asia and is surrounded by Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine. The mean sea salinity is 18 ‰, which is about twice as low as that of other seas and oceans. This is due to the large number of rivers flowing into the Black Sea and its difficult water exchange with the Global Ocean.

Recent analyses of the Black Sea indicate a very rapid increase in sea surface temperatures, – estimated at approximately 0.52–0.65°C per decade since the 1980s (with the Copernicus programme estimating around 0.56°C per decade). This rate of warming is significantly higher than the global average. Particularly pronounced warming has been observed on the northwestern shelf, where river inflows, eutrophication, and coastal pressures interact. As in the Baltic Sea, these changes have significant implications for ecosystem functioning and the provision of ecosystem services.

A most important feature of the Black Sea is that oxygen is dissolved (and a rich sea life is possible) only in the upper water levels with nearly 87% of the waters being anoxic. Below a depth of about 100 meters there is no oxygen and the seawater contains highly toxic hydrogen sulphide. It results in a saturated, gloomy “dead” zone frequented only by adapted bacteria. At a depth of between 100 m and 200 m, there is practically no mixing of surface and lower waters. There is a noticeable difference in water salinity between the surface layer and the layer nearer the bottom: between 17.5-19 ‰ and 22 ‰ respectively. This difference is a permanent characteristic of the Black Sea. Over the last 20 years a 20 – 25 meters rise of the hydrogen sulphide layer has been observed. This dangerous change is considered to be related to the climate change and global warming.

The data on acidification and, particularly, its impacts on biodiversity are fragmentary in the Black Sea. Ocean acidification is controlled by alkalinity – the buffering capacity – of the water. Due to the low salinity and high total alkalinity of river waters entering

the Black Sea, the seawater total alkalinity in the oxic surface waters is higher than typical oceanic values. In addition to the complex carbonate chemistry, an intensive eutrophication of the ecosystem caused by anthropogenic perturbations in both the Black Sea waters and the drainage basins of its major supplying rivers can greatly influence surface water coastal acidification. As an evident result of long-term variations of the carbonate system, one can mention a significant decrease in the ability of the Black Sea to absorb carbon dioxide from the atmosphere. The increase in its equilibrium partial pressure in the surface layer observed in the 1960–1990s resulted in an almost twofold decrease in the ability of the Black Sea to absorb carbon dioxide from the atmosphere. Another extremely negative trend is the decrease in pH values. The most significant decrease in pH values was recorded in the upper part of the suboxic layer.

Eutrophication is also a major environmental pressure in the Black Sea, particularly on the northwestern shelf of the basin. The primary sources of nutrient input are similar to those affecting the Baltic Sea, including agriculture, wastewater, and industrial activities. However, large rivers systems, especially the Danube, play a particularly important role by transporting substantial amounts of nitrogen and phosphorus from their extensive catchment areas into the sea.

Historically, these nutrient inputs have caused severe eutrophication and widespread degradation of coastal ecosystems. Although some improvements have been observed in recent decades, partly due to reduced nutrient loads, eutrophication remains a serious and persistent problem, especially in the context of ongoing climate change.

Research shows that the northwestern shelf of the Black Sea is warming faster than the open sea, particularly during summer months. This is of particular concern because this is where river influences, eutrophication, and multiple coastal pressures converge, increasing ecosystem vulnerability and amplifying environmental impacts.

The Black Sea is unique in its persistent anoxia in its deeper layers, with a large portion of the water volume is naturally depleted of oxygen. As a result, the impacts of eutrophication and climate change are concentrated mainly in the surface and coastal waters, where phytoplankton blooms, shifts in ecosystem structure, and deterioration of water quality are increasingly observed. Local hypoxia also occurs in these areas, particularly in zones heavily affected by nutrient inflows.

Since 2022, Russia's full-scale invasion of Ukraine has become one of the most severe modern threats to the Black Sea, intensifying pollution, habitat destruction, and ecological instability through naval warfare, mining, missile strikes on coastal infrastructure, oil spills, underwater explosions, and the destruction of the Kakhovka Dam. The Russian war has disrupted marine monitoring and accelerated pressures on already fragile ecosystems, affecting marine mammals, fish populations, seabirds, coastal wetlands, and water quality across the northwestern Black Sea.

In both the Baltic and the Black Sea, the interaction of eutrophication, acidification, and warming is disrupting ecosystem functioning and degrading water quality. These pressures reinforce each other, creating a complex and interconnected system of environmental pressures that requires a more integrated and coordinated management approach.

## **Baltic Sea vs. Black Sea**

Both the Baltic Sea and the Black Sea are semi-enclosed and highly vulnerable to pressures originating from their surrounding catchments including agriculture runoff, riverine inputs and urban pollution. Both seas are experiencing effects from rising temperatures, acidification, and eutrophication, while strong feedback between climate change and biogeochemical processes further intensify environmental pressures. These interconnected challenges require coordinated multi-level international governance at the scale of the entire basins.

Despite these similarities, important differences exist between the two. The Baltic Sea is relatively shallow, has limited water exchange rates with the open ocean and is sensitive to near-bottom hypoxia. In contrast, the Black Sea, is strongly stratified, with naturally characterised by anoxic deep waters.

The patterns of eutrophication also differs. In the Baltic Sea eutrophication is a systemic problem affecting much of the basin, including the formation of extensive “dead zones”. In the Black Sea eutrophication is more concentrated in coastal areas and river-influenced zones. Acidification patterns also vary between the seas: the Baltic shows pronounced local and seasonal variability, often with stronger local changes, whereas, the Black Sea acidification is difficult to quantify because of strong spatial and seasonal variability, while its natural buffering capacity may partly moderate, but not prevent, long-term pH changes.

## **4. Environmental, Economic, and Social Impacts**

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From an economic perspective, the decline in fish stocks — particularly commercially important species such as cod — is one of the most significant consequences for the Baltic Sea. Fisheries suffer substantial losses, as a result of hypoxia, ecosystem degradation and broader environmental changes. At the same time, recurring cyanobacterial blooms reduce the attractiveness of coastal areas by forcing the closure of bathing sites and negatively affecting tourism and recreation.

The costs of water treatment and environmental management are also increasing, including investments in wastewater treatment infrastructure, environmental monitoring, and remediation measures. In addition, rising sea level and hydrological changes are placing growing pressure on coastal infrastructure, including ports and urban areas, thereby increasing adaptation and maintenance costs.

These challenges are further shaped by public policies and regulatory frameworks. The implementation of EU policies (e.g., water, maritime, climate directives and nature restoration regulation) creates both financial costs and incentives for investment in environmental protection and adaptation. In this context, strong cooperation has been developed between Helsinki Commission (HELCOM) and EU policy frameworks.

Meanwhile, in the Black Sea, fisheries and aquaculture are also experiencing significant losses due to the degradation of coastal habitats and changes in oxygen conditions that

affect biological productivity. Eutrophication in coastal areas contributes to declining water quality, with direct consequences for economic sectors such as fisheries and tourism. Harmful algal blooms and the deterioration of coastal conditions reduce the attractiveness of tourist destinations and place additional pressure on local economies. The economic impacts are unevenly distributed, with some regions, such as the Danube Delta, bearing a disproportionate share of the burden, thereby exacerbating regional disparities. In addition, limited institutional capacity in some countries in the region constrains the effective implementation of remediation and adaptation measures.

In both the Baltic Sea and the Black Sea, the combined pressures of climate change, eutrophication, and acidification are cumulative and mutually reinforcing. Together, these processes contribute to a declining water quality, disrupted ecosystem functioning and growing economic losses occur in sectors such as fisheries and tourism. Effective river basin management is therefore essential, as many of the underlying pressures originate from activities across the wider catchment areas. However important differences exist between the two seas. In the Baltic Sea environmental degradation represents a systemic problem affecting much of the basin, including the formation of extensive “dead zones”. In contrast, pressures in the Black Sea are more spatially concentrated, particularly coastal zones and river-influenced areas.

The Black Sea is characterized by persistent natural anoxia in its deeper layers, meaning that ecosystem functioning and ecosystem services are concentrated within the relatively thin oxygenated surface layer. Unlike the Baltic Sea, where hypoxia is primarily driven by eutrophication, protecting surface water quality is especially critical in the Black Sea, particularly in coastal zones heavily influenced by rivers inflows.

Current and future environmental changes in both regions may have significant implications for food security and could intensify conflicts between key sectors, including agriculture, environmental protection, transport, fisheries, and energy.

## **5. System Governance – Analysis**

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### **Global Level**

Governance of the climate issues at the global level is addressed through the United Nations Framework Convention on Climate Change (UNFCCC), yet there is still no dedicated and integrated approach to ocean acidification. Under the United Nations Framework Convention on Climate Change (UNFCCC) there is an official process created to strengthen discussions on the links between the ocean and climate change within international climate negotiations – Ocean and Climate Change Dialogue. Established after the 2019 “Blue COP” in Madrid, the Dialogue provides a regular platform for Parties, scientists, and observers to advance ocean-based climate mitigation, adaptation, and resilience actions under the UN climate framework.

The Subsidiary Body for Scientific and Technological Advice (SBSTA) within the UNFCCC has so far acknowledged ocean acidification as an emerging issue of rele-

vance. Recognising the significance of this problem, the SBSTA has outlined ocean acidification research as a priority under the Convention. Additionally, the Ad Hoc Working Group on Long-term Cooperative Action under the Convention has acknowledged ocean acidification as a slow-onset event, which is relevant to the discussion of loss and damage caused by climate change. But there is still no overall clear picture or strategy that describes how the UNFCCC should respond to the issue of acidification. Ocean acidification is a direct, chemically measurable consequence of rising atmospheric CO<sub>2</sub> concentrations and should therefore be understood as an integral component of climate change rather than a separate environmental issue.

The United Nations Agreement on Biodiversity Beyond National Jurisdiction (BBNJ), also known as the “High Seas Treaty,” is a new international agreement aimed at protecting marine biodiversity in areas beyond national jurisdiction. While the treaty does not specifically regulate ocean acidification, it could help address its impacts by strengthening marine protected areas, improving international scientific cooperation and ocean monitoring, supporting ecosystem-based management, and requiring environmental impact assessments for activities in the high seas. Because ocean acidification threatens marine ecosystems, biodiversity, and the resilience of ocean food webs, the BBNJ framework could become an important tool for enhancing global ocean governance and protecting vulnerable marine ecosystems from the combined pressures of climate change and human activities.

Despite this close connection, the United Nations Sustainable Development Goals (SDGs) continue to separate these issues between SDG 13 (Climate Action) and SDG 14 (Life Below Water), resulting in a fragmented policy framework. SDG 13 does not explicitly recognise acidification as a key indicator of the impacts of greenhouse gas emissions, while SDG 14 addresses acidification only in a limited way and without strong links to emission reduction policies. This creates a governance gap in which the causes and consequences of acidification are not addressed coherently.

Such fragmentation weakens the effectiveness of both mitigation and adaptation efforts, particularly in sectors that depend heavily on healthy marine ecosystems. It also contributes to an underestimation of economic risks affecting fisheries, aquaculture, and coastal tourism. In vulnerable regions such as the Baltic and Black Seas, the lack of integration further intensifies existing environmental pressures, including eutrophication and hypoxia.

The insufficient connection between climate policy and marine protection and nature restoration also limits the effective mobilisation of funding, including the development of blue finance instruments. As a result, ocean acidification remains insufficiently visible in mainstream public policy and investment decision-making. Strengthening the climate-ocean-nature nexus through the integration of SDG 13 and SDG 14 should therefore become a key priority in future reforms of the global governance framework for sustainable development.

## EU Level

Meanwhile, at the EU level, strong policy instruments addressing these challenges are embedded within the European Green Deal and EU Biodiversity Strategy for 2030: Bringing Nature Back into Our Lives. In practice, governance is primarily guided by three key legislative frameworks: the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD) and the Nature Restoration Regulation (NRR) .

These two directives recognise that acidification has a combined nature, driven by global factors such as rising atmospheric CO<sub>2</sub> concentrations and by regional pressures, including eutrophication and riverine inflows. Effective implementation of the WFD and MSFD therefore requires close integration and coordination; without this, the intended environmental objectives are unlikely to be achieved. Ocean and sea acidification should be understood as a “source-to-sea” issue, linking activities and emissions across entire catchments to impacts in marine ecosystems.

Marine Spatial Planning (MSP), established under the EU Maritime Spatial Planning Directive (2014/89/EU), should be recognized as an important governance instrument supporting the climate–ocean–nature nexus. By coordinating competing uses of marine space, including offshore renewable energy, fisheries, maritime transport, tourism and nature conservation. MSP can help reduce cumulative pressures on marine ecosystems while supporting climate adaptation and ecosystem resilience.

From a marine conservation perspective, the NRR importance is also significant. Restoring coastal habitats can increase the capacity of ecosystems to sequester carbon, improve local biogeochemical conditions, and strengthen the resilience of marine organisms to the effects of warming, eutrophication, and acidification. Actions targeting coastal wetlands, estuaries, river deltas, and seagrass meadows, which are among the most effective natural carbon stores in the world, may be particularly important. However, despite these benefits, the regulation leaves significant gaps, such as:

- lack of direct recognition of marine acidification as a distinct threat requiring monitoring and remedial action.
- lack of full integration of regulations with developing European ocean and climate monitoring systems,
- insufficient linking of marine ecosystem restoration with European climate financing mechanisms.

Greater integration between Marine Spatial Planning, the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD), and the Nature Restoration Regulation (NRR) would strengthen ecosystem-based management and facilitate a more coherent source-to-sea approach across the Baltic–Black Sea region.

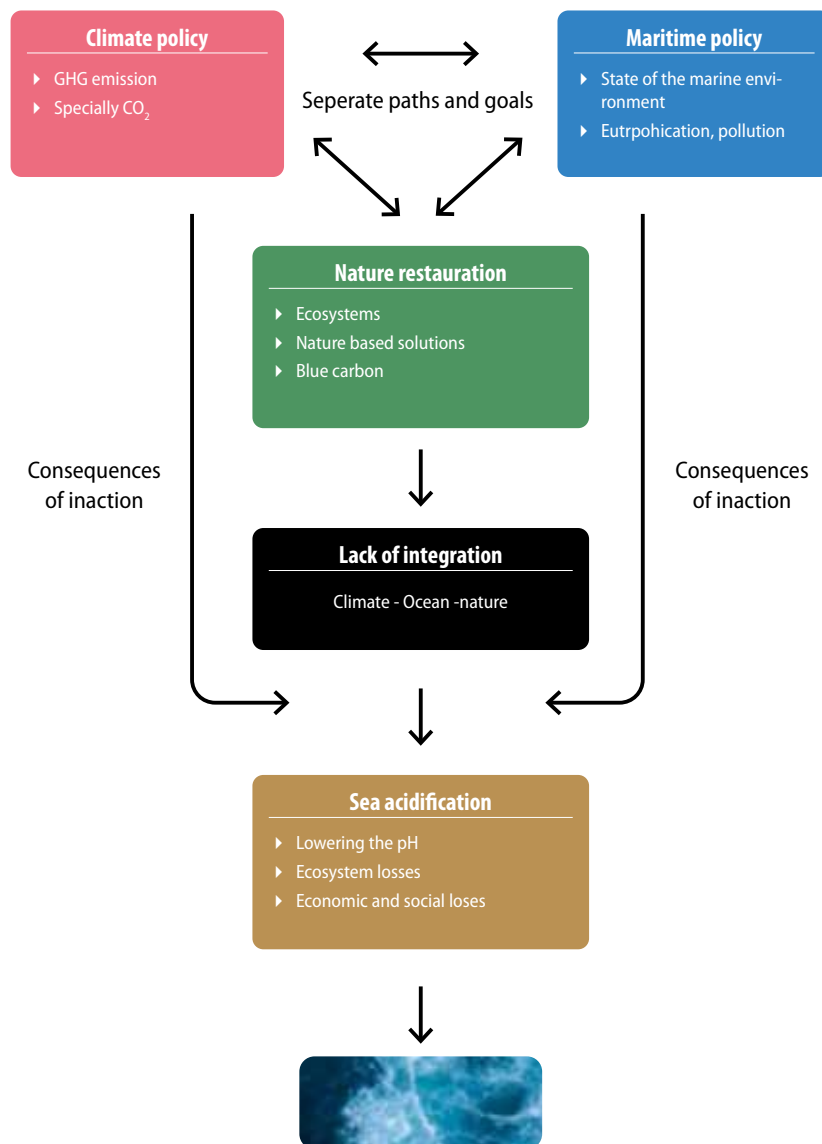
It should be noted that the Baltic Sea region is institutionally more advanced, benefiting from stronger monitoring systems and well-established regional cooperation mechanisms. In contrast, governance in the Black Sea region requires further strengthening through more ambitious interventions, particularly within the Danube basin, as

well as enhanced international coordination among EU Member States, EU candidate countries, and other neighbouring states .

Despite these efforts, an important policy gap remains, as acidification is still not fully recognized as a relevant indicator within EU policy frameworks. There are no harmonised pH targets, and links between acidification and climate policy and nature restoration remain weak.

The limited integration of the “climate - ocean - nature nexus” means that climate policies and marine policies and nature restoration are often developed and implemented in parallel rather than as parts of a single, coherent system, despite their strong interdependence. This fragmentation reduces the effectiveness of both climate action and marine protection measures as well as nature restoration activities. The relationship is illustrated in the diagram below (Fig. 2).

**Fig. 2 Climate policy vs. maritime policy vs. nature restoration**



Source: Prepared by the authors

## 6. Policy Implications

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An analysis of the current governance landscape reveals significant gaps. One of the most important is the insufficient integration of climate and marine environmental policies. There is also a lack of consistent regional data across the Baltic and Black Seas, limiting the ability to fully understand and compare the scale and dynamics of the acidification and related pressures in both regions .

Ocean and sea acidification remain underestimated in policy frameworks, as reflected by the absence of clear targets and corresponding measures in National Energy and Climate Plans (NECPs). The intermarium region includes both EU and non-EU countries, resulting in geopolitical fragmentation that is further exacerbated by the war in Ukraine. In addition, the limited recognition of acidification as a core climate-related issue contributes to insufficient financial and institutional resources dedicated to addressing it. Currently, there are no dedicated policy instruments specifically targeting acidification and its impacts on marine ecosystems. Instead, investments continue to focus primarily on greenhouse gas mitigation, often at the expense of ecosystem protection and restoration.

Effective climate adaptation in the region requires a systemic approach that integrates ecosystems and catchments, strengthens policy coherence, reduces anthropogenic pressures, protects marine and coastal ecosystems, and improves spatial and resource management. At present, relevant actions can be financed through several EU instruments, including the LIFE Programme, Horizon Europe, the Cohesion Fund, and the Common Agricultural Policy (CAP), as well as through the European Investment Bank and European Bank for Reconstruction and Development. However, private sector participation in financing these efforts remains limited .

Marine Spatial Planning and nature-based solutions should become core components of regional adaptation strategies. The integration of ecosystem restoration objectives into marine spatial planning processes can help identify priority areas for habitat restoration, reduce conflicts among maritime sectors, and improve the long-term resilience of coastal and marine ecosystems. Particular attention should be given to restoring and protecting blue-carbon ecosystems, including coastal wetlands, seagrass meadows, river deltas, estuaries and shallow coastal habitats, which provide climate mitigation, adaptation, biodiversity and water quality benefits simultaneously.

These challenges underline the need for stronger integration between the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD), Nature Restoration Regulation (NRR) and climate policy — particularly CO<sub>2</sub> reduction and adaptation strategies — as well as closer alignment between the Common Agricultural Policy and broader climate-marine governance frameworks. Expanding pH and alkalinity monitoring systems is essential, alongside strengthening cooperation between the Helsinki Commission, the Danube Commission, and the Commission on the Protection the Black Sea Against Pollution within the framework of the European Green Deal.

## 7. Recommendations

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### **a) In the Baltic-Black Sea region, the integration between SDG 13 (Climate Action) and SDG 14 (Life Below Water) should be strengthened.**

It is recommended that acidification indicators, such as pH,  $p\text{CO}_2$ <sup>5</sup> and alkalinity, be incorporated into national climate policies and reporting frameworks under SDG 13. At the same time, the operationalization of SDG 14 should be expanded to include  $\text{CO}_2$  emissions and emission reduction scenarios. Developing a coherent monitoring and reporting system that link both goals is essential in order to reflect the direct causal relationship between  $\text{CO}_2$  emissions and changes in marine chemistry. Such an integrated approach would strengthen both climate change mitigation efforts and the protection of marine ecosystems across in the region.

### **b) Addressing ocean acidification within the context of the UNFCCC and under the Ocean and Climate Change dialogue process.**

A logical approach would be not to separate ocean acidification from climate change issues, but to redefine ocean acidification as an effect of climate change. By doing so, the UNFCCC could interpret its existing framework to include an obligation to address ocean acidification alongside other climate change impacts like sea-level rise. The UNFCCC should address ocean acidification and identify knowledge, capacity and process gaps and strengthen coordination of ocean acidification-related activities. Ocean acidification is largely ignored as a main driver of ocean health decline in the governance of marine ecosystems.

### **c) Integrating acidification into NECPs and adaptation policies**

Marine acidification should be systematically incorporated into National Energy and Climate Plans (NECPs) as a key link between climate change and aquatic ecosystems. Including acidification within climate adaptation plans would help identify the sectors most vulnerable to its impacts, such as fisheries, aquaculture and tourism, while supporting the development of measures to strengthen both ecosystem and economic resilience. Such measures could include reducing fishing pressure to sustainable levels, alongside other long-term management approaches that enhance ecosystem recovery and deliver broader environmental and economic benefits over time.

### **d) Strengthening Nature-based Solutions and Ecosystem-based Adaptation**

Nature-based solutions should become a central pillar of climate adaptation and marine protection policies across the Baltic–Black Sea region. Priority should be given to the restoration and protection of coastal wetlands, floodplains, seagrass meadows, river deltas, estuaries, shellfish habitats, and other blue-carbon ecosystems. Such measures can simultaneously improve biodiversity, increase carbon sequestration, reduce nutrient pollution, enhance climate resilience, and contribute to achieving the objectives of the

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<sup>5</sup>  **$p\text{CO}_2$  (partial pressure of carbon dioxide)** is a measure of the concentration of dissolved carbon dioxide in seawater or in the atmosphere. Increasing  $p\text{CO}_2$  leads to higher  $\text{CO}_2$  uptake by the ocean, causing ocean acidification and a decline in seawater pH.

Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), Nature Restoration Regulation (NRR), and the EU Biodiversity Strategy for 2030. Particular attention should be given to ecosystem restoration projects that deliver multiple co-benefits for climate mitigation, adaptation, water quality improvement, and marine ecosystem health. This should be incorporated into National Restoration Plans.

#### **e) Strengthening Integrated Land–Sea Governance through a Source-to-Sea Approach**

Integrated land–sea governance should be strengthened through the adoption of a source-to-sea approach linking river basin management, coastal zone management, marine spatial planning, and climate adaptation policies. This should include scaling up nature restoration measures in catchments, in line with the Nature Restoration Regulation (NRR) and the Water Framework Directive (WFD), to improve water quality and reduce nutrient and pollutant loads before they reach marine environments. Such efforts would contribute directly to achieving Good Environmental Status under the Marine Strategy Framework Directive (MSFD).

Member States should support and promote landscape-based and catchment-based partnerships as practical governance mechanisms. These partnerships should bring together regional and local authorities, civil society organisations, businesses, research institutions, and local communities to implement coordinated, cross-sectoral actions across river basins and coastal areas. Strengthening cooperation across the land–sea interface would improve policy coherence, facilitate ecosystem-based management, and support the more effective implementation of EU environmental, biodiversity, and climate objectives across the Baltic–Black Sea region.

#### **f) Strengthening Marine Spatial Planning as a Climate and Ecosystem Governance Tool**

Marine Spatial Planning (MSP) should be further developed as an operational mechanism for integrating climate adaptation, biodiversity conservation, sustainable blue economy development and ecosystem restoration. MSP processes should explicitly incorporate climate risks, acidification trends, cumulative environmental pressures, and ecosystem-based management principles. Cross-border cooperation within MSP frameworks should be strengthened to support coherent management of the Baltic and Black Sea basins.

#### **g) Establishing the Baltic–Black Sea Climate & Ocean Initiative**

Establishing a regional initiative linking the Baltic and Black Sea countries would strengthen coordination within the “climate–ocean–nature nexus,” which is currently fragmented across multiple governance structures, including HELCOM and various institutions related to the Black Sea governance. Such an initiative could provide a common platform for data sharing, joint research projects, and policy coordination across the region. It could also strengthen the region’s collective voice in EU policymaking and international climate negotiations, while promoting more coherent and integrated approaches to climate adaptation, marine protection, and sustainable regional development.

#### **h) Harmonizing indicators and monitoring systems (pH, pCO<sub>2</sub>, alkalinity)**

A harmonized monitoring system for key marine water chemistry parameters — including pH, partial pressure of CO<sub>2</sub> (pCO<sub>2</sub>), and total alkalinity — should be established across the region. Standardizing measurement methods and reporting frameworks would improve the comparability of data, strengthen process modeling and support the development of more effective adaptation and marine protection policies.

#### **g) Integration of satellite data**

Integrating satellite-based observations, for example from the Copernicus Programme, with in-situ measurements would enable continuous, large-scale monitoring of parameters related to acidification and climate change. Such an approach would increase the accuracy of forecasting and modelling, and support more effective management at both the regional and local levels, particularly in coastal areas that are highly vulnerable to environmental change.

#### **h) Introducing integrated financial instruments (blue finance, adaptation funds)**

The development of blue finance instruments, such as marine conservation bonds and investment funds dedicated to the protection and restoration of marine ecosystems, could play an important role in financing measures that reduce the impacts of acidification and strengthen ecosystem resilience. Dedicated climate adaptation funds should also be expanded to support regional and local responses to marine and coastal environmental change.

Ensuring strong links between these financial mechanisms and EU policy frameworks, including cohesion policy and the EU Emissions Trading System (ETS), will be essential to provide long-term stability, adequate funding and the scale necessary for effective implementation.

#### **g) Strengthening stakeholder participation (science, NGOs, fisheries, tourism, and maritime transport)**

Broader stakeholder participation is essential to effectively address the interconnected challenges of climate change, acidification, and marine ecosystem degradation. This includes stronger involvement of the scientific community in providing data, projections and scenario analyses; NGOs in advocacy, public engagement, and environmental education; and sectors such as fisheries and tourism, which are directly affected by environmental change, as well as maritime transports. Inclusive participation can increase public acceptance of policy measures, improve the quality and legitimacy of decision-making, and enable the earlier identification of conflicts, vulnerabilities, and emerging risks.

## **Conclusions**

The growing climate, ocean acidification, and biodiversity crises in the Baltic–Black Sea region demand an integrated policy approach and coordinated action across governance levels and national boundaries. Strengthened cooperation among countries and stakeholders is essential to address these interconnected challenges and ensure a resilient and sustainable future for both marine basins.

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<sup>6</sup> ChatGPT was used to support the collection and analysis of the literature used in the preparation of this brief.

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