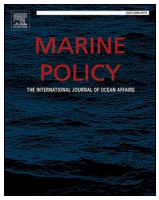
Marine Policy 191 (2026) 107173

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



Full length article

Governing microplastics in the North-East Atlantic: The importance of regional frameworks in the absence of a global treaty

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ARTICLE INFO

Keywords:
Microplastic pollution
Marine governance
Regional seas conventions
North-East Atlantic
Global Plastic Treaty

ABSTRACT

Microplastic pollution constitutes a transboundary challenge for marine governance, particularly as negotiations towards a Global Plastics Treaty remain uncertain. This study examines the role of regional governance frameworks in addressing marine microplastics of five overlapping frameworks in the North-East Atlantic: The European Union (EU), OSPAR, HELCOM, the Barcelona Convention, and the Arctic Council. Using four analytical criteria, namely governance ambition, legal enforceability, monitoring arrangements, and regional coordination, we assess how these frameworks structure policy responses to microplastic pollution and how they may contribute to global governance objectives. The analysis reveals a connected governance architecture in which binding EU regulation establishes common standards, Regional Seas Conventions operationalize these through basin-specific action plans and monitoring systems, and the Arctic Council provides scientific coordination and knowledge integration despite its non-binding mandate. While these frameworks collectively offer important regulatory and institutional capacity, persistent challenges remain related to uneven enforcement, fragmented implementation, and limited integration across the plastic life cycle. The findings highlight both the potential and the structural limits of regional frameworks as intermediary governance layers between global ambition and national policy execution.

1. Introduction

More than 8 million tonnes of plastic are estimated to reach the ocean annually through river run-off, mismanaged waste, uncontrolled landfills, and hard-to-recycle packaging [1–4]. In such contexts, the ubiquitous environmental presence and prevalence of microplastics, nominally defined as particles smaller than 5 mm, has become a pressing issue [1,5]. While microplastics that enter the environment directly (i.e., primary microplastics), (e.g., from synthetic laundry, tire wear, and intentionally added particles in care products) account for 15–31% of microplastics in the oceans, the gradual degradation of larger plastics into fine particles (i.e., secondary microplastics) accounts for 69–81% of marine microplastics [6]. Microplastics are now found from surface waters to deep-sea sediments, including remote polar regions [7], and

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https://doi.org/10.1016/j.marpol.2026.107173
Received 19 December 2025; Received in revised form 6 May 2026; Accepted 7 May 2026
Available online 16 May 2026

make up about 8% of total particle flux in the North-East Atlantic at 2000 m depth [8]. Consequently, microplastics have gradually and inevitably infiltrated the food chain, becoming a part of the human diet. This makes microplastic a major issue as they can absorb toxins and heavy metals from the sea, and there is a risk that toxins bioaccumulate along the food cycle [9,10].

Recognising this pressing issue, the United Nations Environment Programme (UNEP) concluded that existing legal and governance frameworks are inadequate to address marine plastic pollution [11,12]. In 2022, it launched negotiations for a Global Plastics Agreement, with an Intergovernmental Negotiating Committee (INC) tasked to deliver a draft by 2025 [13]. The agreement reflects alternatives to address plastic lifecycles and recyclability of products as well as a strong need for enhanced international cooperation to strengthen technology access and capacity building [14]. The preamble to the resolution highlights that "plastic pollution includes microplastics". Accordingly, the INC considered how best to address microplastics alongside macroplastics and their chemical constituents in the design of a global agreement [14,15]. Unfortunately, the fifth and most recent negotiation session ended without agreement. More than 100 countries within the "High Ambition Coalition" pushed for binding limits on plastic production and controls on chemicals, while some of the petrochemical-producing states, the "like-minded countries," favoured a narrower focus on downstream measures such as recycling and waste management. The resulting deadlock led to the rejection of the draft text, and while talks may resume, no new negotiation date has been set [16].

Nonetheless, a key component of this global process has been its reliance on regional and international cooperation [17]. A study by the Potsdam Institute for Advanced Sustainability Studies (2021) indicated that existing Regional Seas Conventions and Action Plans (RSCAPs) are well-suited to transfer global standards and objectives into regional descriptions of action, roadmaps, and agreements [9,18]. Correspondingly, regional frameworks can accelerate governance and connect global and national levels by translating global norms into regionally adapted regulations, enhancing policy coherence among states, and providing institutional continuity for environmental regimes [19,20]. Considering the impasse at the global level, such regional actions become even more important with several regional frameworks already starting to address microplastics as part of their marine litter policies, especially in globally northern countries [15,21].

In this regard, the North-East Atlantic region is not only characterised as a transboundary hotspot for land-based and sea-based marine litter pollution with high amounts of microplastic [22], but also shows a unique mosaic of international and regional governance systems as well as cooperation mechanisms [23–25]. This includes several overlapping regional frameworks with varying levels of state participation extending from polar to temperate waters longitudinally and from Scandinavia to the waters below Greenland. The primary objective of this paper is to assess how well regional governance frameworks in the North-East Atlantic are equipped to combat microplastic pollution. This also considers a context of potentially continuous efforts to reach an international Global Plastic Agreement in terms of how these frameworks can contribute to the implementation of global measures against the marine microplastic issue. In this context, we define regional governance frameworks as institutionalized arrangements of formal and informal cooperation among states and other regional actors that coordinate policies and manage common affairs through shared institutions, rules, and decision-making processes [19,26–28].

To inform this issue, we provide a regulatory overview of latest governance ambitions, measures, and policies of 5 major regional governance frameworks that are addressing microplastic pollution in the North-East Atlantic region. While macroplastic pollution constitutes an important source of secondary microplastics, our review preferentially focuses on microplastics as a distinct regulatory challenge, characterized by specific sources, pathways, and governance instruments that warrant dedicated analysis. In this context, the 5 reviewed regional governance frameworks are: (1) the European Union (EU); (2) the Convention for the Protection of the Marine Environment of the North-East Atlantic and its Commission (OSPAR Convention and Commission); (3) the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area and its Commission (HELCOM); (4) the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention), and (5) the Arctic Council. The key selection criteria for these 5 frameworks were (i) their impact on North Atlantic pollution prevention and response; (ii) their level of state participation; (iii) the inclusion of microplastics on their official work agenda; and (iv) whether the 5 selected instruments collectively cover most climate zones that occur in the North-East Atlantic, such as polar zone, continental zone or southern warmer temperate zone.

2. Methodology

2.1. Description of research area: the North-East Atlantic region

There are different definitions of the North-East Atlantic region in scientific literature. According to the OSPAR Commission, the North-East Atlantic area can be divided into five sub-regions: The Arctic Waters, Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast, as well as the Wider Atlantic to the West [29–31]. In this study, we define the North-East Atlantic region in correspondence with these five sub-regions which border to the western as well as northern European coastlines. In addition, we include the seas, inland seas and sea arms in our case-study area that are directly connected or semi-enclosed to the North-East Atlantic region. These bodies of water comprise the Mediterranean Sea, Baltic Sea, as well as the southern parts to the Arctic Ocean (including the Barents Sea and Greenland Sea as marginal oceans).

The inclusion of the Mediterranean Sea and Baltic Sea as extensions of the North-East Atlantic in our case-study area was relevant because also they contain microplastic hotspots. Besides, they are characterized by limited water exchange with larger oceans which makes them more susceptible for microplastic accumulations due to surrounding land-based sources and human activities in the basin [32–34]. In addition, the Arctic waters are a transport hub for microplastic where floating plastic is transmitted to the Arctic from the mid-latitudes by ocean currents [35]. A high amount of microplastics is trapped by Arctic Sea ice, with concentrations often higher than in the surrounding water, leading to severe ecological impacts on sediments, food chains, and diverse marine life [36,37].

Altogether the definition of our study area including the OSPAR region, Baltic Sea, Mediterranean Sea, and Arctic Sea allowed an evaluation of essential regional governance approaches, initiatives and policies addressing microplastic pollution by key governance frameworks. This made a comparative analysis possible of what works and what does not, understanding regional vulnerabilities, and what lessons can be applied to the North-East Atlantic area as a cohesive region. Our study area also involves most essential marine regions and sub-regiones that are addressed by the European Marine Strategy Framework Directive [38].

2.2. Definition of microplastic

From the perspective of environmental governance, the way a pollutant is defined has significant implications for how it is regulated, measured, and addressed. Therefore, precise definitions are boundary-setting and determine what is included or excluded from policy frameworks, research agendas, and regulatory interventions [39,40]. For this research, a consistent definition of microplastics is therefore essential because it promotes a more coherent discussion around their adverse effects to the environment, human health, and associated fates [41]. To define microplastics in the context of our analysis, we lean on research by Rognerud et al. (2023) [15]. Accordingly, and fundamental to this study, microplastics comprise plastic particles that are smaller than

5 mm, including nanoplastics (1–100 nm) [42].

Microplastics can be commonly sub-categorized into four broader categories: plastic pallets, flakes, and powders (1) are primary microplastics produced specifically for use in manufacturing and the creation of various plastic products. Another category, intentionally added primary microplastics (2), consist of particles that are purposefully designed to be small for particular applications, such as abrasive scrubbers or cosmetic products. In contrast, use-phase secondary microplastics (3) are generated through the degradation and weathering of plastic materials during their period of use. Finally, degradation-based secondary microplastics (4) arise from the breakdown of larger plastic items after disposal, such as in landfills or when plastics are released into the environment; this category also includes unintentionally produced microplastics during recycling processes [16].

2.3. Data collection and analysis

In this study, data collection on latest governance ambitions, measures, and policies of key international and regional organizations addressing microplastic pollution in the North-East Atlantic region was primarily sourced from the official websites and online platforms of the five international focus frameworks and organizations including EU, OSPAR, HELCOM, Barcelona Convention and Arctic Council. Official websites and public portals of the frameworks were treated as a key source, as they constitute the most direct and institutionally validated expression of policy priorities, measures, and ongoing activities. They also serve as central repositories for official documents, such as reports, policy briefs, and technical guidelines, and provide insight into how each framework frames and communicates its understanding of microplastic pollution. Literature was gathered non-systematically in the form of academic articles, institutional reports, position papers, and other publicly available documents. The inclusion of this broader range of literature provided a comprehensive understanding of the topic. Particular attention was paid to documents related to the governance frameworks, strategies, and regional policy efforts aimed at mitigating the impacts of microplastic pollution in the defined Northeast Atlantic region.

The five regional frameworks were then compared and assessed according to governance ambition, legal enforceability, monitoring guidelines, and degree of regional coordination. These assessment criteria were derived through a qualitative comparative analysis of the frameworks and are in keeping with regulatory criteria previously described in the literature [43,44]. To ensure consistency, each assessment criterion was operationalized through qualitative indicators adapted from established environmental governance and international legal scholarship. Here, governance ambition reflects the breadth and scope of policy commitments [45,46]; legal enforceability reflects the degree of obligation, precision, and delegation in legal instruments [47]; monitoring arrangements reflect the presence of harmonized indicators, reporting systems, and assessment mechanisms [48,49]; and regional coordination reflects the institutional interplay and dynamics between different levels of governance [50,51].

3. Overview of the North-East Atlantic regional instruments

3.1. The European Union (EU)

The European Union (EU) is a supranational governance framework comprising 27 Member States, operating through an institutional structure that includes the European Commission, the European Parliament, and the Council of the European Union. The EU's legal authority allows for the adoption of binding legislation that is directly applicable and transposed into national law across Member States, ensuring a comparatively high degree of regulatory coherence and enforceability [52]. Over recent decades, the EU has continuously expanded its environmental policy portfolio, integrating marine protection, chemicals regulation, and circular economy principles. This evolving policy landscape provides the foundation for the EU's current approach to addressing microplastic and plastic pollution within a broader sustainability and environmental protection agenda [53,54].

The European Green Deal [55] reaffirmed the objectives of the Plastics Strategy by calling for continued action on intentionally added microplastics and by strengthening water protection measures. These commitments were reflected in the Drinking Water Directive (Directive (EU) 2020/2184) [45], which identifies microplastics as an emerging concern and mandates the European Commission to develop a monitoring methodology by 2024. The Circular Economy Action Plan [56] reiterated the importance of addressing microplastic pollution, though it largely repeated measures outlined in the Plastics Strategy [57]. The Zero Pollution Action Plan [58] built on these commitments by setting measurable targets, including a 30 per cent reduction in microplastic emissions and a 50 per cent reduction in plastic litter by 2030. However, these targets remain indicative, with their success depending on the effectiveness of other legislative instruments. The Blue Economy Action Plan [59] also acknowledged the need for all marine sectors, including fisheries, aquaculture, maritime transport, and coastal tourism, to reduce their environmental impacts, linking the issue of plastic and microplastic pollution to the sustainable use of marine resources.

A major step forward in EU legislation was Regulation (EU) 2023/2055 [60], which amended Annex XVII of the Registration, Evaluation, Authorisation and Restriction of Chemicals REACH Regulation to restrict the intentional use of synthetic polymer microparticles in products such as cosmetics, detergents, and fertilisers. The regulation, which entered into force in October 2023, aims to prevent microplastics from entering the environment through product use. It includes a phased prohibition of microplastics in specific products, labelling requirements for producers, and annual reporting obligations to the European Chemicals Agency [61]. This framework reflects the precautionary approach of EU chemical regulation, combining restrictions with transparency requirements along the value chain [62]. While the regulation marks a significant step in controlling intentionally added microplastics, its implementation may face challenges, including ensuring uniform enforcement across MSs and managing compliance by smaller downstream users. The exemption (included in the Annex) of certain biodegradable and water-soluble polymers also raises concerns about the consistency of environmental safeguards.

The EU has also advanced measures to address unintentional microplastic emissions, which are considered the main source of microplastic pollution [63]. Plastic pellet losses during handling and transport, with the European Parliament expected to give its final approval in October 2025. The regulation requires companies to implement comprehensive risk assessment systems covering handling, packaging, and employee training, with stricter verification for larger operators and simplified compliance for smaller ones [64]. Once published in the Official Journal, it will establish mandatory operational standards across the supply chain, marking a significant step in reducing industrial sources of microplastic pollution. The Packaging and Packaging Waste Regulation (PPWR) [65], adopted in 2025, also integrates microplastic concerns into waste and product law. It requires packaging materials to minimise harmful substances, including microplastics, throughout their life cycle. According to recital 55 of the PPWR, the revision of compostability standards (EN 13432:2000) and the planned development of a home composting standard aim to reduce microplastic leakage from compostable packaging and align product standards with CE principles.

Several cross-sectoral instruments complement these legislative developments. The Single-Use Plastics Directive [66] primarily targets macroplastic litter but indirectly supports microplastic reduction by encouraging manufacturers to limit microplastic use in product formulations. Its alignment with the Marine Strategy Framework Directive [67]illustrates how marine and waste policies can be linked, although the directive does not contain specific microplastic reduction targets.

Voluntary measures such as the EU Ecolabel Commission Decision [68] prohibit the inclusion of microplastics and microbeads in cosmetic products and animal care products seeking an eco-label, encouraging companies to innovate towards cleaner formulations. However, since this measure is voluntary, it does not create binding obligations for non-participating producers.

Overall, the EU has established one of the most comprehensive regional frameworks addressing microplastic pollution. Key legislative instruments such as the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) amendment, the Packaging and Packaging Waste Regulation (PPWR), and the Zero Pollution Action Plan demonstrate an increasing level of integration between environmental, product, and waste policies. Nevertheless, important challenges remain, including fragmented governance, delayed implementation of monitoring methodologies, and uneven enforcement among MSs. Strengthening regulatory coherence, improving compliance mechanisms, and investing in research on sustainable material alternatives are essential steps for improving the EU's capacity to mitigate microplastic pollution. While the EU's current approach is ambitious, its effectiveness will depend on consistent application across all policy areas and MSs.

3.2. OSPAR: the convention for the protection of the marine environment of the North-East Atlantic

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) was adopted in 1992 and entered into force in 1998, merging and modernizing the 1972 Oslo Convention on dumping and the 1974 Paris Convention on land-based pollution. It established the OSPAR Commission as its executive body, with sixteen Contracting Parties—fifteen states and the EU. The Convention's legal framework obliges Parties to prevent and eliminate pollution, protect marine ecosystems, and restore degraded areas. Implementation is carried out through legally binding decisions, non-binding recommendations, and cooperative agreements. OSPAR's activities are guided by the Ecosystem Approach, the Precautionary Principle, the Polluter Pays Principle, and the use of Best Available Techniques and Best Environmental Practices [69,70].

The OSPAR Commission operates through five main committees and the expert working groups that provide technical and scientific advice. It also engages an extensive observer community of 22 intergovernmental and 42 non-governmental organizations, ensuring multi-stakeholder participation and policy coherence across environmental, industrial, and scientific domains [71]. This institutional design enables OSPAR to integrate scientific evidence into coordinated policy measures, linking regional commitments to national implementation.

Microplastic pollution forms a core component of OSPAR's marine litter strategy. The North-East Atlantic Environment Strategy 2010–2020 established the first coherent framework for reducing marine litter and microplastics, operationalized through the Measures and Actions Programme (MAP) and the Regional Action Plan on Marine Litter (RAP ML). The strategy's objective is to "prevent and significantly reduce inputs of litter, including plastics and microplastics, to levels that do not cause adverse effects on the marine and coastal environment," with the long-term ambition of eliminating such inputs entirely [72]. Within the first RAP ML, several actions explicitly targeted microplastics. Action 46 called for the evaluation of products and processes containing primary microplastics to reduce their release. Action 47 encouraged cooperation with the cosmetics and personal care industries to phase out intentionally added microplastics. Action 57 aimed for zero pellet loss throughout the plastics supply chain, establishing a voluntary certification scheme and guidelines for best practice approved in 2021 [73]. Complementary monitoring and assessment activities were launched to identify sources and pathways of land-based microplastic pollution and evaluate their environmental and socioeconomic impacts [74].

Building on this foundation, the Second Regional Action Plan on Marine Litter (RAP ML 2022–2030) significantly expanded OSPAR's scope. It introduced eight actions addressing land-based sources, thirteen addressing sea-based sources, and four cross-cutting actions, setting a regional target year of 2030 [75]. The plan includes measures to prevent microplastic emissions from artificial turf, ship greywater, paints, and pellet handling, and promotes knowledge sharing among Contracting Parties. The updated North-East Atlantic Environment Strategy 2023 reaffirmed OSPAR's overarching goal to reduce marine litter to levels that do not cause adverse environmental effects, including a 50% reduction in single-use and maritime plastics by 2025 [71].Recent policy developments have additionally strengthened OSPAR's commitments. At the 2024 Berlin Ministerial Meeting, the Commission adopted a 70% reduction target for beach litter by 2030, building upon existing RAP ML goals. In the same year, new guidelines for microplastic sampling in seafloor sediments were published, improving methodological harmonization and comparability across national monitoring programmes [76]. These advances illustrate OSPAR's continuous evolution towards a science-based, target-driven, and collaborative approach to microplastic governance.

In summary, OSPAR represents one of the most advanced regional frameworks addressing microplastic pollution in the North-East Atlantic. Through a combination of binding and voluntary measures, harmonized monitoring, and industry partnerships, it provides a robust governance mechanism that links scientific assessment with policy implementation. While challenges remain in ensuring uniform enforcement across Contracting Parties, OSPAR's progressive strategies and quantifiable targets position it as a leading regional instrument for combating microplastic pollution and supporting global plastic governance ambitions.

3.3. HELCOM: the convention on the protection of the marine environment of the Baltic Sea Area

The Convention on the Protection of the Marine Environment of the Baltic Sea Area, commonly known as the Helsinki Convention, was originally signed in 1974 to address the environmental impacts of industrialization and other human activities on the Baltic Sea. It entered into force in 2000 following ratification by all contracting parties, including the European Community and the Baltic coastal states. The convention currently has ten contracting parties and 67 observers, comprising governments, intergovernmental organizations, and non-governmental organizations that participate in meetings and contribute to policy development [77–79]. Based on a legally binding treaty, the Helsinki Commission (HELCOM) requires parties to implement measures to protect the Baltic Sea, which are operationalized through Recommendations, Ministerial Declarations, and the Baltic Sea Action Plan (BSAP) [80]. While Recommendations are not legally binding, their unanimous adoption and mandatory reporting by contracting parties ensure broad compliance and support the implementation of the Convention's objectives [81,82]. HELCOM also functions as a coordination platform for the EU to implement the Marine Strategy Framework Directive in the Baltic Sea region [83].

According to the 2019 "Review of existing policies and research related to microplastics" of the HELCOM partner project Fanplesstic-sea, HELCOM's approach to marine protection is supported by a substantial body of research on microplastics in the Baltic Sea. Pilot monitoring programs conducted between 2007 and 2014, and continuing in some regions, have examined microplastic in water, sediments, biota, and strandlines [84]. National analyses indicate that major sources of microplastics are consistent with EU-wide findings, including secondary microplastics from road related sources as well as primary microplastics from synthetic textiles, microbeads in personal care products, and accidental releases from pellets, artificial turf, paints, and sandblasting. Some microplastics pass through wastewater treatment, disperse via stormwater, or enter water bodies directly. However, research across the Baltic region faces challenges due to the lack of standardized

methodologies for sampling, preparation, analysis, as well as uneven geographic coverage of monitoring activities and limited understanding of ecological impacts [84].

The HELCOM Science Agenda highlights these knowledge gaps and sets priorities for research until 2031, including understanding the impacts of macro- and microplastics on species and communities, developing harmonized monitoring methods for different matrices, establishing monitoring of microplastics in the Baltic Sea food web, identifying land- and sea-based sources and pathways, studying the degradation and fragmentation of plastics, and evaluating the effectiveness of management measures such as bans, wastewater treatment improvements, extended producer responsibility schemes, and public awareness programs [80]. These research priorities inform HELCOM's strategic planning and policy implementation.

The Baltic Sea Action Plan (BSAP) is HELCOM's central strategic instrument for achieving good environmental status by 2030. The BSAP is gradually structured into key agenda segments with specific objectives that lead to measures and ultimately to key actions. The agenda segments include biodiversity, eutrophication, hazardous substances and litter, sea-based activities, and horizontal topics [85]]. Microplastics are specifically addressed under hazardous substances and litter, where the main objectives are to prevent waste generation and reduce inputs of litter to levels that do not harm marine life. Next to 4 measures targeting litter in a broader sense, 2 measures address microplastics by minimizing microplastic inputs at source and through end-of-pipe solutions as well as promoting international efforts such as a global plastics agreement to accelerate litter and microplastics reduction. Correspondingly, specific actions within the BSAP include agreeing on core indicators and harmonized monitoring methods for microplastics by 2026 (in close coordination with work undertaken by Contracting Parties in other relevant fora, such as the Technical Group on marine litter under the Marine Strategy Framework Directive), improving the evidence base for marine litter impacts, strengthening municipal wastewater treatment to reduce microplastic, microliter, and hazardous substance emissions, organizing information campaigns to promote proper disposal of plastics and chemicals (e.g., pharmaceuticals, litter) in households, and implementing biofouling management measures to reduce microplastic release from shipping activities [85]. The latter includes a significant strengthening of stakeholder cooperation until 2026.

HELCOM's Regional Action Plan on Marine Litter, adopted as Recommendation 42–43/3, operationalizes the BSAP objectives. It identifies land- and sea-based sources of litter, including microplastics, and aligns regional measures with international commitments such as UNEA Resolutions 3/7 (long-term ambition of eliminating discharge of plastic litter and microplastics into oceans) and 4/6 (address the marine litter and microplastics challenge, prioritizing a whole-life-cycle approach and resource efficiency) [86]. The action plan includes measures to assess significant microplastic sources, evaluate potential regulatory gaps, and develop guidelines to prevent plastic losses from artificial turf. By 2022, an implementation plan was established for each action, specifying concrete steps, target years, follow-up processes, indicators of accomplishment, and stakeholder involvement [86].

In summary, HELCOM provides a structured and adaptive regional governance framework for addressing microplastic pollution in the Baltic Sea. Through legally binding commitments, soft law instruments, strategic action plans, and research agendas, HELCOM integrates monitoring, source reduction, and stakeholder engagement into its approach. Challenges remain in harmonizing monitoring methods and evaluating the effectiveness of measures, but the Convention's combination of scientific assessment, policy guidance, and regional coordination positions it as a key instrument for microplastic mitigation in the North-East Atlantic's southern subregion.

3.4. Barcelona convention: the convention for the protection of the Mediterranean sea against pollution

The Convention for the Protection of the Mediterranean Sea Against Pollution, commonly known as the Barcelona Convention, was adopted in 1976 and entered into force in 1978 as the first Regional Seas Program under the United Nations Environment Programme [87,88]. In 1995, the Convention was renamed the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, reflecting its broader environmental remit. The Convention establishes legally binding obligations for contracting parties to prevent and reduce pollution, manage coastal and marine resources sustainably, integrate environmental concerns into economic and social development, protect natural and cultural heritage, and strengthen cooperation among Mediterranean states. Implementation is supported by seven protocols addressing specific aspects of environmental protection, including pollution from ships and aircraft, land-based sources, hazardous waste, marine biodiversity, offshore exploration, and integrated coastal zone management. While not all parties have ratified every protocol or accepted all amendments, the framework provides a comprehensive regional instrument for environmental governance.

The Mediterranean Sea is highly affected by marine litter, with an estimated 229,000 tonnes of plastic entering the sea annually, 94 per cent of which is macroplastic. Approximately 95 per cent of waste found in open sea areas, seabeds, and beaches consists of plastics, representing 10 per cent of the global plastic mass. In response, the Barcelona Convention has integrated marine litter and microplastic concerns into its protocols, particularly through amendments to the land-based sources protocol in 1995/1996. A landmark policy development was the adoption of the Strategic Framework for Marine Litter Management in 2012, which entered into force as the Regional Plan on Marine Litter (RPML) in 2014. This plan was the first legally binding regional instrument to address marine litter comprehensively and set out measures on waste management, prevention of illegal dumping, sustainable consumption and production, monitoring, and enforcement of national legislation, often with specific timelines for implementation. It sets clear actions and targets to help the Mediterranean Sea reach Good Environmental Status. One of its main goals is to cut beach litter across the whole region by 20% by 2024 [87,89] and emphasizes the urgent need for Member States to monitor microplastic in the marine environment [90]. The RPML balances mandatory obligations with flexibility in implementation, using terms such as "as appropriate" or "to the extent possible" to allow contracting parties discretion while maintaining legal responsibility.

The 2021 amendments to the RPML strengthened the Convention's focus on microplastics, including primary and secondary micro-litter, and expanded management measures across four key areas: economic instruments, circular economy approaches for plastics, and the reduction of land- and sea-based sources of marine litter. These measures include management of abandoned, lost, or discarded fishing gear, extended producer responsibility for plastic components, controls on lightweight plastic carrier bags, and enhanced monitoring of plastic debris [91,92]. Two appendices were added to the plan: one listing single-use plastic items and another identifying chemical additives of concern in plastic production, aligned with the Stockholm Convention. The updated Regional Plan emphasizes coordination across sectors and the integration of microplastic mitigation into national strategies and industry practices [92].

Implementation under the Barcelona Convention is supported by regular reporting, monitoring, and regional cooperation. Contracting parties are required to integrate measures into national legislation and report progress to the Secretariat, ensuring accountability while facilitating adaptation to local conditions [93]. The Convention's focus on both primary and secondary microplastics reflects recognition that microplastic pollution arises from multiple sources, including cosmetic and personal care products, synthetic textiles, paints, and fishing gear.

By embedding microplastic considerations into broader marine litter, pollution prevention, and circular economy policies, the Barcelona Convention seeks to align regional measures with international initiatives, including UNEA resolutions on plastic pollution and the Sustainable Development Goals.

Overall, the Barcelona Convention provides a flexible but binding framework for addressing microplastic pollution in the Mediterranean. Its combination of legally binding obligations, strategic planning, monitoring requirements, and sectoral measures allows contracting parties to implement regionally tailored actions while contributing to broader global objectives. RPML provides structured, Mediterranean-wide monitoring and mitigation strategies, which are implemented alongside the EU Marine Strategy Framework Directive (MSFD). This ensures consistent data collection, identification of pollution hotspots, and harmonised actions against microplastic pollution [89]. The amendments to the Regional Plan on Marine Litter, with a strong emphasis on microplastics, demonstrate the Convention's evolving approach to emerging marine pollution challenges and position it as a key instrument for promoting sustainable management of the Mediterranean Sea.

3.5. The Arctic Council

The Arctic Council, established through the 1996 Ottawa Declaration, is a high-level intergovernmental forum that promotes cooperation and coordination among the eight Arctic states (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States) as well as the involvement of six permanent Indigenous organisations and 38 states and organisations with observer status. The Council was created as a forum for collaboration rather than a binding treaty and, as such, does not possess formal legal authority under international law [94]. Nevertheless, the Council operates with a secretariat, established procedures, and six working groups that provide scientific and technical guidance, enabling it to function as a coherent governance body [95]. Its mandate emphasizes sustainable development and environmental protection in the Arctic, with decisions implemented primarily through soft law instruments such as voluntary guidelines, recommendations, and consensus-based action. While this approach allows the integration of scientific expertise and Indigenous knowledge, the lack of legally binding enforcement mechanisms limits uniform policy adoption across member states [96].

The Council's six working groups structure its operational focus. The Arctic Monitoring and Assessment Programme (AMAP) monitors environmental conditions, ecosystems, and societal impacts across the Arctic; the Conservation of Arctic Flora and Fauna (CAFF) program addresses biodiversity conservation; the Protection of the Arctic Marine Environment (PAME) group coordinates marine ecosystem protection and sustainability measures; the Emergency Preparedness and Response (EPPR) working group develops protocols to prevent and manage accidental pollution releases; the Sustainable Development Working Group (SDWG) promotes environmental protection and economic development at the community level; and the Arctic Contaminants Action Program (ACAP) focuses on reducing emissions and pollution through project implementation. Each group contributes distinct expertise, from monitoring and assessment to policy coordination and on-the-ground implementation, establishing a knowledge base that informs the Council's recommendations and guidance [96,97].

Microplastics have been detected in Arctic waters, sediments, snow, ice, and the atmosphere, highlighting their pervasive presence and persistence in cold environments, where degradation rates are slower [98–103]. Arctic wildlife, including fish species [104] invertebrates [105], seabirds, and marine mammals [106], have been documented to ingest microplastics, emphasizing the potential ecological and human health risks. Recognizing this, the Arctic Council has incorporated microplastic pollution into its environmental agenda through several initiatives led primarily by AMAP, CAFF, and PAME. PAME produced a Desktop Study on Marine Litter, including Microplastics in the Arctic, which assessed the extent, impacts, and sources of marine litter in the region, highlighting the need for improved knowledge, cooperation, and prevention strategies [36]. This work informed the development of the Regional Action Plan on Marine Litter in the Arctic, which outlines 59 actions across eight thematic areas, addressing litter from fisheries, enhancing international coordination, and establishing harmonized monitoring to track spatial and temporal trends [107,108]. Complementing this, AMAP developed both a monitoring plan and monitoring guidelines for marine litter and microplastics, focusing on key compartments such as coastal zones, seabird digestive tracts, marine water, and sediments. The guidelines emphasize harmonized methodologies for sampling, extraction, quantification, chemical identification, quality assurance, and data reporting, ensuring comparability across studies and long-term monitoring [109–111]. CAFF addresses the impacts of plastic pollution on Arctic wildlife, notably through the Arctic Migratory Birds Initiative, which monitors plastic ingestion in seabirds and underscores their vulnerability to microplastic contamination [106,112,113]. Together, these initiatives establish a comprehensive framework for monitoring and assessing microplastics and marine litter, generating baseline data, detecting spatial patterns, and informing policy measures [110].

Despite these efforts, challenges remain. Monitoring is uneven across the Arctic due to limited funding and infrastructure, and data are often collected using differing methodologies, complicating comparisons [103]. The Council's reliance on soft law mechanisms means that implementation of recommendations varies among member states, further limiting consistent regional responses [108]. Nonetheless, the Arctic Council represents a significant platform for knowledge generation, coordination, and policy guidance, integrating scientific and Indigenous perspectives into regional strategies to mitigate microplastic pollution and protect Arctic ecosystems.

4. Discussion

The aim of this study was to review the latest governance ambitions, measures, and policies addressing microplastic pollution of five major regional governance frameworks in the North-East Atlantic region, namely, the EU, OSPAR, HELCOM, the Barcelona Convention and the Arctic Council. Together, these governance frameworks represent essential pillars for environmental governance facilitation and provide an exclusive regional focus on microplastic regulations within the different sea areas of the North-East Atlantic region. Based on our case-study, an overall assessment can be made of how well the North-East Atlantic region is equipped for combating microplastics. Here we term this assessment as "preparedness" which was determined qualitatively, drawing on consistent criteria across frameworks, including legal foundation, governance type, scope, policy instruments, and monitoring mechanisms (Table 1). This structured comparison enables a reasoned evaluation of each framework's relative capacity to address microplastic pollution and furthermore how the regional frameworks, when overlapped, form a basis of comprehensive action in the absence of a Global Plastics Treaty. The key outcomes of our analysis, policy implications and future research needs are discussed in the following sections and summarised in Table 2.

4.1. Governance outcomes across regional frameworks

The first essential outcome of this study is that across all five regional frameworks, microplastic governance varies in plastic scope, but collectively addresses both primary and secondary microplastic sources. The EU applies the most comprehensive measures, with focus on intentionally added microplastics in products as well as unintentional emissions from tires, textiles, or paints through e.g., REACH and circular economy policies. OSPAR and HELCOM adopt regional action plans focusing on primary microplastics from cosmetics and pellets, but also

Table 1
Summary of regional frameworks of the North-East Atlantic based on the criteria of legal basis, governance type, scope of microplastic action, policy instruments, and monitoring.

Framework	Legal Basis	Governance Type	Scope of Microplastic Action	Key Instruments & Actions	Monitoring Plan	Key features
European Union (EU)	Treaty-based supranational body	Binding regulations, directives, and decisions	Comprehensive: addresses both **intentional and unintentional** microplastic releases	SUP Directive, REACH, Circular Economy Plan, Water Quality Directive, Plastics Strategy, Ecolabel	Initiation of steps toward microplastic monitoring, e.g., by mandated method development Wider, fully implemented monitoring still pending rather than fully established.	Strong legal backing, cross-sector policies, current development of monitoring standards, and global alignment
OSPAR Convention	Regional treaty (16 Parties including the EU)	Legally binding decisions, non-binding recommendations and cooperative agreements	Explicit focus on **primary microplastics**, ship greywater, cosmetic microbeads, artificial grass, and pellet loss	Marine Litter Action Plan (2014, 2022), NAES Strategy 2023, actions A46–A57, beach litter targets	Harmonised microplastic monitoring (2024 guidelines), seafloor sediment sampling, periodic progress reporting through MAP and RAP ML	Advanced monitoring, targets (e.g. 70% beach litter reduction by 2030), updated strategy with concrete microplastic actions
HELCOM (Baltic Sea)	Regional treaty (Helsinki Convention)	Binding recommendations, national implementation plans	Detailed coverage of **land- and sea-based** microplastic sources including turf, cosmetics, WWTP	Baltic Sea Action Plan (BSAP), "Additional information on the actions in the updated Baltic Sea Action Plan" facilitation report, Regional Action Plan on Marine Litter, HELCOM Science Agenda, Recommendations, new follow-up- and research publications	Pilot microplastic monitoring (and microplastics) (2004–2014, continuing in some regions), prioritizing harmonized MP monitoring, BSMP: Actions to agree on indicators + harmonized monitoring methods for microplastics by 2026, research on MP monitoring in food webs	Clear goals, regional implementation plan, actions across multiple sectors, including timelines and milestones Development of harmonized monitoring
Barcelona Convention	UNEP-backed regional treaty with 7 protocols	Legally binding plans with implementation flexibility	Targets **macro and microplastics**, including single-use plastics, primary/ secondary microplastics, additives	Regional Plan on Marine Litter (2014, updated 2021), new appendices on SUPs and additives	RPML: Enhanced monitoring of plastic debris including MP, structured monitoring strategies alongside Marine Strategy Framework (MSFD) for consistent data collection	First binding regional marine litter plan; strong ambition but variable national implementation strength, harmonizing monitoring
Arctic Council	Intergovernmental forum (non-binding)	Voluntary cooperation, soft law, guidelines	Broad coverage via **monitoring, assessment**, and **indigenous inclusion**; less on enforceable reduction measures	AMAP & PAME action plans, microplastic monitoring guidelines, Arctic Marine Litter RAP	AMAP leading efforts to establish a multi-taxa and multi-compartment monitoring that prioritizes water, aquatic sediments, shorelines, and seabirds.	Extensive research, monitoring, and awareness efforts; low legal enforcement capability

secondary sources, such as, artificial turf, ship greywater, or wastewater systems. The Barcelona Convention integrates primary and secondary microplastic reduction within its Regional Plan on Marine Litter, emphasizing circular economy approaches and extended producer responsibility. In contrast, the Arctic Council relies on non-binding, science-driven coordination, emphasizing monitoring, data harmonization, and ecosystem assessment. Together, all frameworks reveal a regional convergence toward lifecycle-based microplastic mitigation, albeit with differing legal strength and implementation capacity.

A second outcome of this study is that, despite their shared objective of mitigating marine microplastic pollution, the five regional frameworks differ in their legal basis and enforceability; The EU operates under a supranational legal order, granting it the capacity to adopt directly binding measures that are enforceable across all Member States. In contrast, OSPAR, HELCOM, and the Barcelona Convention is rooted in international treaty law, providing a binding legal foundation but relying on intergovernmental cooperation with a mix of hard and soft law instruments for implementation. Among these, the Barcelona Convention stands out for embedding microplastic reduction within legally binding regional plans under the UNEP framework. Conversely, the Arctic Council functions solely as a non-binding forum, coordinating voluntary actions and scientific collaboration without formal legal obligations. Together, these variations in legal basis directly influence each framework's regulatory strength and compliance mechanisms, with the EU's supranational authority enabling more uniform enforcement, while treaty-based and soft-law mechanisms depend more heavily on political commitment, consensus, and peer accountability among participating states.

A third outcome is that, altogether, the EU, OSPAR, HELCOM, the Barcelona Convention and the Arctic Council employ distinct yet complementary instruments to address microplastic pollution across their respective marine regions. The EU relies on a comprehensive regulatory framework, including its Strategy for Plastics in a Circular Economy that involves REACH restrictions on intentionally added microplastics, the Single-Use Plastics Directive, the Circular Economy Action Plan and water-quality legislation targeting both primary and secondary microplastics. OSPAR implements regionally coordinated measures through its Marine Litter Action Plans and quantitative reduction targets, addressing sources such as cosmetics, artificial turf, ship greywater and pellet loss. Simultaneously, HELCOM advances its microplastic mitigation by its Baltic Sea Action Plan, the Regional Action Plan on Marine Litter and a dedicated science agenda that guides harmonised monitoring, but also wastewater treatment improvements and source-specific interventions, among others. Under the Barcelona Convention, the Regional Plan on Marine Litter and its 2021 amendments introduce

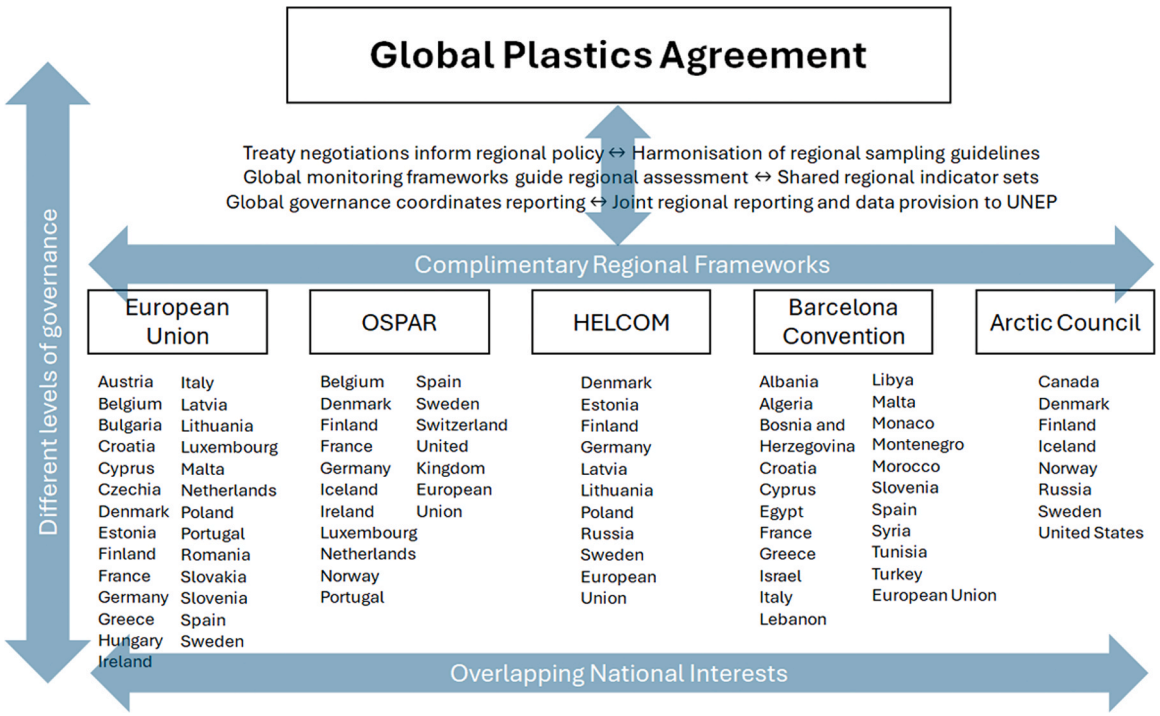

Fig. 1. Schematic illustrating interactions between a (potential) Global Agreement and Regional EU, OSPAR, HELCOM, the Barcelona Convention and the Arctic Council) frameworks addressing microplastic pollution in the North-East Atlantic.Horizontal arrows represent coordination and policy harmonisation among regional frameworks and vertical arrows indicate two-way interaction between governance levels, Individual members of each Regional framework are shown with several countries and the EU participating across a number of frameworks highlighting overlapping national interests. The Regional frameworks, as discussed, exhibit aspects of complementarity (see Discussion and Table 1). The bidirectionality between Regional and Global levels indicates the role one might have in shaping the other, for instance, through harmonisation and coordination of sampling guidelines, monitoring assessments and reporting.

legally binding yet flexible measures on single-use plastics, extended producer responsibility, and primary and secondary microplastics. Lastly, the Arctic Council, though non-binding, contributes through the Arctic Monitoring and Assessment Program (AMAP) and the Protection of the Arctic Marine Environment (PAME) guidelines, monitoring plans and a regional action plan on marine litter in the Arctic that strengthen scientific understanding and cooperation about microplastics. In total, all frameworks integrate regulatory, technical and collaborative approaches that advance regional efforts to reduce microplastic pollution. Here, the issuing of regionally coordinated action plans, reduction at source, waste management measures, science-based policy development as well as monitoring and striven harmonized assessment are overlapping features.

4.2. *Policy implications for microplastic governance*

Based on our findings, the first policy implication of our comparative analysis is that, collectively, the five frameworks form a complementary and sometimes overlapping institutional patchwork in the North-East Atlantic region, in which the EU provides legislative depth, OSPAR, HELCOM, and Barcelona Convention demonstrate regional intergovernmental cooperation with hard-, but also soft-law instruments, while the Arctic Council anchors scientific and monitoring excellence as well as participatory soft-law governance. Despite existing gaps in enforcement and coordination, the complementary mandates create a strong foundation for comprehensive microplastic governance across the North-East Atlantic and adjacent seas and make it one of the most advanced microplastic governance networks on global scale. However, an aspect that needs to be considered here is the close relationship between macroplastic governance and microplastic mitigation. While this study focuses primarily on policies that explicitly address microplastic-specific measures (e.g., microbead bans, pellet loss, fibres, tyre wear, monitoring), it is important to acknowledge that a substantial share of these marine microplastics originates from the environmental degradation of larger plastic items [114]. While, according to our research outcomes, several regional framework policies in this study do indirectly target macroplastics (e.g., waste management interventions, single-use plastics restrictions, circular economy measures) to reduce secondary microplastics, they do not address macroplastic governance as a core strategy for microplastic prevention. Recognizing this linkage highlights that effective regional strategies cannot focus exclusively on microplastics, but must integrate measures addressing macroplastic production, consumption, and management as part of a comprehensive plastic pollution governance approach.

A second policy implication is that each framework on basin-level already uses similar instrument types such as Regional Action Plans on Marine Litter, monitoring plans or source appendices which make policy coordination in the North-East Atlantic more feasible. Here, the alignment of regional action plan formats, priority source lists (pellets, microbeads, tyre wear, fibres), monitoring, regional cooperation structures and similar contribute to synchronizing operational targets and timelines with focus on microplastics in the North-East Atlantic region This template-like instrumental infra-structure provides high potential for evolving structured coordination mechanisms that align regulatory ambition, monitoring practices, harmonized sampling guidelines, shared sets of indicators, and common implementation timelines. This can also strongly facilitate a development of joint reporting schemes to an administration of a potential Global Plastic Treaty. Here, the EU's binding regulatory standards function as a normative benchmark, while regional seas conventions such as OSPAR, HELCOM, and the Barcelona Convention translate these standards into basin-specific action plans and implementation guidance adapted to regional ecological conditions. Simultaneously, the Arctic Council can complement these processes by strengthening scientific cooperation, harmonizing monitoring methodologies, and integrating Indigenous and local knowledge into regional assessments [115,116]. Ultimately, by making use of the overlapping

groundwork of instrumental infrastructure within the regional frameworks, the establishment of regular cross-framework dialogue platforms, joint monitoring programmes, and shared data infrastructures could further enhance policy coherence and reduce fragmentation across governance layers. This would allow the regional frameworks to operate as mutually reinforcing governance nodes, combining regulatory authority, regional implementation capacity, and scientific expertise to create a more resilient and adaptive regional response to microplastic pollution.

However, at the same time, the need for harmonization of regional action plans is also a structural consequence of the geographic and political realities of marine governance. There are several coastal states that participate simultaneously in more than one regional framework because their coastlines extend across several marine basins (see Fig. 1). For example, while France and Spain are contracting parties to both the OSPAR and Barcelona Conventions, Germany participates in both OSPAR and HELCOM. Norway is involved in both OSPAR and the Arctic Council's Arctic Monitoring and Assessment Program (AMAP), and except in the Barcelona Convention, Denmark is involved in all regional case-frameworks. This institutional overlap assumes that national administrations must implement several regional action plans addressing similar sources of marine litter including microplastics. Consequently, without a certain degree of alignment in monitoring methodologies, priority source lists, and mitigation strategies, such overlap risks creating fragmented policy implementation and administrative inefficiencies. In conclusion, improving coherence between instruments such as regional action plans are not merely desirable but functionally necessary to ensure consistent policy application across adjacent marine regions and to support coordinated responses to transboundary microplastic pollution.

A third policy implication is that, together, the frameworks provide high potential to facilitate global marine plastic and microplastic governance, especially in the light of the disagreement about how a global plastic treaty architecture should look like. Based on the frameworks' collective scope of microplastic action, enforceability, monitoring and governance instruments, they can provide regulatory blueprints that can inform or inspire treaty negotiations, UN resolutions, but also national regulation beyond the North-East Atlantic region. Here, they can shape, test, and operationalise governance approaches, forming a knowledge hub that the global system can build on. By jointly addressing cross-sectoral sources of microplastic, but also trans-national plastic life cycles (e.g. by altering production standards on EU-level), regional regulation can influence global regulation by linking it to global plastic value chains. This makes the regional frameworks in the North-East Atlantic region serve as an operational middle layer that can facilitate between global goals and national policy execution when it comes to global microplastic governance.

However, in their function as an intermediary layer between global ambition and national implementation, the regional frameworks also have structural limitations. While the EU does have the potential to act as a regulatory power that can, for example, force international producers to adopt stricter and more sustainable standards to maintain access to the European market, it is important to acknowledge that the mandates of other discussed regional frameworks primarily address marine litter and microplastic inputs into the marine environment, rather than the upstream drivers of plastic pollution. Here, the regional action plans such as OSPAR's Regional Action Plan on Marine Litter or HELCOM's Regional Action Plan on Marine Litter are concrete examples. Yet, a consideration of whole plastic lifecycles and issues such as expanding oil production, product design standards, and international trade in plastic materials fall outside the regulatory scope of regional marine governance. As a result, basin-specific action plans among the regional frameworks tend to focus on mitigation and management of pollution at later stages of the plastic life cycle, instead of systemic drivers of plastic production and consumption. This highlights the continued necessity of a comprehensive Global Plastics Treaty because a

Table 2
Key outcomes, policy implications and research recommendations identified in the comparative governance assessment.

Category	Summary
Outcomes	**Scope of microplastic governance:** Across the EU, OSPAR, HELCOM, Barcelona Convention, and Arctic Council, governance addresses both primary and secondary microplastic sources, though the scope and strength of measures vary. The EU applies the most comprehensive regulatory framework, while other frameworks focus more on regional action plans and monitoring. **Differences in legal authority:** The frameworks differ significantly in legal enforceability. The EU operates under supranational law with binding measures, while OSPAR, HELCOM, and the Barcelona Convention rely on treaty-based cooperation combining hard and soft law. The Arctic Council functions as a non-binding coordination and scientific forum. **Complementary governance instruments:** Despite institutional differences, all frameworks use combinations of regulatory tools, regional action plans, monitoring systems, and science-policy coordination, collectively forming a broad governance response to microplastic pollution in the North-East Atlantic region. Thus, together, these instruments create a multi-layered governance approach combining regulatory authority, regional coordination, and scientific expertise.
Policy implications	**Institutional complementarity:** The frameworks collectively create a complementary governance network where EU regulation provides legislative depth, regional seas conventions coordinate implementation, and the Arctic Council strengthens scientific cooperation and monitoring. Worth considering is that most policies target microplastic-specific sources, even though many marine microplastics originate from degrading macroplastics. Although some measures indirectly address macroplastics, they are not yet treated as a core prevention strategy. **Need for stronger policy coordination:** Similar instruments (e.g., regional action plans, monitoring frameworks, priority source lists) across governance systems create opportunities for harmonization, joint reporting, and coordinated policy development, which could also support future global plastics treaty implementation. This is also relevant in terms of member states that participate in several regional governance frameworks. **Regional frameworks as global governance models:** These frameworks can function as testing grounds and regulatory blueprints for global plastic governance, though their mandates often focus on marine pollution mitigation rather than upstream drivers like production and trade. The latter is especially connected to regional seas frameworks such as OSPAR, HELCOM, and Barcelona Convention. **Conditional regional transferability:** Transferability of the regional governance frameworks to other regions might be context-dependent, requiring sufficient capacity, compatible legal systems, and regional cooperation. Thus, they represent a tendentiously conditional blueprint with adaptable elements rather than a universally fully replicable model. **Interaction with global governance:** Regional governance interacts with global initiatives (e.g., UN bodies and international forums), raising questions about whether regional systems will remain policy innovators or become implementation platforms for future global rules.
Research recommendations	**Comparative analysis with other regions:** Expand the regulatory assessment to additional regional seas (e.g., Caribbean, South Pacific, Southeast Asia) to identify global governance gaps and evaluate the transferability of North-East Atlantic governance models. **National-level implementation studies:** Investigate how regional commitments translate into national policy implementation, enforcement mechanisms, and real environmental outcomes across participating states. **Quantitative evaluation of enforcement effectiveness:** Conduct empirical studies on compliance, inspection regimes, policy costs, and environmental outcomes to assess the real effectiveness of microplastic governance instruments. **Governance model comparisons:** Examine the effectiveness of rule-based versus goal-based governance approaches across the frameworks to inform future international plastic governance and treaty design.

globally coordinated agreement should be equipped to establish harmonised rules across the entire plastic life cycle [117].

Nevertheless, in the absence of a Global Plastic Treaty, the EU, OSPAR, HELCOM, Barcelona Convention, and the Arctic Council have become strong engines for maintaining momentum, generating knowledge, and providing regulatory structure for marine microplastic and plastic pollution governance. They provide thus an institutional and regulative infrastructure that has high potential to keep plastic governance in the North-East Atlantic functioning, evolving, and learning. This ensures that progress does not halt while the world remains without a global agreement.

Related to the third policy implication is the global transferability of the regional governance frameworks' ambitions, measures, and policies. As discussed above, global relevance of the North-East Atlantic governance architecture can be attributed to its function as an advanced "laboratory" of microplastic governance across different levels of governance. Supranational regulation, regional treaties, and soft-law coordination can operate in parallel, collectively translating regulative and mitigative approaches into more concrete policy instruments. However, the transferability of this institutional configuration and its operationalization to other regions should be regarded as conditional rather than universal. While specific elements, for example regional action plans, harmonised monitoring systems, and source-oriented mitigation measures offer adaptable governance modules, the broader system might depend on individual enabling conditions such as administrative capacity, legal traditions, and stable regional cooperation structures. That assumes that in other regions with limited institutional capacity and different economic priorities, implementation of similarly comprehensive frameworks may require phased approaches, external financial and technical support, but also stronger reliance on flexible, soft-law instruments. Consequentially, the North-East Atlantic model should therefore be best understood, not as a template for direct replication, but as a conditional blueprint where components can inform context-specific adaptations in global microplastic governance.

Lastly, a fourth policy implication addresses the broader institutional landscape in which the regional governance frameworks operate. While this study focuses on five governance frameworks in the North-East Atlantic region, microplastic governance is also influenced by a wider set of global initiatives. These include UN–related bodies such as the Basel Convention, and the International Maritime Organization (IMO), but also forums like the G7 and G20, which increasingly address microplastic pollution. Here an example is the maritime transport of plastic pellets under the IMO. Such initiatives can shape regulatory standards and expectations that affect UN-related Regional Seas Conventions, including OSPAR, HELCOM, and the Barcelona Convention. This raises an important governance question in terms of the direction of influence between global and regional levels (Fig. 1). While Regional Frameworks in general have the potential to inform and influence global rulemaking, a future global plastics treaty could also introduce obligations that require regional conventions to adjust their strategies and coordination for harmonization, monitoring systems, and reporting. This would potentially shift the relationship toward a more hierarchical governance dynamic where global rules reshape regional policies and implementation pathways. This perspective is important to consider because it determines whether Regional Sea Conventions can function as policy innovators feeding into global governance, or rather as implementation platforms for globally agreed standards for plastic and microplastic pollution.

4.3. Future research needs

Based on our study, a recommendation for further research is to extend our regulatory review and analysis to other regional governance frameworks outside the North-East Atlantic region and learn from additional comparative assessment (e.g. [118–120]). Considering that institutional capacities differ widely, new insights based on our study design would provide a more accurate overview of global regulatory gaps and opportunities within microplastic governance. It also responds to the transboundary challenge of microplastic pollution by better understanding global supply chains, and if governance approaches in the North-East Atlantic region can be transferable. In case of gaps in transferability, such further research can increase knowledge about what models might instead suit regions with different legal, economic, or ecological contexts.

Further research is also needed at the other end of the spectrum, which is national regulation. While our study shows that the five regional frameworks have made progress in shaping norms, setting targets, coordinating monitoring, and articulating pathways for reducing microplastics, they do not automatically translate into uniform national implementation, enforcement, or effectiveness. For example, if OSPAR sets a 70% reduction target for beach litter, comparison and evaluation is needed regarding how individual states operationalize such targets, which instruments they choose, and at what levels of ambition. This includes knowledge about e.g., domestic political drivers, national regulatory innovation, or administrative constraints. Therefore, further research would strongly benefit from more empirical assessment of how effective enforcement mechanisms are applied in practice. While many regional frameworks establish targets and regulatory obligations, there is limited quantitative assessment of enforcement effectiveness, socio-economic analysis of compliance costs, inspection regimes, and actual environmental outcomes of these policies across participating states. Accordingly, future studies could utilize more quantitative policy-evaluation methods to measure enforcement effectiveness and compare implementation performance [121].

A third research recommendation is associated with the effectiveness of various types of legal basis and enforcement among the five regional instruments. The regional frameworks in this study bring together legal-, but also soft-law enforcement. This opens a discussion about the benefits of rule-based governance and goal-based governance with focus on marine plastic. While rule-based governance is characterized by precisely drafted, prescriptive rules that provide parties with clear guidance on permissible and prohibited actors [122], goal-based governance seeks to build a shared vision that strengthens collective aspirations through well-defined and achievable targets [123]. The current disagreement on a Global Plastic Treaty is thus also a disagreement on how rule-based approaches should be established and how compatible they are. Consequently, soft-law-, and goal-based oriented approaches among the five regional frameworks in this study can provide deeper knowledge about how they can contribute to international governance, and what can be learned from them from a global plastic- and microplastic perspective.

5. Conclusions

Overall, the findings indicate that the five assessed frameworks collectively constitute a highly advanced regional governance architecture, although some challenges remain regarding enforcement, coordination, and scientific uncertainty. Differences in legal basis and enforceability shape how the frameworks operate with treaty-based and soft-law arrangements relying more on political commitment, consensus-building, and peer accountability, respectively. Rather than weakening governance, this diversity can enhance resilience by allowing multiple regulatory approaches to complement one another. In the broader context, the North-East Atlantic frameworks provide institutional experience that can inform emerging global plastic governance, including a Global Plastics Treaty. They demonstrate how lifecycle-based approaches, combinations of hard- and soft-law instruments, regional action plans, and harmonized monitoring systems can function in practice. These frameworks have high potential to operate as an intermediate governance layer between global ambitions and national implementation. If a Global Treaty is adopted, they offer tested institutional and regulatory models to support its design, implementation,

and compliance mechanisms.

CRediT authorship contribution statement

Helge M. Flick: Conceptualization; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review and editing. **Farhan R. Khan:** Conceptualization; Investigation; Validation; Visualization; Writing – original draft; Writing – review and editing. **Barbara Bokor:** Investigation; Writing – original draft; Writing – review and editing. **Frans P. de Vries:** Investigation; Writing – original draft; Writing – review and editing. **Samantha L. Garrard:** Investigation; Writing – original draft; Writing – review and editing. **Tenaw G. Abate:** Investigation; Writing – original draft; Writing – review and editing. **Nicola J. Beaumont:** Conceptualization; Investigation; Writing – original draft; Writing – review and editing.

Acknowledgements

This study was supported by the North Atlantic Microplastic Centre (NAMC) Pillar 5 "Society and Regulation" funded by the Sparebanken Vest Foundation.

Data availability

No data was used for the research described in the article.

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