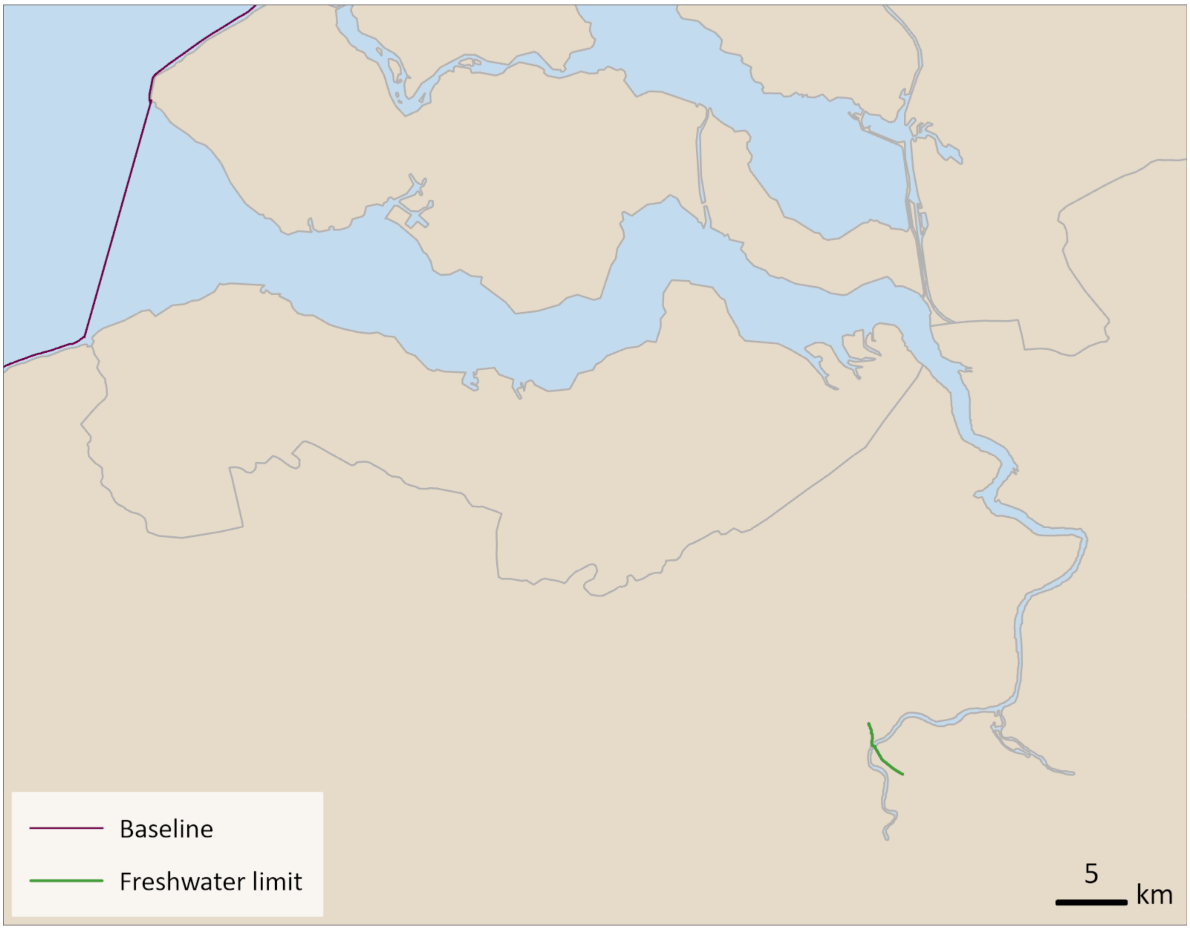
2025



How much plastic reaches the sea? A case study from the Scheldt

Policy Informing Brief

FLANDERS MARINE INSTITUTE

This final policy informing brief is part of the project PLASTFLOW (2024-2025) funded by the Public Waste Agency of Flanders (OVAM). The goal of this brief is to highlight the project's final results and support the long-term thinking behind specific policy objectives.

The project is a collaboration between the Flanders Marine Institute (VLIZ), the University of Antwerp, the Flemish Institute for Technological Research (VITO), the Ghent University (UGent), the University of Leuven (KU Leuven), and International Marine and Dredging Consultants (IMDC). This study was conducted within the scope of the Cmartlife project LIFE19 IPE/BE/000008, action 'D2 – Monitoring the plastic flux'. The Cmartlife project has received funding from the LIFE Programme of the European Union.

Date: December 17th 2025

Authors: Carina R. Lalyer, Lisa I. Devriese, Prof. Dr. Ronny Blust, Els Knaeps, Arne Van Overloop, Liesbeth De Keukelaere, Prof. Dr. Jana Asselman, Hanne Diels, Prof. Dr. Raewyn M. Town, Prof. Dr. Erik Toorman, Dr. Nithin Achutha Shettigar, Dr. Theofano Koutrouveli, Dr. Boudewijn Decrop, Charlotte A. L. Dhondt, Jelle Rondelez, Larissa Bonifacio, Dr. Nelle Meyers, Dr. Ana I. Catarino

Suggested reference: Lalyer, C.R.; Devriese, L.I.; Blust, R.; Knaeps, E.; Van Overloop, A.; De Keukelaere, L.; Asselman, J.; Diels, H.; Town, R.M.; Toorman, E.; Shettigar, N.A.; Koutrouveli, T.; Decrop, B.; Dhondt, C.A.L.; Rondelez, J.; Bonifacio, L.; Meyers, N.; Catarino, A. (2025). How much plastic reaches the sea? A case study from the Scheldt. VLIZ Beleidsinformerende Nota's, 2025_002. Flanders Marine Institute (VLIZ): Ostend. 19 pp. https://dx.doi.org/10.48470/127

ISSN: 2295-7474

Contact person: Project lead: Dr Ana Isabel Catarino (ana.catarino@vliz.be)
Policy brief: Carina R. Lalyer (carina.lalyer@vliz.be)

Source maps: Britt Lonneville, Lawrence Whatley (VLIZ)

With thanks to the VLOOT crews of the RV Simon Stevin and the MS Veremans, and all colleagues, including the technical teams, who supported the field work and sample processing and the VLIZ Library.

Contents

Extended summary

Marine plastic pollution is a major global challenge, with most plastics originating from land-based sources and transported through rivers, estuaries, and coastal zones to the sea. The Scheldt Estuary in Belgium is a key conduit in this land-to-sea pathway, making it a focus point for evidence-based policy and management. The PLASTFLOW project was launched to quantify plastic fluxes entering the North Sea, assess Flanders' target of reducing marine plastic inflow by 75% by 2025, and provide actionable insights into the behaviour and fate of plastics, including macro-, meso-, and microplastics, as well as industrial pellets. Building on baseline studies, PLASTFLOW combined extensive field sampling with advanced modelling to reveal that the estuary mostly acts as a dynamic plastic trap, with distinct hotspots closely linked to urban and industrial sources.

Plastic pollution transcends political boundaries, complicating governance. Legal definitions of the "marine environment" differ between frameworks: the United Nations Convention on the Law of the Sea (UNCLOS and most EU directives, including the Marine Strategy Framework Directive (MSFD), place the boundary at the low-water mark at the North Sea mouth, whereas the OSPAR Convention extends it inland to the freshwater limit near the Rupel. This ambiguity is particularly important for Flanders' 75% reduction target, as clear, consistent boundaries are essential to accurately monitor inflows and evaluate mitigation success. **The PLASTFLOW project confirms that while some plastics reach the North Sea, the estuary largely retains pollution, and according to the models, it is dominated by a mobile legacy stock of microplastic accumulated over decades, which continues to circulate and masks the effects of recent mitigation efforts.** A robust assessment of trends in plastic pollution over time and thus plastic export to the sea is currently not possible due to limited sample sizes and remaining model uncertainties.

PLASTFLOW research shows that accumulation is concentrated in specific hotspots, often associated with physical infrastructure such as bridges, walls, and river bends, as well as areas of high urban or industrial input. Macro- and mesoplastics from end-of-life waste break down *in-situ*, accumulate near urban areas, contributing to microplastic levels. Plastic pellets accumulate near their source in industrial areas. Riverbanks and vegetated zones act as critical retention areas, with terrain steepness and vegetation density predicting where litter accumulates. Particle transport is further influenced by tidal mixing and seasonal variation, with peaks observed during ebb and flood tides and in winter months, emphasising the need for monitoring that captures temporal as well as spatial variability.

Plastic pollution is a priority at global, EU, and regional levels, with reduction targets embedded in the EU Green Deal and Flanders' own Action Plan for Marine Litter. Achieving these ambitions requires reliable, harmonised monitoring of pollution pathways and hotspots, to which PLASTFLOW contributes by providing plastic flux data and standardised measurement protocols, including for industrial pellets. A new EU regulation targeting zero pellet loss strengthens microplastic reduction goals for 2030, and places stricter obligations on operators across the pellet supply chain. Broader initiatives such as the EU Ocean Pact and the forthcoming UN Global Plastics Treaty highlight the need for cross-border coherence and harmonised monitoring, particularly relevant in shared systems such as the Scheldt estuary. Together, these frameworks emphasise a source-to-sea perspective, recognising that effective plastic reduction must address the entire aquatic continuum rather than focus solely on marine or freshwater boundaries.

The Source-to-Sea (S2S) approach is essential for effective management, recognising that plastics move throughout the entire aquatic continuum regardless of - albeit potentially impacted by - salinity. By integrating data, coordinating across jurisdictions, and linking upstream and downstream management, S2S provides a framework for prioritising interventions, reducing pollution at its source, and monitoring outcomes in a holistic way.

Effective mitigation in the Scheldt requires a dual strategy: policy actions that reduce inputs and strategic, evidence-based interventions in identified hotspots. This includes strengthening urban waste management, promoting circular economy solutions, ensuring industry compliance with EU regulations on pellet loss, and targeting seasonal hotspots for cleanup before meso- and macroplastics degrade into micro- and nanoplastics. Research and monitoring must continue to develop and refine predictive models, refine mitigation technologies, and leverage high-resolution drone imagery and AI to map potential accumulation zones. Together, these measures will support long-term reductions in plastic pollution, advance local and global targets, and provide a model for managing estuarine plastic contamination across interconnected river-to-sea systems.

Information on the project can also be accessed through the PLASTFLOW Story Map.

Uitgebreide samenvatting

Mariene plasticvervuiling is een grote mondiale uitdaging, waarbij het merendeel van het plastic afkomstig is van landgebonden bronnen en via rivieren, estuaria en kustzones naar zee wordt getransporteerd. Het Schelde-estuarium in België vormt een belangrijke schakel in deze land-zee-route en is daarom een cruciaal aandachtspunt voor evidence-based beleid en beheer. Het PLASTFLOW-project werd opgestart om de plasticfluxen naar de Noordzee te kwantificeren, de Vlaamse doelstelling om de instroom van plastic naar het mariene milieu met 75% te verminderen tegen 2025 te evalueren, en bruikbare inzichten te bieden in het gedrag en transport van plastics, waaronder macro-, meso- en microplastics, evenals industriële pellets. Voortbouwend op eerdere baselinestudies combineerde PLASTFLOW uitgebreide metingen met geavanceerde modellering, waaruit blijkt dat het estuarium grotendeels fungeert als een dynamische plasticval, inclusief duidelijke plastic hotspots die nauw verbonden zijn met stedelijke en industriële bronnen.

Plasticvervuiling houdt geen rekening met politieke grenzen, wat het beheer ervan bemoeilijkt. De juridische definitie van het “mariene milieu” verschilt tussen beleidskaders: het VN-Zeerechtverdrag (UNCLOS) en de meeste EU-richtlijnen, waaronder de Kaderrichtlijn Mariene Strategie (KRMS), leggen de grens bij de laagwaterlijn aan de monding in de Noordzee, terwijl het OSPAR-Verdrag deze landinwaarts verlegt tot aan de zoetwatergrens nabij de Rupel. Deze onduidelijkheid is bijzonder relevant voor de Vlaamse reductiedoelstelling van 75%, aangezien heldere en consistente afbakeningen essentieel zijn om instromen correct te monitoren en het succes van maatregelen te evalueren. **Het PLASTFLOW-project bevestigt dat, hoewel een deel van het plastic de Noordzee bereikt, het estuarium het grootste deel van de vervuiling vasthoudt en volgens de modellen wordt gedomineerd door een mobiele, historische voorraad microplastics die zich over decennia heeft opgebouwd en blijft circuleren, waardoor de effecten van recente mitigatiemaatregelen moeilijk detecteerbaar zijn.** Een robuuste beoordeling van trends in plasticvervuiling doorheen de tijd, en dus van de plasticexport naar zee, is momenteel niet mogelijk vanwege beperkte steekproefgroottes en aanhoudende modelonzekerheden.

Het PLASTFLOW-onderzoek toont aan dat plasticaccumulatie geconcentreerd is in specifieke hotspots, vaak in verband met fysieke infrastructuur zoals bruggen en kademuren, en rivierbochten, evenals met zones met hoge stedelijke of industriële input. Macro- en mesoplastics uit “end-of-life” afval breken ter plaatse af, hopen zich op nabij stedelijke gebieden en dragen zo bij aan microplasticconcentraties. Plastic pellets concentreren zich vooral nabij hun bron in industriële zones. Rivieroevers en begroeide zones fungeren als cruciale retentiegebieden, waarbij terreinhelling en vegetatiestructuur sterke voorspellers zijn voor waar zwerfvuil zich ophoopt. Het transport van deeltjes wordt verder beïnvloed door getijmenging en seizoensvariatie, met pieken tijdens eb- en vloedtijden en in de wintermaanden, wat onderstreept dat monitoring zowel ruimtelijke als temporele variatie moet omvatten.

Plasticvervuiling staat hoog op de agenda op mondiaal, Europees en regionaal niveau, met reductiedoelstellingen verankerd in de Europese Green Deal en het Vlaamse Actieplan Marien Zwerfvuil. Het realiseren van deze ambities vereist betrouwbare en geharmoniseerde monitoring van vervuilingsroutes en hotspots, waaraan PLASTFLOW bijdraagt door het leveren van gegevens over plasticfluxen en gestandaardiseerde meetprotocollen, inclusief voor industriële pellets. Een nieuwe EU-verordening die inzet op nul pelletverlies versterkt de doelstellingen voor de reductie van microplastics tegen 2030 en legt strengere verplichtingen op aan actoren in de volledige pelletketen. Brede initiatieven zoals het EU Ocean Pact en het aankomende VN Wereldwijde Plasticverdrag benadrukken bovendien het belang van grensoverschrijdende coherentie en geharmoniseerde monitoring, wat bijzonder relevant is voor gedeelde systemen zoals het Schelde-estuarium. Samen onderstrepen deze kaders het belang van een source-to-sea-benadering, waarbij effectieve plasticreductie het volledige aquatische continuüm moet omvatten en niet beperkt kan blijven tot strikt mariene of zoetwatergrenzen.

De Source-to-Sea (S2S)-benadering is essentieel voor doeltreffend beheer, aangezien plastic zich doorheen het volledige aquatische continuüm kan verplaatsen, ongeacht – maar mogelijk beïnvloed door – zoutgehaltes. Door data te integreren, samenwerking tussen bevoegde instanties te bevorderen en upstream- en downstreambeheer te verbinden, biedt S2S een kader om interventies te prioriteren, vervuiling aan de bron te verminderen en resultaten op een holistische manier te monitoren.

Effectieve mitigatie in de Schelde vereist een tweesporenstrategie: beleidsmaatregelen die de instroom van plastic verminderen en strategische, evidence-based interventies in geïdentificeerde hotspots. Dit omvat het versterken van stedelijk afvalbeheer, het bevorderen van circulaire economie-oplossingen, het waarborgen van naleving door de industrie van EU-regelgeving inzake pelletverlies, en het gericht aanpakken van seizoensgebonden hotspots via opruimacties voordat meso- en macroplastics verder degraderen tot micro- en nanoplastics. Onderzoek en monitoring moeten worden voortgezet om voorspellende modellen verder te ontwikkelen en te verfijnen, mitigatietechnologieën te verbeteren en hoog-resolutie dronebeelden in combinatie met AI te benutten voor het in kaart brengen van potentiële accumulatiezones. Samen ondersteunen deze maatregelen een duurzame vermindering van plasticvervuiling, dragen zij bij aan lokale en mondiale doelstellingen en bieden zij een voorbeeld voor het beheer van plasticverontreiniging in estuaria binnen onderling verbonden rivier-naar-zee-systemen.

Informatie over het project is ook beschikbaar via de PLASTFLOW Story Map.

1. Introduction

Marine plastic pollution is recognised as one of the major environmental challenges to date, with most plastics entering the ocean from multiple land-based sources, such as industrial discharges, urban runoff, agricultural activities, and insufficient waste management[1]. Plastic litter is transported through rivers, estuaries, and coastal zones, where it can be deposited and retained along its path or carried over long distances from its source before entering marine waters, where it can pose a danger to marine life and different habitats[2–4]. Additionally, in the European Union, plastic pellets have become a growing concern, where tens of thousands of tonnes are leaking into the environment at various stages along the value chain[5]. Estuaries such as the Scheldt in Belgium play a key role in the transport of plastics from land to the sea. A clear understanding of how much plastic from Flanders enters the North Sea is key to guiding effective policies and targeted actions to reduce plastic pollution in the environment.

The PLASTFLOW project

PLASTFLOW aimed to understand **how much plastic flows into the North Sea**. The focus was on the Scheldt River and its estuary in the Belgian territory. In Flanders, the Public Waste Agency of Flanders (OVAM) set ambitious targets within the Flemish Integral Action Plan for Marine Litter as per **objective 9: reduce the inflow of plastic waste into the marine environment from Flanders by 75% by 2025**. The Scheldt estuary is considered to have high natural value, with the unique feature of a freshwater tidal zone[6]. Its catchment is located in an urban area with intense industrial activity[7]. PLASTFLOW aimed to evaluate OVAM's objective through:

- Plastic sampling and data collection in several locations along the Scheldt River and Estuary,
- Modelling the fate and accumulation of macro-, meso-, microliter and pellets in the Scheldt estuary, considering the asymmetric tidal retention[i] of litter,
- Evaluating the plastic flux from the Scheldt River to the Sea,
- Disseminating the results to the public and interested stakeholders.

In Flanders, under the PLUXIN project, a baseline study was conducted to provide a first indication of the amount of plastic transported into the sea[9]. This study showed that plastics are present across all sampled river sites, with **the Scheldt estuary acting as a sink where plastics accumulate rather than flow out to sea**, a pattern also observed in other European rivers[10,11]. PLASTFLOW built on existing knowledge to advance understanding of how plastics, including pellets, disperse, accumulate, and behave in the Scheldt River and its estuary.

[i] Asymmetric tidal retention refers to the uneven movement of litter during tidal cycles, leading to its accumulation in estuarine and tidal zones. In some estuaries, tidal dynamics cause more litter to be carried inland than flushed back out to sea. For further explanation, please refer to Dronkers,1968[8].

Insights into the occurrence and behaviour of plastic in our water systems could inform decision-making and develop solutions for plastic pollution removal or prevention at the sources. For example, plastic hotspots in estuaries could serve as key targets for future mitigation. In addition, monitoring efforts and assessments provide a means to evaluate progress toward policy objectives[12] .

Further information on the project including the final reports can be found on the dedicated online interactive tool: PLASTFLOW Story Map

2. Defining the sea demarcation: implications for pollution policy

2.1 Pollution does not recognise boundaries

The aquatic ecosystem is a physical, chemical and biological continuum where rivers, estuaries, coastal zones, and the marine environment are inherently interconnected[12]. Pollutants and contaminants, including plastic litter, can reach long distances from their source[1,13], making it difficult to identify their origin. Nonetheless, this land-sea continuum is artificially divided into different geopolitical jurisdictions, each governed by distinct competent authorities with their own legal responsibilities[14]. Additionally, what constitutes the marine environment differs depending on the applicable policy or legal framework. This highlights the need for coordinated, transboundary solutions, supported by robust monitoring to identify hotspots, track pathways, and guide targeted mitigation tailored to regional conditions[13,15,16]. The Scheldt Estuary is jointly managed by Belgium and the Netherlands, with parts of it falling under Flanders' jurisdiction[6]. For a comprehensive review of the legal framework and governance competencies in the Scheldt estuary, please refer to the PLASTFLOW report[14].

2.2 Policy perspective: Is the Scheldt Estuary considered a marine environment?

Maritime zones and the responsibilities of states within them are defined by international agreements that establish binding obligations for environmental protection, like tackling pollution, among others. Focusing on the Scheldt river and estuary, two legal instruments are of main importance, the Law of the Sea (UNCLOS) and the Regional Seas Conventions such as OSPAR (for more relevant policies: De Buyser et al, 2024[14]):

- **The international United Nations Convention on the Law of the Sea (UNCLOS)** recognises the boundary between internal waters and the marine environment at the **low-water mark** along the coast[14,17]. According to De Buyser et al.[14] this boundary for the Scheldt estuary lies in the Netherlands at the mouth of the Scheldt into the North Sea (Figure 1). The low-water mark as a limit (baseline) is adopted by most EU directives and regulations, including the Marine Strategy Framework Directive (MSFD), to which Belgium has obligations as an EU Member State.

- **The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)** recognises the boundary between the marine environment and the freshwater at the **freshwater limit**, therefore extending the marine environment to include estuaries. Like any estuary, the Scheldt estuary is composed of a river subject to tidal influences and contains a mix of seawater and fresh surface water[6]. The boundary between the freshwater and the oligohaline lies at the mouth of the Rupel into the Scheldt[6,14] (Figure 1). The freshwater limit is adopted by the OSPAR Convention, to which Belgium is also a Contracting Party.

Considering plastic pollution and the term "into the marine environment" in the context of the environmental target in Flanders, "reduce the inflow of plastic waste into the marine environment from Flanders by 75% by 2025 of the marine area, especially in transition zones such as the Scheldt estuary (Figure 1), are crucial.

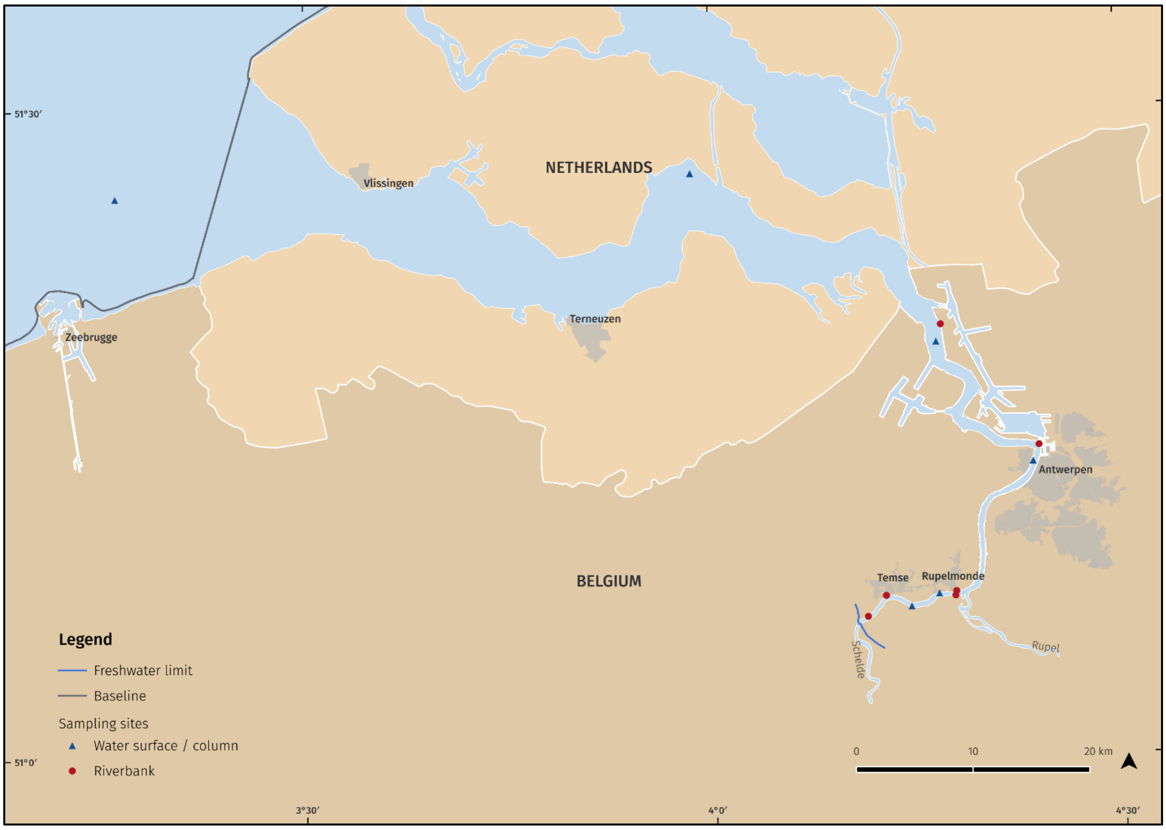


Figure 1. The difference between the baseline and the freshwater boundary at the Scheldt. Sampling sites within the PLASTFLOW project are illustrated. Image by Lawrance Whatley, VLIZ.

2.3 Practical implications for pollution governance

The two ways of defining the marine environment have practical implications for evaluating Flanders' efforts under Objective 9, particularly in determining whether plastic pollution in the Scheldt estuary is accounted for:

- Baseline (low-water mark). Plastic litter in the estuary is **not considered part** of the marine environment, as the Scheldt Estuary lies landward of the baseline and is therefore excluded under UNCLOS and EU legislation such as the MSFD.
- Freshwater limit: Plastic litter in the estuary is **considered part** of the marine environment, as the OSPAR Convention recognises the freshwater limit and thus includes the Scheldt estuary within its marine region definition.

Applying the baseline definition could exclude plastic waste in the Scheldt Estuary from efforts to tackle plastic pollution under Objective 9, even though this waste can ultimately reach the North Sea.

3. How much plastic flows into the sea?

The PLASTFLOW project confirms that the Scheldt Estuary acts as a major trap for all plastic sizes monitored herein with limited transport to the sea.

Microliter results show:

- Results from the baseline modelling study[9] (2020–2022) indicated that the Scheldt Estuary likely functions as **a major sink for microplastics**.
- The PLASTFLOW project further refined and enhanced the previous model, confirming **retention patterns in the Upper Scheldt**.
- However, due to remaining uncertainties and data limitations associated with the model upgrade, the extent of microplastic export to the Sea remains uncertain. Direct comparison between the two models (PLASTFLOW and the baseline study[9]) is challenging, and thus quantitative assessment of changes in microplastic flux to the Sea over the past five years, is not currently possible.
- Microplastic concentrations in the Scheldt Estuary show **strong spatial and temporal variability**, with levels generally remaining within the same order of magnitude across locations and between the baseline and current study. This high variability makes it **difficult to detect trends over time** and implies that robust, long-term monitoring with sufficiently large sample sizes is essential. A power analysis indicates that detecting meaningful changes in microplastic levels would require more than 400 samples, while PLASTFLOW collected 73 water samples, limiting the ability to assess trends or policy impacts.
- Based on the microplastics model, the estuary is **dominated by a large, mobile legacy pool of accumulated microplastics**, making it difficult to assess whether there have been any recent changes in pollution levels.

Macroliter and pellet results show:

- The total **macro- and mesoplastic exported flux to the Sea is calculated at 0.6 tonnes/year**, however this value remains highly uncertain due to sampling and model limitations. The previous baseline study[9] did not include a macroliter transport model, and a trend evolution over time cannot be assessed.
- The total mean number of macro- mesoplastics and pellets in the water column is comparable to the previous baseline study[9] and there are no major differences detected.
- On the riverbanks, Antwerp-Droogdokken showed the highest pellet concentration (5,126 pellets/m^2) and Rupelmonde showed the highest macroliter concentration (194 macroplastics/m^2).

The PLASTFLOW project assesses plastic concentrations and fluxes to the sea using the UNCLOS definition of the marine environment. In contrast, the OSPAR Convention considers the entire Scheldt estuary to be part of the marine environment, meaning that all sampled locations already fall within marine waters. As a result, under OSPAR, the Scheldt estuary should be regarded not only as a potential transport pathway but as a key marine accumulation zone, with important consequences for policy: mitigation measures, monitoring efforts, and reduction targets must address the estuary itself, not solely the export to the open sea. In this regard, a source-to-sea management approach is better suited.

For complete results and further explanations on the highlights found in this policy informing brief, please refer to the final research report of the PLASTFLOW project.

Macro-, Mesolitter and Plastic Pellets

❖ Plastic hotspots on the Scheldt riverbank reflect human activities and manmade infrastructure

The Scheldt Estuary exhibits highly variable plastic contamination, with peak abundances concentrated in specific hotspots like Droogdokken, Galgenschoor, and Rupelmonde (Figure 2). This pollution stems from two primary, distinct sources: macro- and mesoplastics resulting from the fragmentation of urban end-of-life waste, and plastic pellets directly linked to industrial handling losses. Interventions should be geographically targeted, focusing mitigation efforts on areas where physical structures (e.g., man-made walls, bridges, river bends) and proximity to urban or industrial activity foster plastic accumulation.

❖ Riverbanks as retention zones for plastics and seasonal variation

Plastics were found deposited and accumulated along the riverbank together with other natural and organic floating materials. The outer bend of the Scheldt River seems to act as a **natural trap** within the river system, making it an important area **for targeted mitigation and monitoring**. Plastic concentrations in the sampled locations displayed **seasonal trends**, which might be explained by the latest high tide, the presence of reed vegetation and the plastics' source. This highlights that plastic mobility is dynamic and seasonally dependent, requiring monitoring and mitigation approaches that capture temporal variability.

❖ Drone imagery as proxy for plastic pellet abundance

High resolution imagery indicates that litter accumulates within and between vegetation along the lower and higher water lines. Smaller items reach the higher water line while larger items remain at the lower line. Terrain steepness also seems to influence the accumulation of plastic pellets and small plastics. This highlights the **need for hotspot maps** that can predict accumulation patterns and **deploy targeted clean-up activities** based on the size of the plastics.

❖ Modelling of macroplastics places the Scheldt Estuary as a plastic trap

Model results show that macro- and mesoplastics concentrate upstream, while sinking plastics are largely trapped in the Western Scheldt, especially near the banks and in the Vlissingen harbor. In contrast, floating and sheet-like items (6% and 15% respectively) remain more mobile and can reach the sea. High uncertainty in the model results due to insufficient data was identified. Findings highlight the **need to prioritise retention hotspots** and compile continuous monitoring data to refine the models.

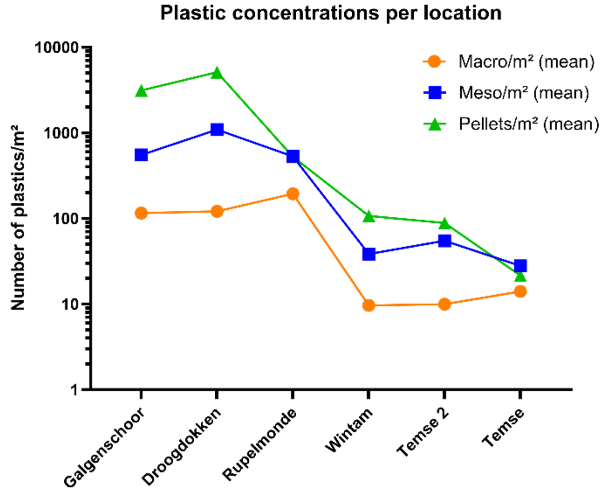


Figure 2. Plastic concentrations in number of items per m^2 across the sampled locations during the PLASTLFOW project.

Microplastics

❖ Spatial Patterns of Microplastic Contamination

Microplastic concentrations varied widely across the Scheldt in all three water compartments (surface, column and sediment), as seen in Figure 3. The highest levels were found upstream and strong sediment accumulation near Antwerpen, reflects significant urban pressures. These patterns confirm that plastics do not disperse uniformly but instead concentrate in predictable hotspots shaped by hydrodynamics and morphology. River bends such as near Hansweert enhance sedimentation, increasing long-term retention. This highlights the need for spatially targeted monitoring and interventions rather than uniform measures across the estuary.

❖ Microplastic Mobility and Estuary Dynamics

Model outputs and field data together show that microplastic transport is highly dynamic, driven by tidal mixing, resuspension, and channel geometry. Concentrations increased during ebb and flood tides, confirming that tidal phases strongly influence exposure and movement. The model highlights key retention zones in the Upper Scheldt and near Doel, where narrowing channels and faster currents trap particles, while only limited export occurs at the estuary mouth. These patterns indicate that targeted interventions should focus on tidal hotspots and physical choke points that regulate downstream transport, and monitoring must explicitly account for tidal variability to produce reliable assessments. However, the model results contain high uncertainty due to several limitations.

❖ Legacy Pollution

The model, based on cumulative emissions since 1950, closely matched measured concentrations, demonstrating that legacy microplastics remain the dominant contributor to today's pollution. Most contamination circulating in the estuary is decades old, meaning recent improvements will take considerable time to appear in monitoring data. This persistence of legacy plastic pollution inhibits to understand the evolution of the problem in the Scheldt in the past years. Frameworks that support long-term strategies are needed. Reducing the existing legacy stock, while preventing new inputs, is essential for meaningful improvement in the system.

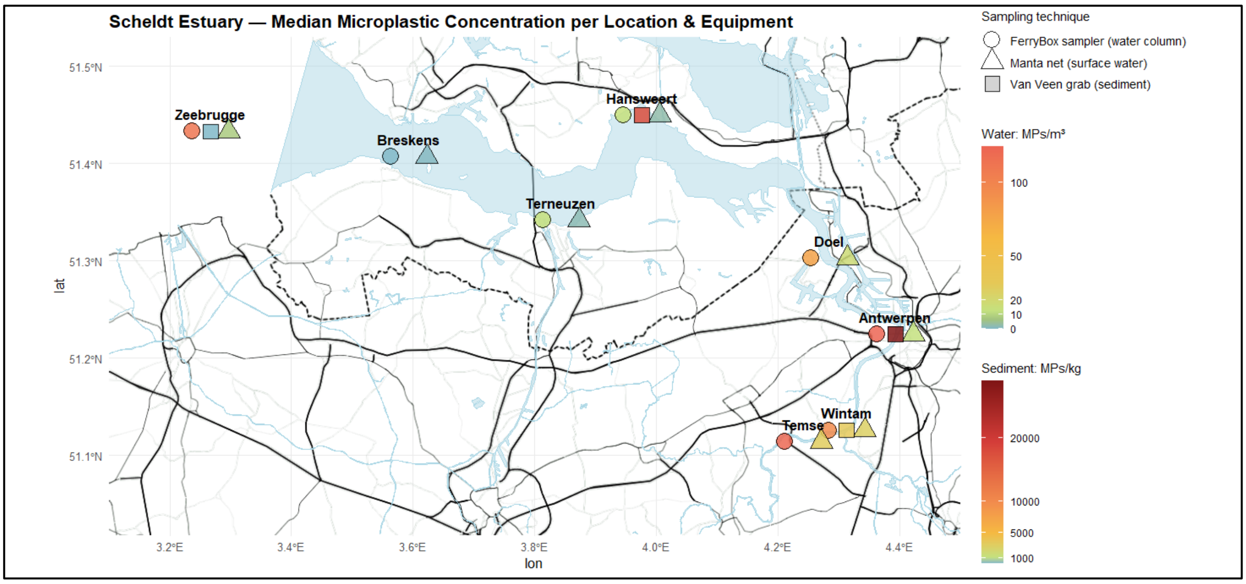


Figure 3. Hotspots of microplastic pollution. Each sampled location shows the median microplastic concentrations in surface waters (triangle), water column (circle) and sediment (square).

4. Important policy goals and ambitions for marine litter

At the global, European Union (EU) and local levels, plastic pollution is regulated through a variety of legal and policy instruments[15], with the main reducing policy targets mentioned in the text box.

Plastic pollution is high on the global and EU agenda, with reduction targets under the Green Deal and in Belgium via Flanders' own Integral Action Plan for Marine Litter through its Objective 9. Achieving these ambitions depends on reliable monitoring of pollution pathways and hotspots[13,18,19] which PLASTFLOW contributes to by providing insights into plastic flux data for Flanders and protocols for quantifying plastics, including pellets.

Additionally, the new EU regulation to reduce plastic pellet losses[20] aims at achieving zero pellet loss by imposing rules on its economic operators, including maritime transportation, and contributing to the overarching goal of reducing microplastics by 2030 [5,21].

Instruments like the established EU Ocean Pact[22] and the upcoming Global Plastics Treaty (GPT)[23] further underline the urgency of harmonised monitoring and cross-border policy coherence, also relevant for the Scheldt estuary. The EU Ocean Pact[22] and the European Water Resilience Strategy[24] highlight the need to curb plastic and microplastic pollution by adopting a source-to-sea approach and addressing the entire water continuum. Measures to reduce plastic pollution cannot be confined to the baseline or freshwater limits.

Key EU and Flemish goals

At the EU level, the Green Deal is a pivotal strategy aiming at creating societal well-being and a toxic-free environment. The **Zero Pollution Action Plan** aims to:

- Reduce plastic litter at sea by 50% by **2030;**
- Reduce microplastics released into the environment by 30% by **2030;**
- Achieve pollution levels no longer considered harmful to human health and natural ecosystems by **2050.**

The **Marine Strategy Framework Directive** applies to marine and coastal environments and aims to:

- Achieve a good environmental status where the properties and quantities of marine litter do not cause harm (Descriptor 10).
- In areas where seafloor litter is monitored using trawl surveys, no increase in litter levels over time is permitted. In areas monitored visually, litter density must not exceed one item per 1,000 square metres.

New EU regulation on **preventing plastic pellet losses** aims to:

- Set obligations for economic operators along the supply chain and achieve **zero pellet losses,** contributing to the 2030 microplastics reduction goals.

Flanders also sets ambitious goals through objective 9 of the **Flemish Integral Action Plan for Marine Litter**:

- Reduce the inflow of plastic waste into the marine environment from Flanders by 75% by **2025**.

5. The Source-to-Sea concept and its importance in tackling marine litter

Plastic pollution spreads throughout aquatic environments regardless of salinity, affecting both freshwater and marine ecosystems, underscoring the need for coherent policies across land, freshwater, and marine systems. Adopting a Source-to-Sea (S2S) approach provides a systemic and systematic framework to manage the entire water continuum[16,25–27], enabling coordinated action to reduce pollution from land-based sources through rivers and estuaries to the ocean. This approach is increasingly promoted at the EU level through the EU Ocean Pact[22], the European Water Resilience Strategy[24] and advocated by several authors[4,13,25,26], including for its addition in the future GPT[13], reflecting a growing recognition of the need for integrated water management that starts at the source. This need is particularly relevant because plastic litter is not currently addressed in EU policy for freshwater systems, such as the Water Framework Directive[28] (WFD), creating a gap in plastic monitoring and assessment in rivers and transitional waters, as opposed to marine water, which is covered by the MSFD [15,29].

By enhancing policy alignment, data sharing, and collaboration among policymakers, industries, scientists, and communities, the S2S approach fosters shared responsibility and delivers more effective, holistic measures to reduce plastic pollution. For an overview of the responsible bodies along the Scheldt estuary, see De Buyser et al (2024)[14].

Following the S2S management approach for plastic reduction could:

- Support integrated management of the land-to-sea continuum by building on and complementing the already established EU policies, such as the WFD and the MSFD[25],
- Foster collaboration between upstream and downstream actors, together with considering the plastic sources across the land-to-sea continuum[13],
- Establish local priorities that can help achieve the desired targets and goals through stakeholder engagement and participatory processes[13],
- Integrate data on plastic flows from various sources, including land-based[13],
- Encourage long-term investments and partnerships as explored in several case studies[4,26,30],
- Promote coordinated management across sectors and jurisdictions to overcome fragmented governance and align actions from local to transboundary levels[4,31],
- Provide an adaptive management strategy that encourages long-term monitoring and feedback mechanisms to ensure continuous improvement and success in tackling plastic pollution [26,30,31],
- Help countries progress towards the achievement of the UN Sustainable Development Goals, notably goal 14, “Life below water” [4,30,31].

Figure 4. Representation of the source-to-sea system and the main sources (urban, industrial, agricultural areas) of macro- and microplastic pollution illustrated by white bags and dots. Adapted from Granit et al. (2017)[16].

The way forward…

…for Policy

1. **Reducing plastic pollution at the source** remains the most effective way to tackle plastic pollution. There is a need to **enhance urban waste management, develop new materials and support a circular economy** to reduce the input of end-of-life plastic waste, the main source of macro and mesoplastics in the environment.
2. A need for **continued collaboration with industry** and swift **implementation of the new EU regulation on pellet loss prevention is crucial**. Providing targeted support and guidance to industries can further help reduce environmental releases, stopping it at the source and ensure effective compliance across the supply chain.
3. **Implement targeted clean-up and prevention efforts based on accumulation patterns** and sources. Mitigation efforts that can also be supported by citizen science initiatives should focus on identified plastic accumulation areas and be guided by evidence on seasonal trends to ensure effective and timely action. **Removing the macroplastics** from the environment will **prevent them from breaking down** in the field and further releasing micro and nano plastics in the environment.
4. Strengthen **collaboration between upstream and downstream** actors along the Scheldt River and estuary to align reduction targets and provide coordinated and adaptive reduction measures.
5. A need to consider the **ecological integrity of the Estuary** and thus to adopt the EU supported **source-to-sea** management approach.
6. Continuous and **standardised monitoring** to improve data on the evolution of plastic reduction efforts and the models, especially given the presence of a **plastic legacy** stock. Credible data should be capable of informing and evaluating environmental policy targets.
7. Attention must be paid to **clearly defining the units** used in reporting and target setting, as ambiguous metrics (e.g., volume, mass, or item counts) hinder effective interpretation and implementation of (micro)plastic reduction goals.

…for Research

1. Identification of appropriate and efficient **mitigation measures and technologies** for the prevention, identification and reduction of plastic pollution.
2. A need for a very **large number of samples** in order to formulate an assessment of the evolution of plastic trends and fluxes across the Scheldt estuary.
3. Applying **standardised and cost-efficient monitoring methods** enables consistent comparison and analysis over time, supporting evidence-based assessment of progress in plastic reduction ambitions. Develop an integrated monitoring and modelling framework to clarify (micro)plastic transport pathways and quantify the relative contributions of key emission sources.
4. Ensure **continuous monitoring and transparent data exchange** in line with the source-to-sea approach and plastic reduction commitments, to refine models, track the effectiveness of mitigation measures and adapt actions as needed.
5. **Remote sensing technologies, such as high-resolution drones** coupled with AI can be further improved and upscaled to create hotspot maps in aiding targeted clean-up interventions.

References

1. Devriese, L. *et al. SOS-Zeropol2030: Deliverable D2.1 'The EU Zero Pollution Ambition*. 79 (2023).

2. Hatzonikolakis, Y. *et al.* Quantifying Transboundary Plastic Pollution in Marine Protected Areas Across the Mediterranean Sea. *Front. Mar. Sci.* **8**, 762235 (2022).

3. Devriese, L. & Janssen, C. Beleidsinformerende Nota: Overzicht van het onderzoekslandschap en de wetenschappelijke informatie inzake (marien) zwerfvuil en microplastics in België. *Title : VLIZ Beleidsinformerende Nota's. Vlaams Instituut voor de Zee (VLIZ): Oostende. ISSN 2295-7464 Volume : 2023_002 Issue : Pagination : 55* https://doi.org/10.48470/64 (2023) doi:10.48470/64.

4. Liss Lymer, B., Weinberg, J. & Clausen, T. J. Water quality management from source to sea: from global commitments to coordinated implementation. *Water International* **43**, 349–360 (2018).

5. European Commission. *Proposal for a Regulation of the European Parliament and of The Council on Preventing Plastic Pellet Losses to Reduce Microplastic Pollution*. (2023).

6. Plancke, Y., Maris, T., Verleye, T. & Sandra, M. Scheldt estuary. *Title : Compendium voor Kust en Zee = Compendium for Coast and Sea. Vlaams Instituut voor de Zee (VLIZ): Oostende. ISSN 2983-5526; e-ISSN 2983-5534 Volume : 2023 Issue : Pagination : 1-12* https://doi.org/10.48470/60 (2023) doi:10.48470/60.

7. Interreg North Sea Region. The Scheldt Estuary. *IMMERSE* https://northsearegion.eu/immerse/project-estuaries/the-scheldt-estuary/index.html (2020).

8. Dronkers, J. Tidal asymmetry and estuarine morphology. *Netherlands Journal of Sea Research* **20**, 117–131 (1986).

9. Everaert, G. *et al.* Plastic baseline (t0) measurement in the scope Flemish Integral Action Plan on Marine Litter (OVAM). Plastic t0 study 2020-2021. *Title : Volume : Issue : Pagination :* https://doi.org/10.48470/26 (2022) doi:10.48470/26.

10. Kuizenga, B., Tasseron, P. F., Wendt-Potthoff, K. & Van Emmerik, T. H. M. From source to sea: Floating macroplastic transport along the Rhine river. *Front. Environ. Sci.* **11**, 1180872 (2023).

11. Van Emmerik, T., Mellink, Y., Hauk, R., Waldschläger, K. & Schreyers, L. Rivers as Plastic Reservoirs. *Front. Water* **3**, 786936 (2022).

12. Massoud, M. A., Scrimshaw, M. D. & Lester, J. N. Integrated coastal zone and river basin management: a review of the literature, concepts and trends for decision makers. *Water Policy* **6**, 519–548 (2004).

13. Van Leeuwen, J. *et al.* Bridging currents: an interdisciplinary source-to-sea approach is essential to align regional and national priorities with the future global plastics treaty ambitions. *Camb. prisms Plast.* **3**, e22 (2025).

14. De Buyser, S., Devriese, L., Lonneville, B., Verleye, T. & Pirlet, H. Mapping of policy instruments and powers of authorities in the transition zone from inland waters to sea: three study areas in Flanders. *Flanders Marine Institute* https://doi.org/10.48470/90 (2024) doi:10.48470/90.

15. Devriese, L. I. *et al.* Setting the course: aligning European Union marine pollution policy ambitions with environmental realities. *Front. Mar. Sci.* **12**, 1586918 (2025).

16. Granit, J. *et al.* A conceptual framework for governing and managing key flows in a source-to-sea continuum. *Water Policy* **19**, 673–691 (2017).

17. UNCLOS. United Nations Convention on the Law of the Sea. (1982).

18. Lusher, A. L. & Primpke, S. Finding the Balance between Research and Monitoring: When Are Methods Good Enough to Understand Plastic Pollution? *Environ. Sci. Technol.* **57**, 6033–6039 (2023).

19. Scientists' Coalition for an Effective Plastics Treaty. *Policy Brief. Removal of Existing and Legacy Plastic Pollution*. https://ikhapp.org/wp-content/uploads/2024/10/Removal-of-existing-and-legacy-plastic-pollution_V1-3.pdf (2024).

20. European Parliament & The Council. *Regulation (EU) 2025/2365 of the European Parliament and of the Council of 12 November 2025 on Preventing Plastic Pellet Losses to Reduce Microplastic Pollution*. (2025).

21. Council of the European Union. *Position of the Council at First Reading with a View to the Adoption of a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Preventing Plastic Pellet Losses to Reduce Microplastic Pollution*. (2025).

22. European Commission. *Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions The European Ocean Pact*. (2025).

23. UNEP. *Intergovernmental Negotiating Committee to Develop an International Legally Binding Instrument on Plastic Pollution, Including in the Marine Environment; Chair's Text*. (2024).

24. European Commission. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Water Resilience Strategy*. (2025).

25. Michels-Brito, A., Ferreira, J. C. & Saito, C. H. Source-to-sea, integrated water resources management, and

integrated coastal management approaches: integrative, complementary, or competing? *J Coast Conserv* **27**, 66 (2023).

26. Mathews, R. E. *Building Momentum to Accelerate Adoption of Source-to-Sea Management: Lessons Learned and Recommendations from Seven Case Studies*. (Havs- och vattenmyndigheten, Göteborg, 2023).

27. Mathews, R. E. *Implementing the Source-to-Sea Approach: A Guide for Practitioners*. (SIWI, Stockholm, 2019).

28. European Commission. *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy*. (2000).

29. Black, J. E., Kopke, K. & O'Mahony, C. A Trip Upstream to Mitigate Marine Plastic Pollution – A Perspective Focused on the MSFD and WFD. *Front. Mar. Sci.* **6**, 689 (2019).

30. United Nations Economic Commission for Europe. *Guidance Note for the Implementation of Source-to-Sea Management in Transboundary Basins*. https://unece.org/sites/default/files/2025-10/2514654E_FINAL_WEB.pdf (2025).

31. Groeneweg-Thakar, K., Mathews, R. E., Liss Lymer, B. & Sundman, V. *Starting at the Source to Save the Sea. Look Upstream to Achieve SDG 14*. https://waterandnature.org/wp-content/uploads/2021/03/starting-at-the-source-to-save-the-sea-final_webb.pdf (2020).

Read the full story