PLASTFLOW Final Report
Version I

Quantifying plastic fluxes and identifying plastic hotspots in the Scheldt Estuary

Deliverable D1.2 Final project report

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Extended English summary

The PLASTFLOW project aimed to better understand the plastic pollution dynamics in the Scheldt River and Estuary, Belgium, to support targeted mitigation measures aligned with Goal 9 of the Flemish Marine Litter Action Plan, which aims to achieve a 75% decrease in plastic flowing from land into the marine environment by 2025. Building on the 2020–2022 baseline studies, including the PLUXIN project, PLASTFLOW samples were acquired in previously identified locations in the 2024–2025 campaigns, and expanded its scope to include structured data workflows, modelling activities, and targeted assessments of pellet accumulation. This summary brings together the main activities, findings, and outputs of the final project phase.

Sampling campaigns combined tidal cycle measurements, spot sampling, and hotspot investigations across Zeebrugge, Hansweert, Doel, Antwerpen, Wintam, and Temse. Surface waters, the water column, riverbed sediment, and riverbanks were sampled using consistent techniques targeting different plastic size classes. The systematic recording of metadata, combined with harmonised dataset templates, ensured compatibility across our datasets and compliance with international data standards.

Macro- and Mesolitter, and Pellets - Obtained results showed that the plastic presence varied strongly across sites, with Droogdokken, Galgenschoor, and Rupelmonde showing the highest abundances. Macro- and mesoplastics mainly originated from fragmented end-of-life waste, while pellets reflected industrial losses from pristine materials. Accumulation hotspots were typically located near urban or industrial areas, often in outer river bends or against physical structures that influence flow, such as bridges. Seasonal differences were linked to vegetation cover and tidal conditions affecting the vertical distribution of plastics along riverbanks. Larger items tended to remain lower on the banks, whereas smaller mesoplastics and pellets reached higher areas. A TELEMAC-3D modelling system confirmed that only a proportion of plastics travelling through the estuary has the mobility needed to reach the North Sea: around 15% of sheet-like plastics and less than 10% of floating macro- and mesoplastics. Sinking plastics, although abundant in measurements, largely remained within the estuary. The estimated annual export of macro- and mesoplastics is roughly 0.6 tonnes, though with high uncertainty. These findings underline the need for continued monitoring and model refinement to support progress toward reduction targets.

Drone Observations - High-resolution drone imagery provided valuable insights into pellet deposition patterns and the influence of terrain characteristics. Accumulation occurred mainly within or between vegetation at both high and low water lines, with smaller items

dominating the upper lines. Terrain steepness emerged as an important factor controlling where pellets and small litter settle. Although vegetation indices did not correlate directly with litter loads, drone-based indicators show promise for future hotspot identification.

Microlitter - Microplastic concentrations in water ranged from 0 to 125 particles m^{-3} and from 160 to over 29,000 particles kg^{-1} in sediment. Upstream locations generally showed higher concentrations in water, while Antwerpen displayed the highest sediment load, reflecting urban influence. Distribution patterns aligned with polymer density: buoyant polyethylene and polypropylene (PE, PP) dominated surface waters, while denser materials such as polyacrylic acid (PAA) accumulated in sediments. Local hydrodynamics explained several hotspots, including enhanced retention near bends and constricted channels. Concentrations tended to peak during ebb and flood tide, due to tidal mixing and resuspension. Based on a performed power analysis, approximately 440 water samples would be needed to be able to reliably detect a small reduction in microplastic pollution with 80% certainty. A coupled TELEMAC–MASCARET model system simulated microplastic behaviour across the estuary, integrating hydrodynamics, sediment processes, and a population balance model for particle size distributions. Initial conditions were informed by historical material flow analysis, capturing the legacy load stored in the system. Validation using tidal cycle and spot sampling data showed reasonable agreement with manta net measurements, while FerryBox comparisons were less reliable due to small sampled volumes and high spatial variability. Flux analyses revealed strong export at the mouth (Vlissingen), decreasing transport at Doel, and significant retention in the upper Scheldt around Wintam. Spatial model outputs identified hotspots near constricted sections, which align with observed patterns. Results suggest that long-term accumulated (historical) microplastics continue to dominate the system's behaviour, which limits the detectability of recent changes in emissions.

To make project results accessible to a broad audience, an interactive ArcGIS **StoryMap** was created. It presents the project context, methods, results, maps, multimedia elements, and links to related material. The story map will be connected to the ScheldeMonitor to ensure long-term public visibility. A **policy brief** translated the scientific evidence collected within PLASTFLOW into targeted messages for decision makers, stakeholders and the wider public towards reducing plastic pollution. Project findings were presented at multiple international and national conferences, including MICRO2024, VLIZ Marine Science Day, and SETAC, supporting knowledge exchange and wider dissemination. Several scientific manuscripts are in preparation.

Open and FAIR Data - All PLASTFLOW datasets follow FAIR (Findable, Accessible, Interoperable, and Reusable) and Open Science principles. Data and metadata are published through the Marine Data Archive and MarineInfo catalogue, using harmonised templates aligned with international standards and controlled vocabularies. Persistent identifiers and clear licensing ensure their long-term accessibility and reuse.

Conclusion and Perspectives - Plastic pollution poses well-documented risks to aquatic ecosystems, estuarine and marine biodiversity, and potentially human health, underscoring the need for robust monitoring and targeted mitigation. The PLASTFLOW project advanced the knowledge towards the 75% reduction target of the Flemish Marine Litter Action Plan through consistent sampling, by assessing pellet accumulation, modelling plastics of all sizes, and delivering FAIR open-access datasets. The obtained findings highlight hotspots, support mitigation along the entire source-to-sea continuum, and support policy measures such as the EU Plastic Pellet Loss Regulation. Future efforts should combine targeted cleanups, particularly during high-accumulation seasons, improved waste management; and expanded monitoring by including drone, satellite and other innovative tools, and modelling approaches to evaluate the reduction of plastic fluxes, and to guide effective and coordinated actions.

Extended Dutch summary

Uitgebreide Nederlandstalige samenvatting

Het PLASTFLOW-project had tot doel meer inzicht te krijgen in de dynamiek van de plasticvervuiling in de Schelde en het Schelde-estuarium in België, ter ondersteuning van gerichte mitigatiemaatregelen in overeenstemming met doelstelling 9 van het Vlaamse actieplan tegen zwerfvuil op zee, dat tot doel heeft tegen 2025 een vermindering van 75 % te realiseren van de hoeveelheid plastic die van het land in het mariene milieu terechtkomt. Voortbouwend op de basisstudies van 2020-2022, waaronder het PLUXIN-project, werden in de campagnes van 2024-2025 PLASTFLOW-monsters genomen op eerder geïdentificeerde locaties en werd het toepassingsgebied uitgebreid met gestructureerde data workflows, modelleringsactiviteiten en gerichte beoordelingen van de accumulatie van pellets. Deze samenvatting geeft een overzicht van de belangrijkste activiteiten, bevindingen en resultaten van de laatste projectfase. De staalnamecampagnes combineerden getijdencyclusmetingen, spot sampling en hotspot sampling in Zeebrugge, Hansweert, Doel, Antwerpen, Wintam en Temse. Oppervlaktewater, de waterkolom, rivierbeddingafzettingen en rivieroevers werden bemonsterd met behulp van consistente technieken die gericht waren op verschillende plasticgrootteklassen. De systematische registratie van metagegevens, in combinatie met geharmoniseerde dataset templates, zorgde voor compatibiliteit tussen onze datasets en naleving van internationale gegevensnormen.

Macro- en mesolitter en pellets - De verkregen resultaten geven aan dat de aanwezigheid van plastic sterk varieerde tussen de locaties, met Droogdokken, Galgenschoor en Rupelmonde als locaties met de hoogste abundantie. Macro- en mesoplastics waren voornamelijk afkomstig van gefragmenteerd afval aan het einde van de levensduur, terwijl pellets het gevolg waren van industriële verliezen van geproduceerde plastics. Hotspots voor accumulatie bevonden zich doorgaans in de buurt van stedelijke of industriële gebieden, vaak in buitenbochten van rivieren of tegen fysieke structuren die de stroming beïnvloeden, zoals bruggen. Seizoensgebonden verschillen hielden verband met de vegetatiebedekking en getijdenomstandigheden die van invloed waren op de verticale verspreiding van plastic langs rivieroevers. Grotere voorwerpen bleven meestal lager op de oevers liggen, terwijl kleinere mesoplastics en pellets hogere gebieden bereikten. Een TELEMAC-3D-modelleringssysteem bevestigde dat slechts een deel van het plastic dat door het estuarium stroomt, de mobiliteit heeft die nodig is om de Noordzee te bereiken: ongeveer 15 % van het plaatvormige plastic en minder dan 10 % van het drijvende macro- en mesoplastics. Zinkend plastic, hoewel overvloedig aanwezig in metingen, bleef grotendeels binnen het estuarium. De geschatte jaarlijkse export van macro- en mesoplastics bedraagt ongeveer 0,6 ton, maar de onzekerheid hierover is groot. Deze bevindingen benadrukken de noodzaak van voortdurende monitoring en modelverfijning om de voortgang naar reductiedoelstellingen te ondersteunen.

Drone-observaties - Hoge-resolutie dronebeelden leverden waardevolle inzichten op in de afzettingspatronen van pellets en de invloed van terreinkenmerken. De ophoping vond voornamelijk plaats binnen of tussen de vegetatie bij zowel hoge als lage waterlijnen, waarbij kleinere voorwerpen de bovenste lijnen domineerden. De steilheid van het terrein bleek een belangrijke factor te zijn die bepaalt waar pellets en klein afval terechtkomen. Hoewel vegetatie-indexen niet direct correleerden met de hoeveelheid afval, lijken op drones gebaseerde indicatoren veelbelovend voor het identificeren van toekomstige hotspots.

Microlitter - De concentraties microplastics in water varieerden van 0 tot 125 deeltjes m^{-3} en van 160 tot meer dan 29.000 deeltjes kg^{-1} in sediment. Stroomopwaarts werden over het algemeen hogere concentraties in water aangetroffen, terwijl Antwerpen de hoogste sedimentbelasting vertoonde, wat waarschijnlijk een weerspiegeling is van een stedelijke invloed. De verspreidingspatronen kwamen overeen met de polymeerdichtheid: drijvend polyethyleen en polypropyleen (PE, PP) domineerde het oppervlaktewater, terwijl dichtere materialen zoals polyacrylamide (PAM) zich ophoopten in sedimenten. Lokale hydrodynamica verklaarde verschillende hotspots, waaronder een verhoogde retentie in de buurt van rivierbochten. De concentraties piekten meestal tijdens eb en vloed getijden als gevolg van getijdenmenging en resuspensie. Op basis van een uitgevoerde poweranalyse zouden ongeveer 440 waterstalen nodig zijn om een kleine reductie in microplasticvervuiling met 80% zekerheid betrouwbaar te kunnen detecteren. Een gekoppeld TELEMAC-MASCARET-modelsysteem simuleerde het gedrag van microplastics in het estuarium, waarbij hydrodynamica, sedimentprocessen en een populatiebalansmodel voor deeltjesgrootteverdelingen werden geïntegreerd. De beginvoorwaarden werden bepaald op basis van een analyse van de historische materiaalstroom, waarbij de in het systeem opgeslagen historische belasting in kaart werd gebracht. Validatie met behulp van getijdencyclus- en spotbemonsteringsgegevens toonde een redelijke overeenstemming met mantanetmetingen, terwijl FerryBox-vergelijkingen minder betrouwbaar waren vanwege de kleine bemonsterde volumes en de hoge ruimtelijke variabiliteit. Fluxanalyses toonden een sterke export aan bij de monding (Vlissingen), een afnemend transport bij Doel en een aanzienlijke retentie in de bovenloop van de Schelde rond Wintam. Ruimtelijke modelresultaten identificeerden hotspots in de buurt van vernauwde secties, wat overeenkomt met de waargenomen patronen. De resultaten suggereren dat langdurig opgehoopte microplastics het gedrag van het systeem blijven domineren, wat de detecteerbaarheid van recente veranderingen in de uitstoot beperkt.

Om de projectresultaten toegankelijk te maken voor een breed publiek, werd een interactieve ArcGIS **StoryMap** gemaakt. Deze presenteert de projectcontext, methoden, resultaten, kaarten, multimedia-elementen en links naar gerelateerd materiaal. De story map zal worden gekoppeld aan de ScheldeMonitor om de zichtbaarheid voor het publiek op lange termijn te waarborgen. In een **beleidsnota** werd het wetenschappelijke bewijs dat binnen PLASTFLOW werd verzameld, vertaald naar gerichte boodschappen voor besluitvormers, belanghebbenden en het bredere publiek met het oog op het verminderen van plasticvervuiling. De projectresultaten werden gepresenteerd op verschillende internationale en nationale conferenties, waaronder MICRO2024, VLIZ Marine Science Day en SETAC, ter ondersteuning van kennisuitwisseling en bredere verspreiding. Er zijn verschillende wetenschappelijke manuscripten in voorbereiding.

Open en FAIR Data - Alle PLASTFLOW datasets volgen de FAIR- (Findable, Accessible, Interoperable, and Reusable) en Open Science-principes. Data en metadata worden gepubliceerd via het Marine Data Archive en de MarineInfo-catalogus, met behulp van geharmoniseerde datatemplates die zijn afgestemd op internationale normen en gecontroleerde vocabulaires. Permanente identificatiecodes en duidelijke licenties zorgen ervoor dat ze op lange termijn toegankelijk en herbruikbaar zijn.

Conclusie en vooruitzichten - Plasticvervuiling vormt een goed gedocumenteerd risico voor aquatische ecosystemen, de biodiversiteit in estuaria en zeeën, en mogelijk ook voor de menselijke gezondheid, wat de noodzaak van robuuste monitoring en gerichte mitigatie benadrukt. Het PLASTFLOW-project heeft de kennis rond de doelstelling van 75 % reductie van het Vlaamse actieplan voor zwerfvuil in zee vooruitgeholpen door middel van consistente bemonstering, door de accumulatie van pellets te beoordelen, plastic van alle groottes te modelleren en FAIR open-access datasets te leveren. De verkregen bevindingen brengen hotspots in kaart, ondersteunen mitigatie langs het hele continuüm van bron tot zee en ondersteunen beleidsmaatregelen zoals de EU-verordening over het verlies van plastic pellets. Toekomstige inspanningen moeten gericht zijn op doelgerichte schoonmaakacties, met name tijdens seizoenen waarin veel afval accumuleert, verbeterd afvalbeheer en uitgebreide monitoring door middel van drones, satellieten en andere innovatieve hulpmiddelen, en modelleringsmethoden om de vermindering van de plastic flux te evalueren en effectieve en gecoördineerde acties te sturen.

Introduction

It is essential to implement strong monitoring and well-directed mitigation strategies towards plastic pollution, since plastic contamination can pose a risk to aquatic environments, marine and estuarine biodiversity and may also impact human health. In alignment with Goal 9 of the Flemish Marine Litter Action Plan, which aspires to achieve a 75% reduction in the inflow of plastic waste into marine environments by 2025, the PLASTFLOW project developed a comprehensive sampling framework. This framework followed-up measurements conducted in 2024–2025 to assess plastic pollution levels in the Scheldt River and its estuary, building on the baseline study from 2020–2022 (Everaert et al., 2022). Throughout the project, we applied consistent sampling methodologies and techniques and returned to the same locations to maintain comparability with the baseline data. Beyond replicating the baseline assessment, the project also addressed additional objectives set out in the call, including the identification and evaluation of accumulation areas for plastic pellets.

Within the PLASTFLOW project, we aimed to:

1. Calculate the plastic flux from the Scheldt to the sea and evaluate this flux using the t_0 measurement.
2. Develop a sampling and data management plan to establish an improved data flow and to collect, process, and analyse data, ultimately publishing open-access and FAIR datasets on observations of litter in the Scheldt estuary and surrounding coast (WP2 and WP3).
3. Model the fate and accumulation of macro-, meso- and microlitter and pellets (plastic ‘hotspots’) in the Scheldt estuary, considering the asymmetric tidal retention of litter (WP4).
4. Develop a story map as a multimedia tool combining interactive maps with text, images, videos, and other multimedia elements to narrate and illustrate the project’s activities and findings (WP5).
5. Compile the new insights and main conclusions into a policy briefing paper (WP5).

This final report summarises the progress achieved during the project PLASTFLOW, the methodologies applied, and the key findings that enhanced our understanding of plastic pollution trends in the Scheldt Estuary.

Material & Methods

During the planned campaigns within PLASTFLOW, as per the baseline measurements, three types of follow-up measurements were acquired: tidal cycle measurements (TCM), to assess and quantify the tidal movement of plastic litter and debris along the Scheldt River; spot sampling measurements (SSM); and hotspot measurements (HSM), to assess which environmental parameters contribute to the accumulation of plastics in the environment. More details can be found in the Intermediate PLASTFLOW Report (**D1.1**) (Meyers et al., 2025a).

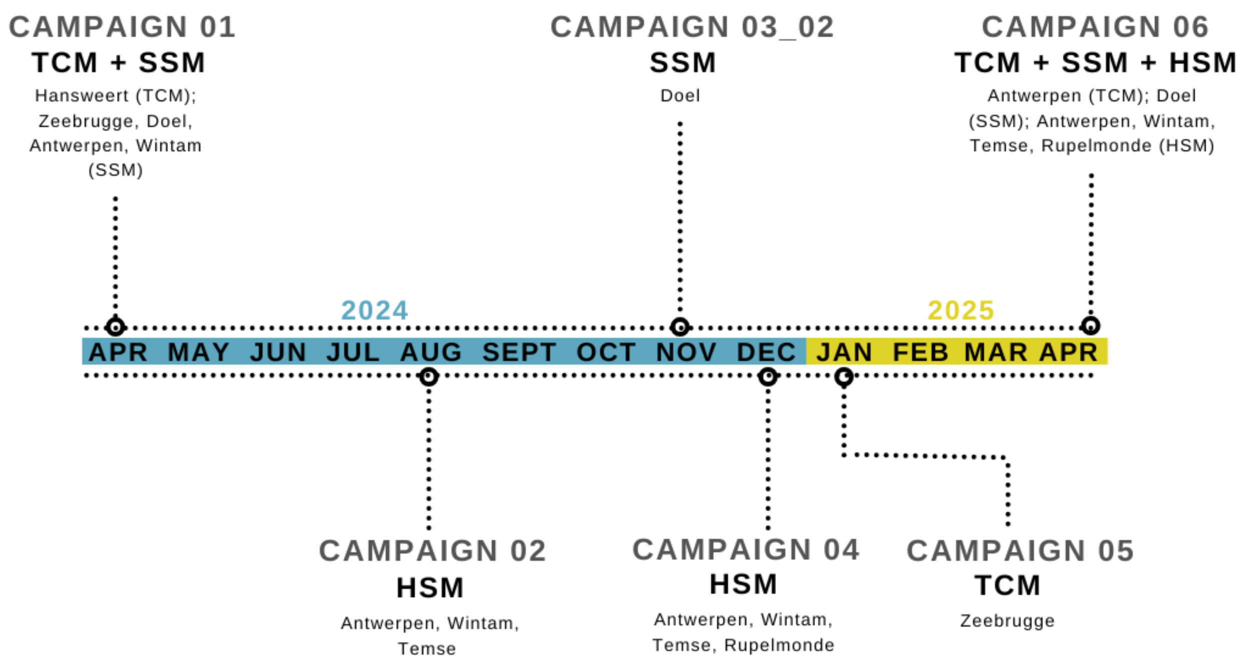


Fig. 1: Sampling timeline. *A timeline of the performed sampling activities within the PLASTFLOW project. TCM = tidal cycle measurements, SSM = spot sampling measurements, HSM = hotspot measurements.*

Sampling activities took place during multiday campaigns with the RV Simon Stevin and the MS Veremans, and during single day campaigns on riverbanks and pontoons, at locations throughout the Scheldt estuary: Zeebrugge, Hansweert, Doel, Antwerpen, Wintam, and Temse (**Table 1**). Tidal cycle measurements and spot sampling measurements were acquired during three separate sampling campaigns: 2-3 April 2024 and 14-15 January 2025 (both with the RV Simon Stevin), and 9-10 April 2025 (with the MS Veremans) (**Fig. 1**). Adverse weather and technical constraints on the research vessel resulted in slight deviations from the TCM schedule outlined in the sampling plan (**D3.2**). Hot spot sampling was performed during August 2024, December 2024, and April 2024, in line with the PLASTFLOW sampling plan (**Fig. 2**).

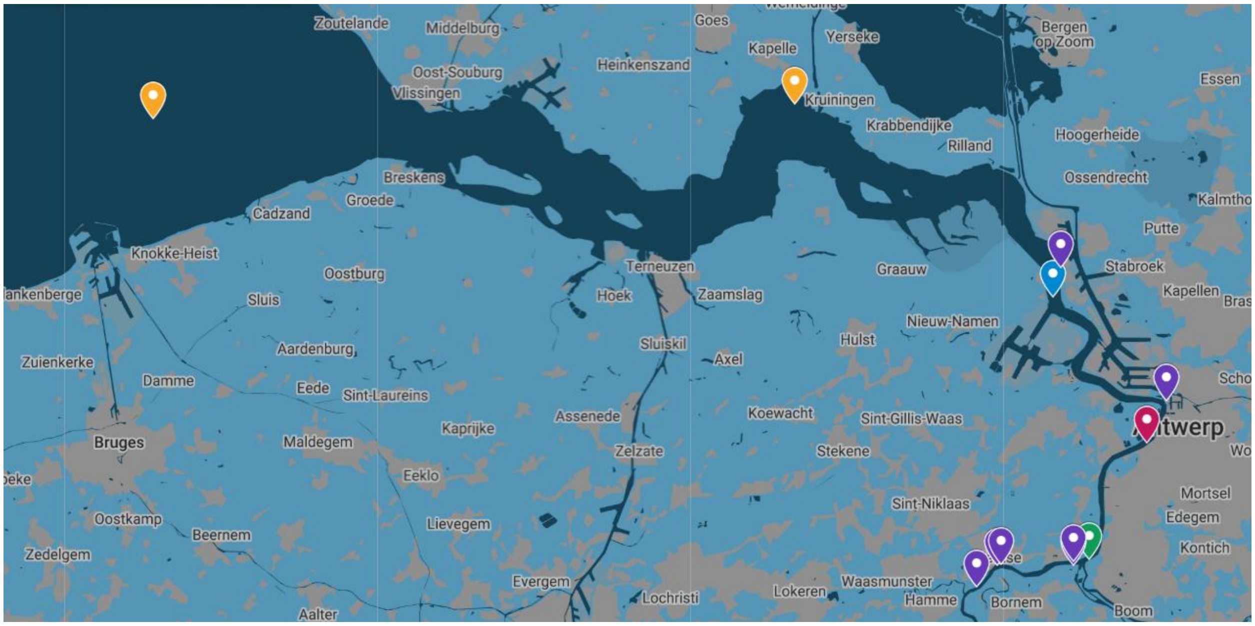


Fig. 2: Sampling map. *A map with the sampling locations indicated. The yellow marker indicates locations where both tidal cycle measurements (TCM) and spot sampling measurements (SSM) were acquired (Zeebrugge and Hansweert). At the blue marker only SSM were acquired (Doel); at the pink marker TCM measurements (Antwerpen Galgenweel) were acquired, at the green marker SSM and hotspot measurements (HSM) (Wintam), and at the purple marker HSM only (multiple locations near Antwerpen (VLOOT pontoon, Galgenschoor, and Droogdokken), Temse and Wintam, and Rupelmonde).*

To assess plastic pollution in the Scheldt estuary, we sampled both water and sediment across different depths and locations, accounting for the varying behaviours of different polymer types. Microplastics were collected from surface water using a net-based method and throughout the water column with a specialised sampler, while macro- and mesolitter were sampled using a bedload sampler above the estuary bottom, and a suspension sampler throughout the water column. Riverbank material, including pellets, was obtained using a quadrant-based approach, supported by drone imagery. Detailed descriptions on the sampling strategy, including equipment per compartment, sampling frequency and timing, locations, and targeted plastic types and size classes, are available in the PLASTFLOW sampling plan.

Throughout the Scheldt Estuary sampling campaigns, comprehensive metadata were collected for all samples, including precise coordinates, sampling equipment specifications, and sample details such as depth and volume. Plastic macrolitter was classified using the J-list (Fleet et al., 2021), while dedicated metadata templates (developed by VLIZ) were employed for all plastic size classes to standardise and harmonise data in line with international standards, including the EMODnet Chemistry data portal. This approach ensured data integrity, comparability across locations and campaigns, and added value for future use and integration with other datasets. Further details on metadata handling are provided in the PLASTFLOW Data Management Plan (Annex III, **D2.1** and **D2.2**) (Rondelez et al., 2025) and the PLASTFLOW Sampling Plan (**D3.2**) (Meyers et al., 2024).

*Table 1: **Campaign overview.** Overview of the multiday and single day campaigns.*

Type of campaign	Type of measure ment	Means of sampling	Frequency	Location	Matrix sampled	Type of plastics sampled	Partners involved
Multi-day campaign	Tidal cycle measure ment	RV SiSt; MS Veremans	3 / year	1xZeebrugge; 1xHansweert; 1xWintam	Water; sediment	Micro; pellets; meso; macro	VLIZ/ UAntwerp
Multi-day campaign	Spot sampling	RV SiSt; MS Veremans	3 / year	Zeebrugge, Hansweert, Doel, Antwerpen, Wintam	Water; sediment	Micro; pellets	VLIZ
Single-day campaign	Hotspot sampling	Pontoon/ Riverbank	3 / year	Antwerp; Wintam; Temse, Temse 2, Rupelmonde	Water; sediment; riverbanks	Micro; pellets; meso	VLIZ/ UAntwerp/ VITO

Open and FAIR datasets

Data generated in the PLASTFLOW project complies with the FAIR principles and the Open Science best practices as much as possible (see Data Management Plan **D2.1** and **D2.2,** Annex V) (Rondelez et al., 2025). Metadata and data are made findable, openly accessible and reusable via the Marine Data Archive and the MarineInfo catalogue (https://marinedataarchive.org/ and https://marineinfo.org/search), and by assigning a clear usage licence and a unique persistent identifier.

Data are made interoperable and reusable by creating predefined and harmonised (meta)data templates that are used by all relevant project partners for data collection, management and sharing. These templates consider currently existing international data management guidelines and best practices and controlled vocabularies, and ensure that general and specific metadata (such as sampling methodology) is captured and provided with the data.

More detailed information in **D2.3** Open and FAIR Data (Annex V).

Main results

Macro- and Mesolitter, and Pellets

The University of Antwerp has led the observations of macro- and mesolitter, and plastic pellets, both in riverbanks and water column.

Riverbank observations

Plastic concentrations on different sampling locations

Macro-, mesoplastics and pellet concentrations differed across locations (**Table 2**). For pellets, on average, Droogdokken showed the highest concentrations (5,126 pellets / m^2), followed by Galgenschoor (3,131 pellets / m^2). In Rupelmonde, Wintam, Temse2 and Temse, the average pellet concentration amounted to respectively 527, 107, 89 and 22 pellets / m^2. For macroplastics, on average, Rupelmonde showed the highest concentrations (194 macroplastics / m^2), closely followed by Droogdokken (121 macroplastics / m^2) and Galgenschoor (115 macroplastics / m^2). In Temse, Temse 2 and Wintam, macroplastic concentrations were similar to each other, respectively 14, 10 and 10 macroplastics / m^2. In the case of mesoplastics, Droogdokken showed the highest concentrations (1,094 mesoplastics / m^2), followed by Galgenschoor (553 mesoplastics / m^2) and Rupelmonde (531 mesoplastics / m^2). In Temse2, Wintam and Temse mesoplastic concentrations amounted to respectively 55, 39 and 28 mesoplastics / m^2.

Analysis of the measured concentrations (number of items / m^2) of plastics (macro-, mesoplastics, pellets) show that Galgenschoor and Droogdokken are hotspots for accumulation of all plastics, and Rupelmonde is a hotspot for macroplastic accumulation (**Table 2, Fig. 3**). Hotspots for plastic accumulation are typically located close to urban (for macro- and mesoplastics) and industrial areas (for plastic pellets). These hotspots act as a trap for plastics and are often situated at the river's outer bend or close to a physical barrier such as a human-made wall or a bridge, that might influence the river flow dynamics. Macro- and mesoplastics and plastic pellets differ in source: macro- and mesoplastics are typically (fragments of) end-of-life waste, while plastic pellets are entering the environment due to inadvertent pellet losses from industrial production and logistics chain. The magnitude of pellet losses can influence the measured pellet concentrations on the riverbanks, although it is likely that it takes a certain amount of time for pellets to reach the riverbanks. Thus, there will be some delay between increased pellet losses and an increase in pellet concentrations on the riverbank, also depending on other processes which affect the environmental distribution of pellets (e.g. sinking/sedimentation).

Table 2: Descriptive statistics. *Statistics on macro-, mesoplastics and plastics pellet concentrations (number of plastics / m^2) on 6 locations along the Scheldt riverbanks.*

PLASTICS /m²	**Galgenschoor**			**Droogdokken**			**Wintam**			**Temse**			**Temse2**			**Rupelmonde**		
	MACRO	**MESO**	**PELLETS**	**MACRO**	**MESO**	**PELLETS**	**MACRO**	**MESO**	**PELLETS**	**MACRO**	**MESO**	**PELLETS**	**MACRO**	**MESO**	**PELLETS**	**MACRO**	**MESO**	**PELLETS**
Mean	115	553	3131	121	1094	5126	10	39	107	14	28	22	10	55	89	194	531	527
Median	24	60	248	64	224	1847	4	8	0	4	4	0	8	4	24	20	38	40
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	632	6924	28932	800	8556	22892	84	364	756	88	344	176	32	408	496	1700	4840	5548
Interquartile Range	196	636	2833	136	704	3704	12	36	72	16	12	8	17	28	136	140	303	207
N	27	27	27	27	27	27	27	27	27	27	27	27	18	18	18	18	18	18

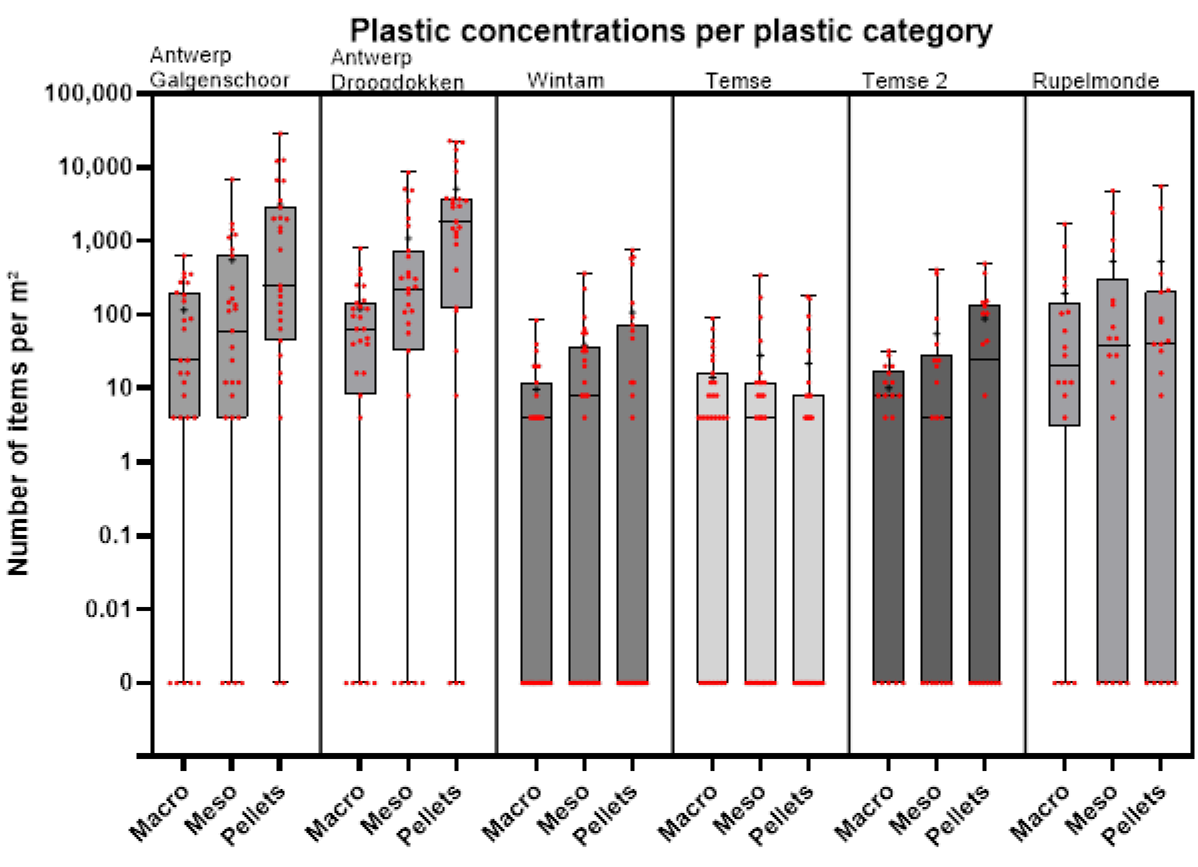


Fig. 3: Plastic concentrations per plastic category (macro, meso, pellets) *on 6 locations along the Scheldt riverbank. The graphs show all datapoints (red dots) and boxplots with minimum- maximum range and 5th to 95th percentile whiskers. The x axis represents the plastic categories (macro-, mesoplastics, pellets and all plastics) and the y axis represents the number of items / m^2 (log scale).*

Seasonal patterns in plastic concentrations

Seasonal patterns show lower plastic concentrations in August and higher plastic concentrations in December 2024, except in Galgenschoor where concentrations peaked in August (**Table 3, Fig. 4**). This might be explained by the presence of full-grown vegetation in August 2024 and the level of the latest high tides. Firstly, during summer, fully grown reed vegetation was dominantly present on all locations except Galgenschoor. The vegetation acts as a trap for plastics, whereafter not all plastics are able to reach the higher parts of the riverbank, as they get stuck before entering the sampling zone with the biggest volume of tidal deposited materials. The same reasoning applies to the lower high tides in February 2025, with the consequence that plastics cannot be transported to the zone on the riverbank with the greatest volume of tidal deposited materials. This means that plastics may still be present at the riverbank, but on the lower parts, closer to the water and not at the level where sampling took place.

***Table 3: Descriptive statistics**. Statistics on plastic concentrations (number of plastics / m^2) per sampling campaign (Augustus 2024, December 2024, February 2025) on 6 locations along the Scheldt riverbank.*

	PF_02 Aug 2024	**PF_04 Dec 2024**	**PF_06 Feb 2025**
Number of values	36	54	54
Minimum	0	0	0
25% Percentile	0	7	1
Median	7	72	18
75% Percentile	251	654	91
Maximum	12,163	10,749	7,691
Range	12,163	10,749	7,691
Mean	925	904	362
Std. Deviation	2,499	2,002	1,140
Std. Error of Mean	417	272	155

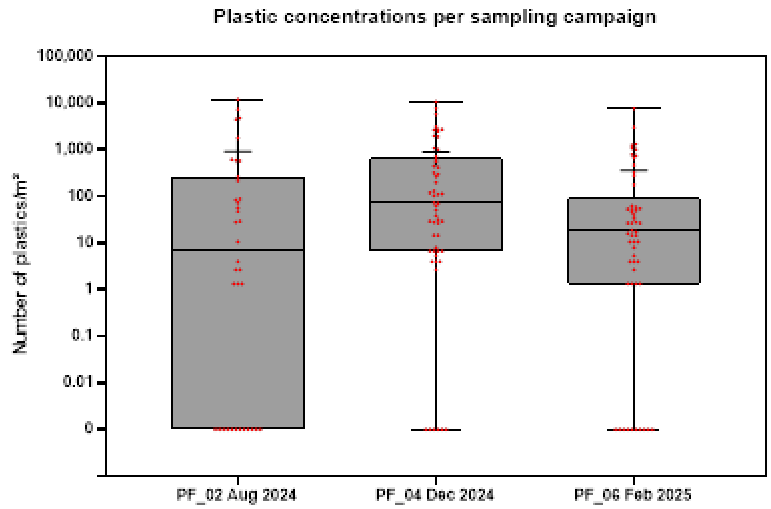


***Fig. 4: Plastic concentrations per sampling campaign**. The graphs show all datapoints (red dots) and boxplots with minimum- maximum range and 5th to 95th percentile whiskers. The x axis represents the campaigns (Augustus 2024, December 2024, February 2025) and the y axis represents the number of items / m^2 (log scale).*

Heterogeneity in plastic concentrations on the riverbanks

Most plastics are found on the same line as the largest volume of tidal deposited materials determined by field observation (**Table 4, Fig. 5**). This means that floating plastics are deposited and accumulate along the riverbanks together with other natural and organic floating materials, resulting in a heterogeneous distribution of plastic on the riverbanks in terms of concentrations between the waterline and the upper part of the riverbank. In Droogdokken, plastic concentrations appeared to show no differences between the maximum tidal accumulation zone and zones below and above this zone. This location in the outer bend of the Scheldt River, appears to be an extensive accumulation zone, encompassing all 3 sampling lines.

Table 4: Descriptive statistics. *Statistics on plastic concentrations (number of plastics / m²) per sampling line (sampling line (line 1 lower on the riverbank (3 horizontal meters in the direction of the river), line 2 with biggest volume of tidal deposited materials, determined by observation in the field, line 3 higher on the riverbank) on six locations along the Scheldt riverbank.*

	LINE 1	LINE 2	LINE 3
Number Of Values	48	48	48
Minimum	0	0	0
25% Percentile	0	7	37
Median	9	125	22
75% Percentile	84	965	111
Maximum	10,749	12,163	5,749
Range	10,749	12,163	5,749
Mean	486	1,262	371
Std. Deviation	1,691	2,559	985
Std. Error of Mean	244	369	142

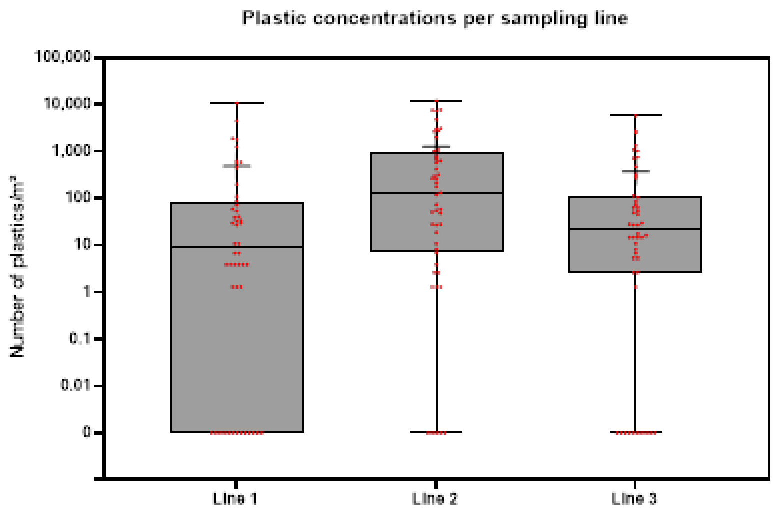


Fig. 5: Plastic concentrations per sampling line. *The graphs show all datapoints (red dots) and boxplots with minimum-maximum range and 5th to 95th percentile whiskers. The x axis represents the sampling lines (line 1 lower on the riverbank (3 horizontal meters in the direction of the river), line 2 with biggest volume of tidal deposited materials, determined by observation in the field, line 3 higher on the riverbank) and the y axis represents the number of items / m² (log scale).*

Despite variations among locations, overall larger-sized plastics remain lower on the riverbank, while smaller mesoplastics and pellets reach higher lines, especially on locations where high vegetation is present on the riverbank (**Fig. 6**). This indicates that larger plastic items can get trapped more easily by an unevenness due to the size, shape, aspect ratio, of the plastic object or due to the riverbanks' structure. As the tide rises, larger plastics are likely to get stuck earlier, while smaller floating plastics remain mobile and stay in the water until high tide is reached. As a result, smaller plastics are deposited higher on the riverbank.

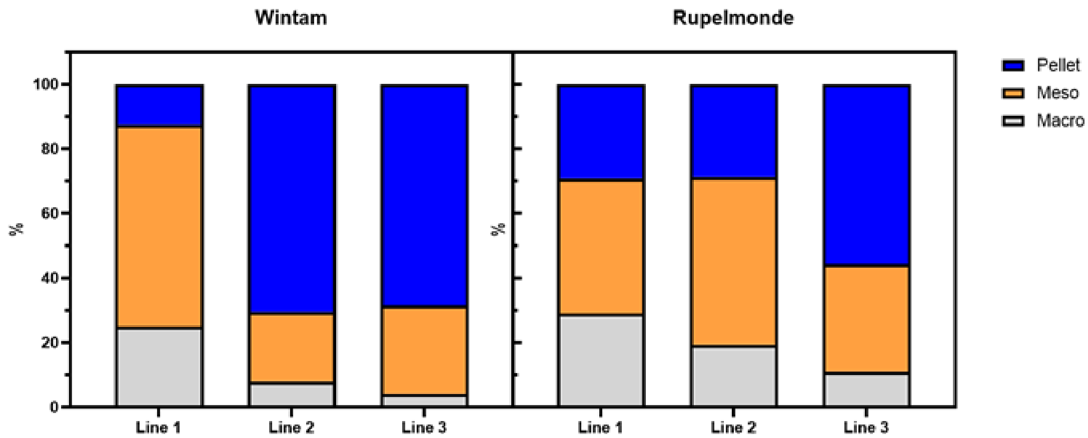


***Fig.6**: Percentages (y axis) of different types of plastics (coloured bars) per sampling lines (x axis) for Wintam and Rupelmonde, both locations with dominantly very high vegetation (reed vegetation and trees).*

Associations between macro-, mesoplastics and plastic pellets

The ratios between the number of beached macro-, mesoplastics and plastic pellets found in each quadrat show that – across all locations – the occurrence of 1 macroplastic is associated with the occurrence of, on average, 5 mesoplastics (95% CI of the mean 3.0-6.3 – median 2.0) and 31 plastic pellets (95% CI of the mean 13.2-49.0 – median 2.3). The ratios varied by site. Remarkably, high ratios were identified in Droogdokken and Galgenschoor (**Table 5**) (**Fig. 7**). The ratios between macro- and mesoplastics suggest breakdown of larger items. The highest ratios between macro- and mesoplastics were identified in Droogdokken, Wintam and Temse 2. The occurrence of 1 macroplastic is respectively associated with the occurrence of 11, 5 and 3 mesoplastics on average (**Table 5**). All three locations are characterised by the presence of boulders, where larger macroplastic might break down faster due to mechanical stress from the movement of the water and the boulders. These results confirm that mesoplastic concentrations are predominantly the result of degradation of macroplastics, which may be retained in and around the area for longer time. It indicates that these locations have trapped plastics already for a long time.

Droogdokken and Galgenschoor showed the highest ratios between macroplastics and pellets. The occurrence of 1 macroplastic is respectively associated with the occurrence of 96 and 29 plastic pellets, on average (**Table 5**). This is likely explained by the proximity to the port where pellet related activities take place, with associated pellet losses and accumulation on the Scheldt riverbanks close to their sources. In Wintam and Temse 2, located further away from the port, ratios with pellets were also high (**Table 5**). In this region, pellets occur either due to losses from any pellet-related activity nearby, or due to asymmetric tidal movements in the Scheldt River that transport plastic pellets upstream from the port.

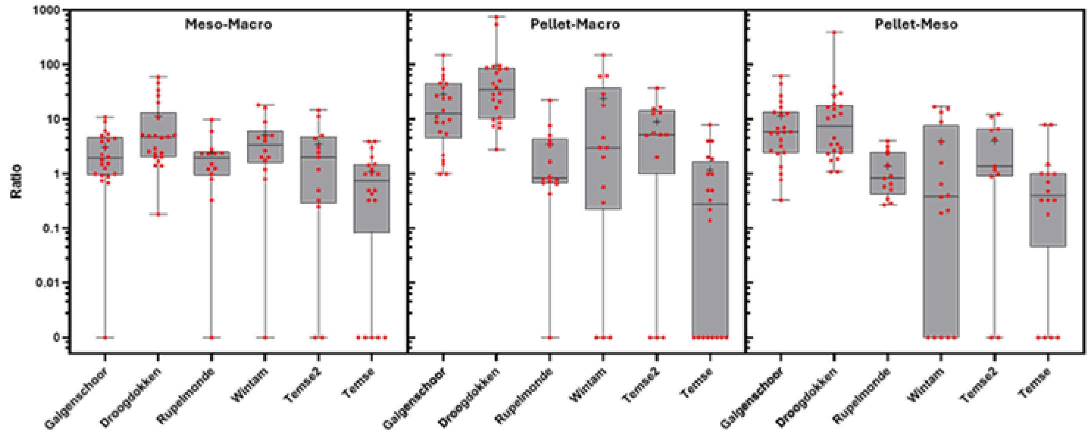


Fig. 7: The ratios between the concentrations of different types of plastic found in each quadrat. *a. between meso- and macroplastic concentrations – b. between pellets and macroplastic concentrations – c. between pellets and mesoplastic concentrations. The boxplots go from minimum to maximum with whiskers showing 5 to 95 percentiles and all datapoints.*

Table 5: Concentration ratios. *The ratios between the concentrations of different types of plastic found in each quadrat for each location*

MESO/MACRO	Galgen schoor	Droog dokken	Rupel monde	Wintam	Temse2	Temse	All locations
N	22	22	14	14	13	20	**105**
Mean	3,08	11,24	2,44	5,14	3,46	1,10	4,65
Median	1,90	4,67	1,92	3,34	2,00	0,75	2,00
Min	0,00	0,18	0,00	0,00	0,00	0,00	0,00
Max	10,96	60,00	9,73	18,20	14,57	3,91	60,00

PELLET/MACRO	Galgenschoor	Droogdokken	Rupelmonde	Wintam	Temse2	Temse	All locations
N	22	22	14	14	13	20	**105**
Mean	28,51	95,94	3,50	24,07	9,05	1,18	31,10
Median	12,67	34,20	0,85	3,00	5,20	0,28	5,20
Min	1,00	2,82	0,00	0,00	0,00	0,00	0,00
Max	151,10	749,00	22,37	152,00	37,00	8,00	749,00

PELLET/MESO	Galgenschoor	Droogdokken	Rupelmonde	Wintam	Temse2	Temse	All locations
N	23	22	13	16	11	16	101
Mean	11,53	28,08	1,38	3,88	4,10	1,43	10,21
Median	5,79	7,48	0,83	0,39	1,38	0,41	2,33
Min	0,33	1,10	0,27	0,00	0,00	0,00	0,00
Max	62,00	391,50	4,00	16,89	12,33	8,00	391,50

Characteristics of the plastics found on the riverbanks

Visual characteristics and occurrence of different polymer types of macro-, mesoplastics and plastic pellets on the Scheldt riverbank (**Figs. 8-12, Table 6**) indicate that *in situ* degradation of macroplastics is the main source for mesoplastics along the Scheldt riverbanks: 75% of the macroplastics and 96% of the mesoplastics observed were fragmented, due to breakdown, either by use before entering the environment or by environmental processes after deposition - colours (white, transparent and yellow) and polymer types (polypropylene and polyethylene) were generally the same for macro- and mesoplastics - sizes were not normally distributed for macro- and mesoplastics. Size distribution of macroplastics (length mean 57.61 mm – median 43.95 mm) and mesoplastics (length mean 14.38 mm – median 13.84 mm) resulted in asymmetrical histograms, especially for macroplastics. This suggests that macroplastics indeed are an important source for the occurrence of smaller mesoplastics. Pellets were commonly white or transparent and mainly consisted of polyethylene, which reflects the production of large numbers of polyethylene in the port of Antwerpen. The presence of plastic pellets reflects the accidental release of pellets handled in and around the port. Macro- and mesoplastics originated from end-of-life waste, while plastic pellets are entering the environment due to pellet losses, caused by industrial and/or logistic pellet related activities.

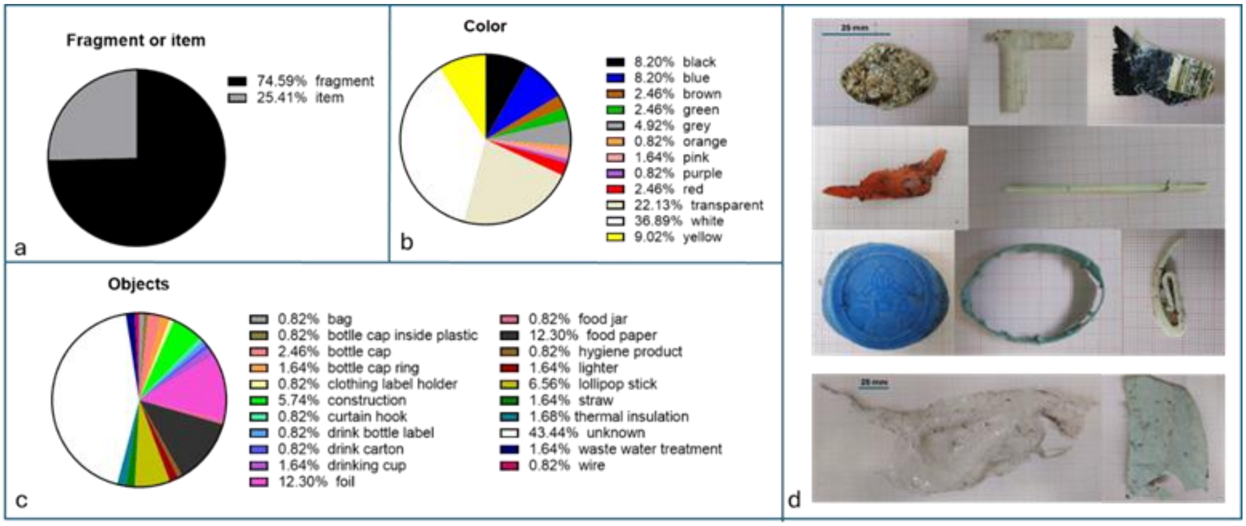


Fig. 8: Visual characteristics of macroplastics on the Scheldt riverbank: *a. percentage of fragments and whole items – b. occurrence of different colours – c. occurrence of different object types or their fragments – d. examples of macroplastics*

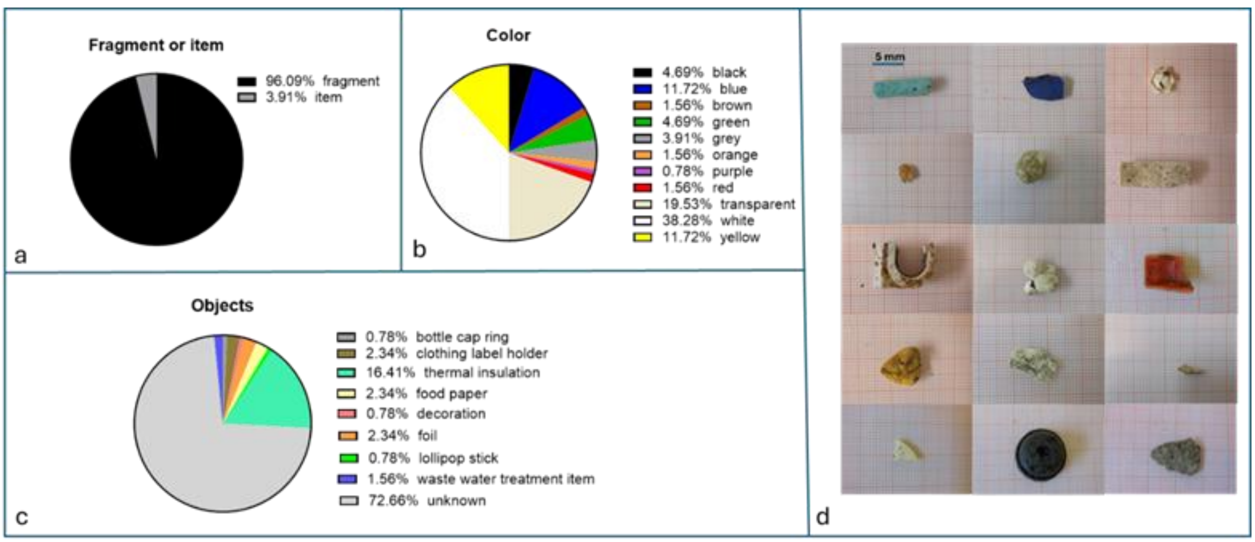


Fig. 9: Visual characteristics of mesoplastics on the Scheldt riverbank: *a. percentage of fragments and whole items – b. occurrence of different colours – c. occurrence of different object types or their fragments – d. examples of mesoplastics*

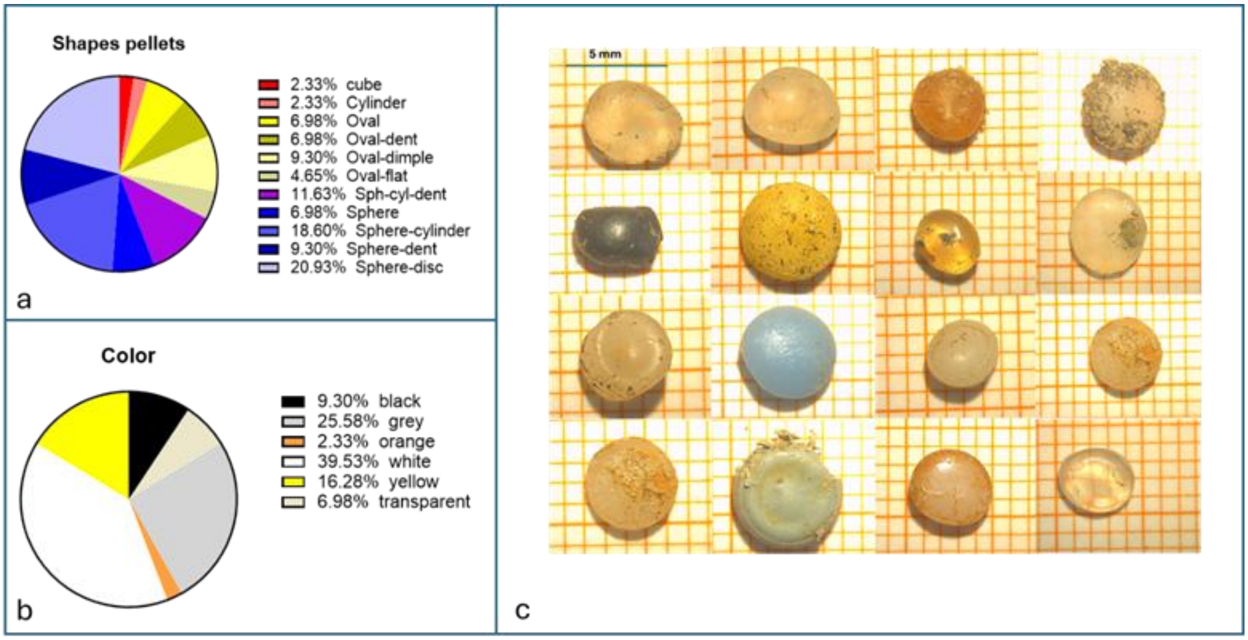


Fig. 10: Visual characteristics of plastics pellets on the Scheldt riverbank: *a. occurrence of different shapes – b. occurrence of different colours – c. examples of plastic pellets*

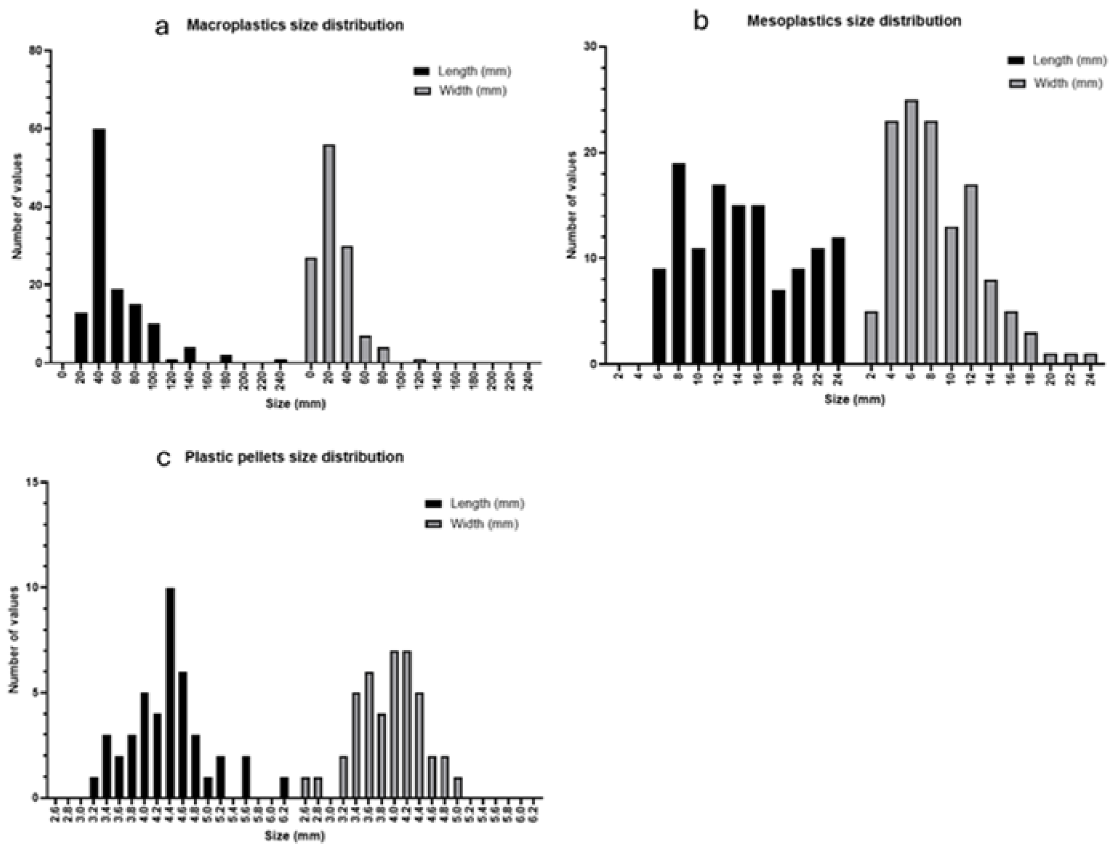


Fig. 11: Plastic items size distribution*: a. macroplastics – b. mesoplastics and c. plastic pellets found on the Scheldt riverbanks.*

Table 6: Descriptives statistics. *Statistics on size distribution of macro-, mesoplastics and plastics pellets found on the Scheldt riverbanks.*

	MACRO		MESO		PELLETS	
	Length (mm)	Width (mm)	Length (mm)	Width (mm)	Length (mm)	Width (mm)
N	125	125	125	125	43	43
Minimum	25.43	0.97	5.13	1.14	3.1	2.62
25% Percentile	33.39	10.95	9.43	5.39	3.96	3.51
Madian	43.95	24.43	13.84	7.63	4.42	3.96
75% Percentile	73.89	35.35	19.05	11.54	4.68	4.30
Maximum	241.75	129.86	24.97	24.55	6.14	5.07
Mean	57.61	26.32	14.38	8.66	4.35	3.93
Lower 95% CI of mean	51.36	22.77	13.39	7.88	4.16	3.77
Upper 95% CI of mean	63.86	29.86	15.37	9.45	4.54	4.09

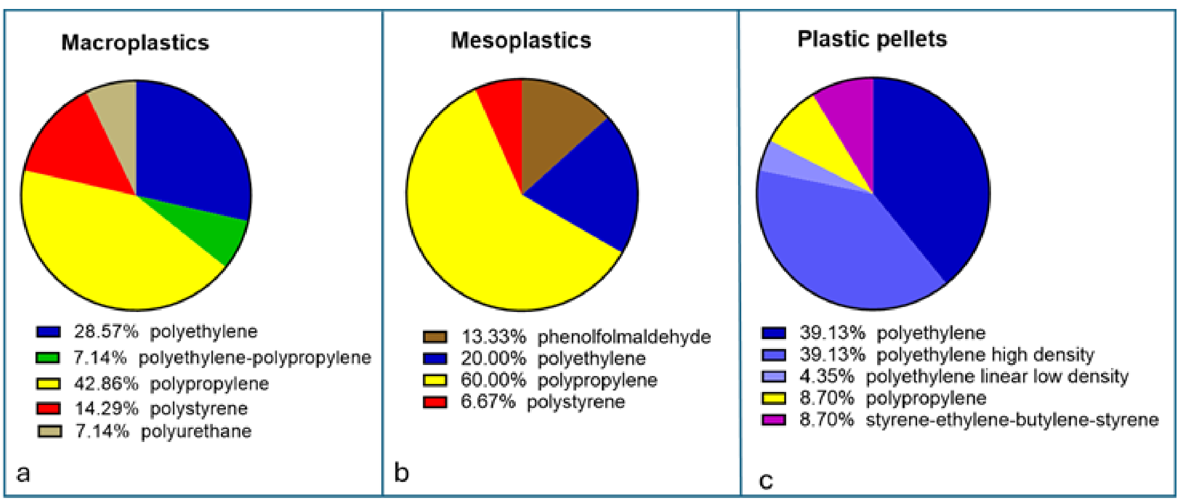


Fig. 12: Occurrence of different polymer types of plastics on the Scheldt riverbank *for: a. macroplastics – b. mesoplastics and c. plastic pellets*

Summary

The presence of pellets is evidence of their loss from industrial activities. In situ breakdown of macroplastics is the main source for mesoplastics along the Scheldt riverbanks. Both mesoplastics and pellets further degrade into microplastics and nanoplastics.

Macro-, mesoplastics and pellet concentrations differed across locations and sampling campaigns. On average, Droogdokken showed the highest pellet concentrations (5,126 pellets / m^2), followed by Galgenschoor (3,131 pellets / m^2) and Rupelmonde showed the highest macroplastic concentrations (194 macroplastics / m^2), closely followed by Droogdokken (121 macroplastics / m^2) and Galgenschoor (115 macroplastics / m^2).

Hotspots for plastic accumulation are typically located close to urban (for macro- and mesoplastics) and industrial areas (for plastic pellets). These hotspots act as a trap for plastics, and are often situated in an outer bend of the river, or close to a physical barrier like a man-made wall or a bridge, that might influence the river flow dynamics.

The observed seasonal patterns with more plastic items (macro-, mesoplastics and plastic pellets) in December, may be explained by the absence of full-grown vegetation and the occurrence of higher tides that may influence the distribution of plastics on the riverbanks. Full grown vegetation in August 2024 and lower tides in February 2025 may have resulted in less plastics on the higher part of the riverbank where sampling took place according to the standardised methodology. This means that it is possible that plastic amounts remained constant, while only the distribution differed.

Macro- and mesoplastics are typically (fragments of) end-of-life waste. Plastic pellets are entering the environment due to pellet losses, caused by industrial or logistic pellet related activities. The magnitude of pellet losses can influence the measured pellet concentrations on the riverbanks, although it is likely that it takes a certain amount of time for pellets to reach the riverbanks. Thus, there will be some delay between increased pellet losses and an increase in pellet concentrations on the riverbank, also depending on other processes which affect the environmental distribution of pellets (e.g. sinking/sedimentation).

Plastics are deposited and accumulate along the riverbanks together with other natural and organic floating materials. Despite variations between locations, overall larger-sized plastics remain lower on the riverbank, while smaller mesoplastics and pellets reach higher lines.

Water Column observations

In Zeebrugge, 14 January 2025, 3 macroplastics were found in 1,890 m^3 of riverbed water (0.0016 macroplastics / m^3 - 0.0597 mg / m^3). No mesoplastics and no plastic pellets were found in the riverbed water and the water column (**Fig. 13, Table 7**). In Schelle and Antwerpen, 9 and 10 April 2025, macro- and mesoplastic concentrations showed the same order of magnitude (mean 2.5 and 2.7 mg / m^3; median 1.7 and 1.6 mg / m^3, respectively), higher than the concentrations measured in Zeebrugge. Only in Antwerpen 9 plastic pellets were measured in the upper net (depth 0 – 0.46 m) of the suspension sampler in 4,000 m^3 of water volume (0.09 mg /m^3) (**Fig. 14, Table 7**).

Table 7: Descriptive statistics. *Statistics on the measured plastic concentrations (macro- and mesoplastics, pellets) (mg / m^3) measured during a tidal cycle in Zeebrugge, Schelle and Antwerpen in the water column and riverbed.*

	Zeebrugge			**Schelle**			**Antwerpen**		
	MACRO	**MESO**	**Pellets**	**MACRO**	**MESO**	**Pellets**	**MACRO**	**MESO**	**Pellets**
Number of samples (N)	8	8	8	4	4	4	16	16	16
Minimum	0	0	0	0.40	0.02	0	0	0	0
25% Percentile	0	0	0	0.55	0.02	0	0.17	0	0
Median	0	0	0	1.69	0.03	0	1.57	0.06	0
75% Percentile	0	0	0	5.79	0.08	0	4.03	0.08	0
Maximum	0.06	0	0	6.94	0.09	0	9.31	0.25	0.09
Mean	0.00	0	0	2.68	0.04	0	2.50	0.07	0.01

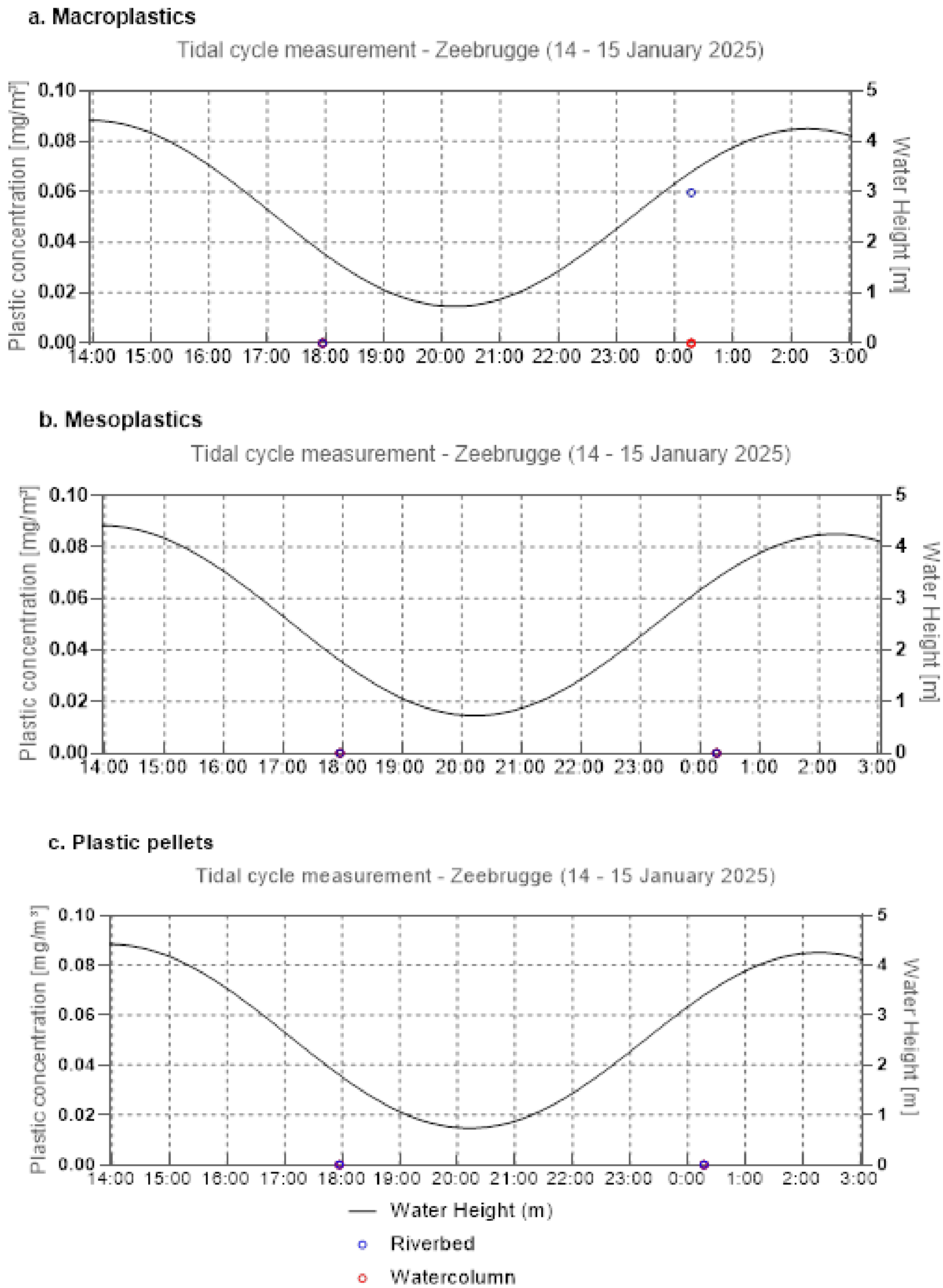


Fig. 13: Plastic concentrations - tidal cycle near Zeebrugge. *Plastic concentrations (macro and mesoplastics, pellets) (mg / m³) measured during a tidal cycle in Zeebrugge. Red circles are measured concentrations in the water column, using a suspension sampler, blue circles are measured concentrations on the riverbed using a bedload sampler.*

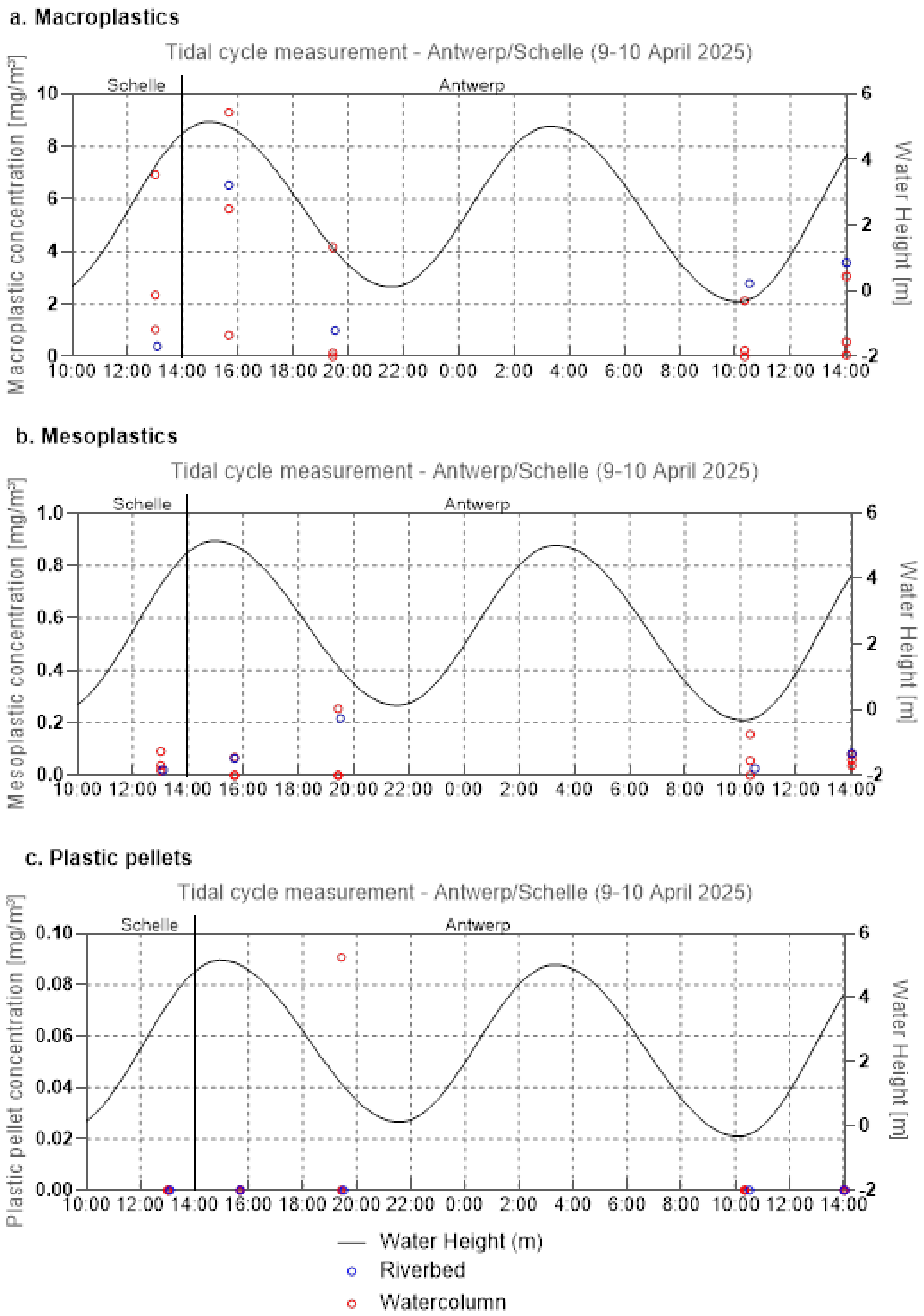


Fig. 14: Plastic concentrations - tidal cycle near Schelle and Antwerpen. *Plastic concentrations (macro- and mesoplastics, pellets) (mg / m^3) measured during a tidal cycle in Schelle and Antwerpen. Red circles are measured concentrations in the water column, using a suspension sampler, blue circles are measured concentrations on the riverbed using a bedload sampler.*

In contrast with the results from the riverbank, in the water column and on the riverbed, higher microplastic concentrations were found compared to mesoplastic concentrations and higher mesoplastic concentrations were found compared to plastic pellet concentrations (**Fig. 15**). On average, higher plastic concentrations were found in the upper part of the water column, compared to the lower parts (**Fig. 15, Table 8**). Higher plastic concentrations were found in the Scheldt River (Schelle and Antwerpen), compared to the North Sea (Zeebrugge) (**Fig. 16, Table 9**).

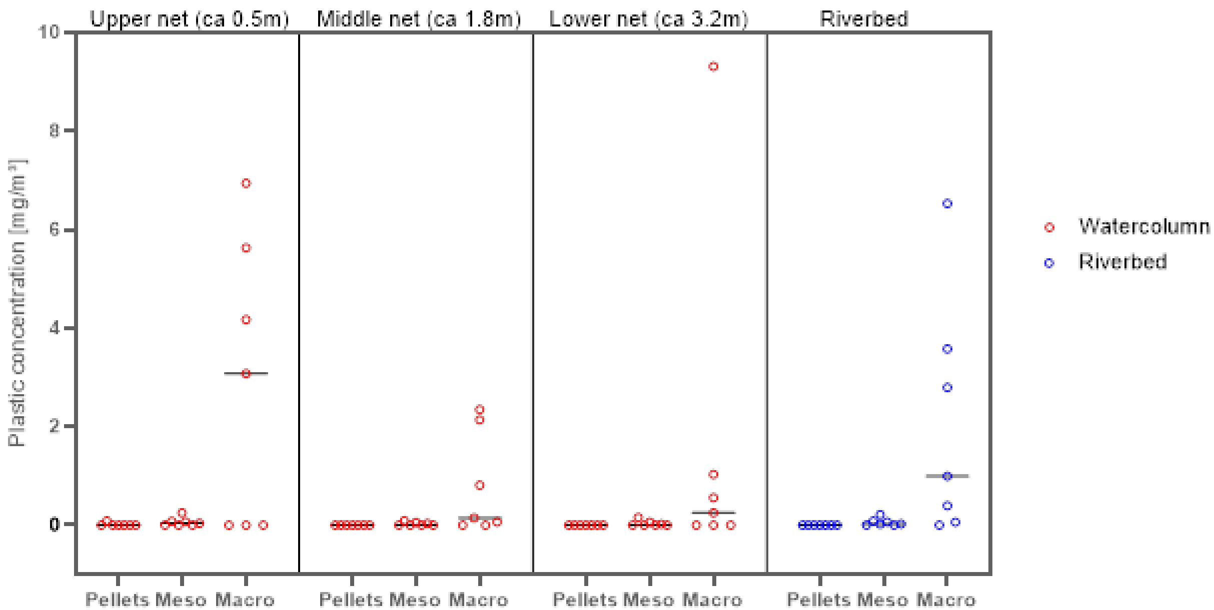


Fig. 15: Plastic concentrations in the water column. *Plastic concentrations (plastic pellets, mesoplastics and macroplastics) in the water column (suspension sampler) and on the riverbed (bedload sampler). Each dot represents the concentrations of plastics in mg / m^3, the black line represents the median.*

Table 8: Descriptive statistics. *Statistics on the occurrence of plastic concentrations (plastic pellets, mesoplastics and macroplastics) in the water column (suspension sampler) and on the riverbed (bedload sampler) in mg / m^3.*

Plastic concentrations (mg / m^3)	Upper net (0.5m)	Middle net (1.8m)	Lower net (3.2m)	Riverbed
Number of samples (N)	7	7	7	7
Minimum	0	0	0	0
25% Percentile	0	0	0	0
Median	1.1	0.1	0.1	0.4
75% Percentile	1.9	0.7	0.3	1.2
Maximum	2.3	0.8	3.1	2.2
Mean	1.0	0.3	0.5	0.7

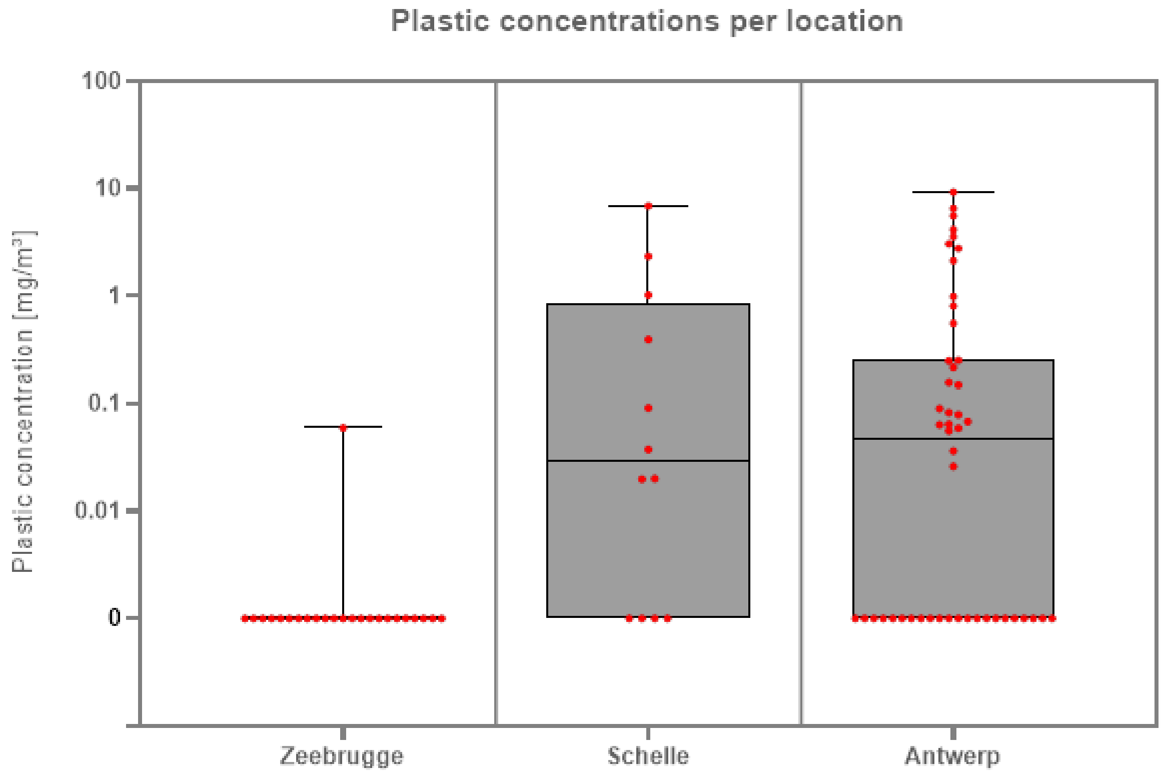


Fig. 16: Plastic concentrations per location. *Plastic concentrations (macro, mesoplastics and plastic pellets) measured in the water column (suspension sampler) and on the riverbed (bedload sampler) per location. Each dot represents the measured plastic concentration (mg / m^3), the box plot goes from minimum to maximum and represents the median, with interquartile ranges.*

Table 9: Descriptive statistics. *Statistics on the occurrence of all plastic items in the water column (suspension sampler) and on the riverbed (bedload sampler) per location in mg / m^3*

Plastic concentrations (mg / m^3)	**Zeebrugge**	**Schelle**	**Antwerpen**
Number of samples (N)	24	12	48
Minimum	0	0	0
25% Percentile	0	0	0
Median	0	0.0	0.1
75% Percentile	0	0.9	0.3
Maximum	0.1	6.9	9.3
Mean	0.0	0.9	0.9

Summary

This section documents plastic pollution measurements taken from the water column and riverbed at three locations: Zeebrugge, Schelle, and Antwerpen, in early 2025. Overall, the Scheldt River locations (Schelle and Antwerpen) showed significantly higher total plastic concentrations than the North Sea location (Zeebrugge). Furthermore, the analysis indicates that plastic concentrations tend to be greatest in the upper parts of the water column compared to lower depths or the riverbed, and larger plastic types generally show higher concentrations than smaller pellets, except when compared to microplastics (which are mentioned separately). The total mean number of macro- and mesolitter, and pellets, observed in this study varied between 0.3 and 0.5 mg / m^3 for the medium and lower nets, comparable to the mean numbers observed during the previous baseline studies (c.a. 0.3 mg / m^3) (Everaert et al., 2022).

Macroplastics transport modelling

The macroplastics transport modelling in the Scheldt Estuary was developed by IMDC.

Objective and methodology

The goal of this work's component was to determine the yearly macroplastic flux from the Scheldt to the sea. This was done by using a combination of observational data and model results. Determining the plastic flux is a challenging task, given the number of uncertainties and scarcity of the available data on plastic in the Scheldt. These uncertainties related first of all with the need for a large number of parameters as input or calibration data, which are currently not always available. The most important missing data in this work is related to the amount of macroplastics objects entering the estuary as well as their spatial distribution.

To determine the flux of macroplastics, the following methodology (Wang et al., 2025) was used:

- An analysis of the sampling data was performed, to determine the different kinds of plastics in the Scheldt. Hereby, the classification of plastic objects was done based on their expected hydrodynamic behaviour:
    - floating (typically plastic objects of a material less dense than water),
    - suspended (i.e., plastics such as fragments of plastic bags with a negligible settling velocity),
    - sinking (typically with plastic with a density larger than water).

- A model simulation was done using a 3D macroplastic model of the Scheldt with the objective to determine the fate of the plastic objects of the three different categories above. In particular, the aim was to determine:
    - The plastic fluxes (as a percentage of the initial plastic present in the model) through three predefined transects,
    - The resulting plastic distribution (hotspots) in the estuary.

- To estimate the plastic flux using an estimation based on the model results as well as on the measured plastic concentrations in the estuaries.

Model setup

Hydrodynamic model setup

In this chapter a TELEMAC-3D model of the Scheldt was used. The model contained the full tidal part of the Scheldt estuary, including the different upstream branches (**Fig. 17**). It used 143,872 calculation points in the ground plain forming 260,595 triangular elements with a spatial resolution that varies between 300 m at sea, 150 m in the Wester Scheldt to a very high resolution (order of 10 m) in the upstream branches. Five vertical nodes were considered in the model, which were refined near the bed of the model.

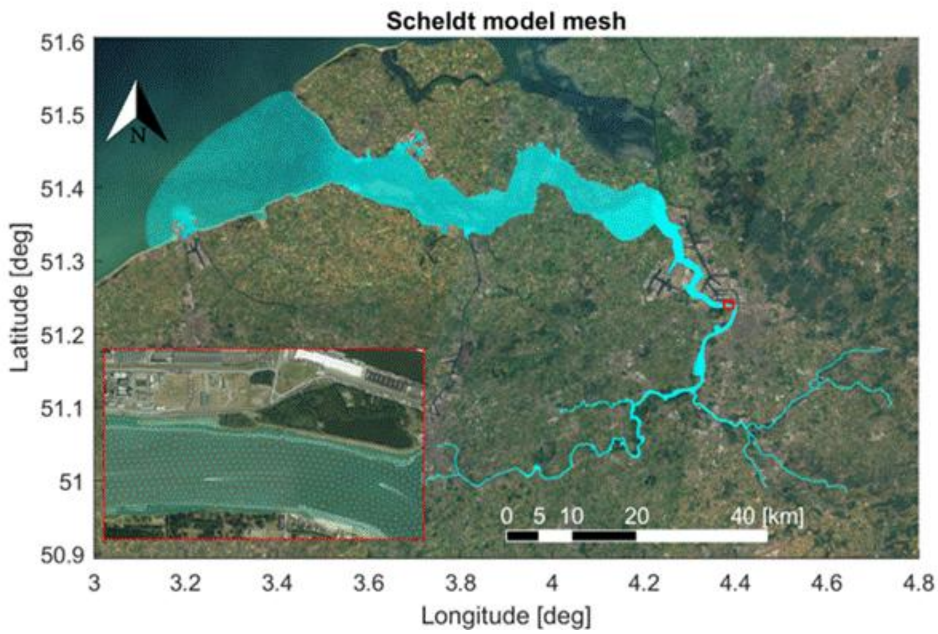


Fig. 17: Scheldt model mesh. *Computational mesh of the Scheldt Model.*

The model considered all relevant hydrodynamic processes, namely flow due to tides, as well as due to the wind, and it takes the effect of the salinity on the baroclinic pressure gradient into account. The turbulence was modelled using the k-epsilon from the GOTM turbulence model (Burchard et al., 1999), which was coupled to TELEMAC by Lanckriet et al., 2018. For the boundary conditions at sea, water level and velocity data from the IMDC's continental shelf model of the North Sea were used (Chu et al., 2022a, Chu et al., 2022b), whereas observed river discharge data from *http://www.waterinfo.be* were used for the upstream boundary conditions of the model. The wind data in the model come from the ERA-5 meteorological model.

The model was calibrated using automatic calibration on bottom friction, with typical root mean square errors (RMSE) for the water levels of around 10 cm in the Western Scheldt (Chu et al., 2022c) and lower than 15 cm in the Lower Sea Scheldt. Extensive validation using measured ADCP velocities was also performed (Chu et al., 2022c).

Setup of the plastic module

The plastic model is based on a particle tracking algorithm, in which the motion of plastic objects depends on the flow and turbulence, settling and rising effects, windage effects (for particles floating at the surface), interaction of particles with the bed (i.e. the application of a critical velocity before a plastic at the bed starts moving). Beaching and resuspension were handled implicitly by the model, where it was assumed that plastic does not move in water depth less than 1 cm. Effects of breakage as well as biofouling were not considered. The plastic model was validated using the GPS and acoustic data from the observation in PLUXIN (Breugem et al., 2023), where it was found that the large-scale patterns in the plastic distribution were reproduced by the model.

In the current project, the model was run for six different classes of plastics: floating objects, suspended sheet-like objects (such as fragments of plastic bags), and sinking plastic objects, for which macro plastics (size > 25 mm) and mesoplastics (size between 5 mm and 25 mm) were simulated. These six classes correspond to the samples collected in the measurement campaign of April 2025, conducted by University of Antwerp, which are classified as floating macro- and mesoplastics caught by the upper net, suspended macro- and mesoplastics caught by the middle and lower nets, and bottom macro- and mesoplastics caught by the bedload sampler cage. Because it is presently not accurately known how much plastic enters the Scheldt and at which locations, the model was used to study the dispersion of the plastics, and in particular the percentage of plastics moving out to the North Sea. To do so, the plastics were homogeneously distributed in the Belgian part of the Scheldt Estuary during the first day of the simulation. It was chosen to release the plastic particles at regular time instances, to limit the effect of the initial conditions (in particular, the influence of the tide at the moment of the release). The number of particles was taken large enough such that statistically converged results of the plastic distribution could be obtained. The simulation was run for 100 days using realistic conditions of discharge and wind.

Model results

The model was used to determine the plastic distribution in the Scheldt. **Fig. 18** gives an example of the spatial distribution of plastic particles at the beginning and after 100 days. The plastic concentration in the model is shown in **Fig. 19**. Only the macroplastics were shown, since the model provided very similar results for the mesoplastic particles. The results show that the highest plastic concentration can be found upstream in the estuary. More downstream, the larger area and depth of the estuary lead to a dilution of the concentrations. The sinking plastics seem to get caught in the Western Scheldt and hardly reach the sea. This is likely to be due to the residual circulation due to the salinity gradient in the estuary, which near the bed is directed inland. Furthermore, in the Wester Scheldt we can expect the highest concentrations near the banks, and in the harbour of Vlissingen, which seem to be a sink of plastics. The sheets and the floating plastics show a similar behaviour and can reach the sea.

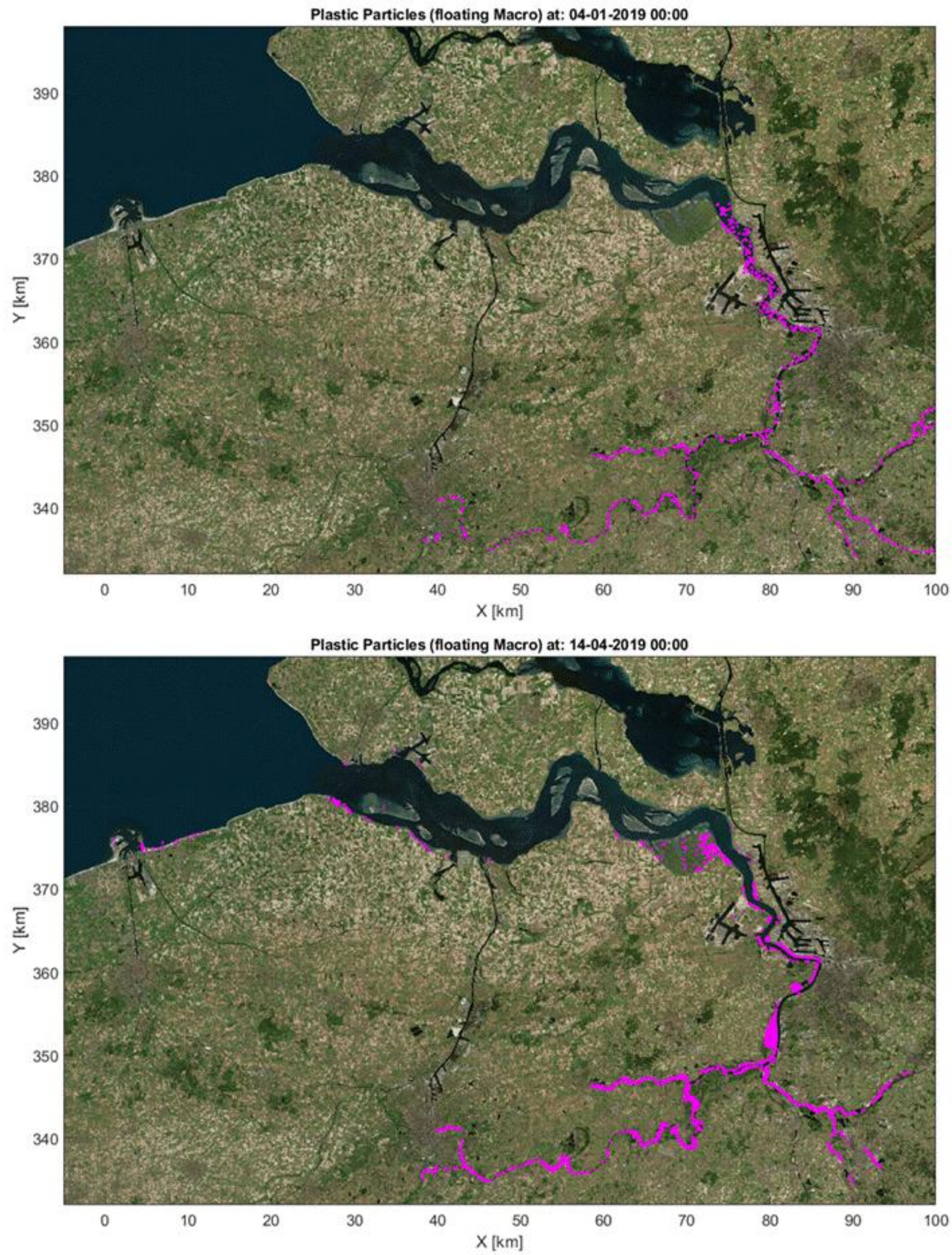
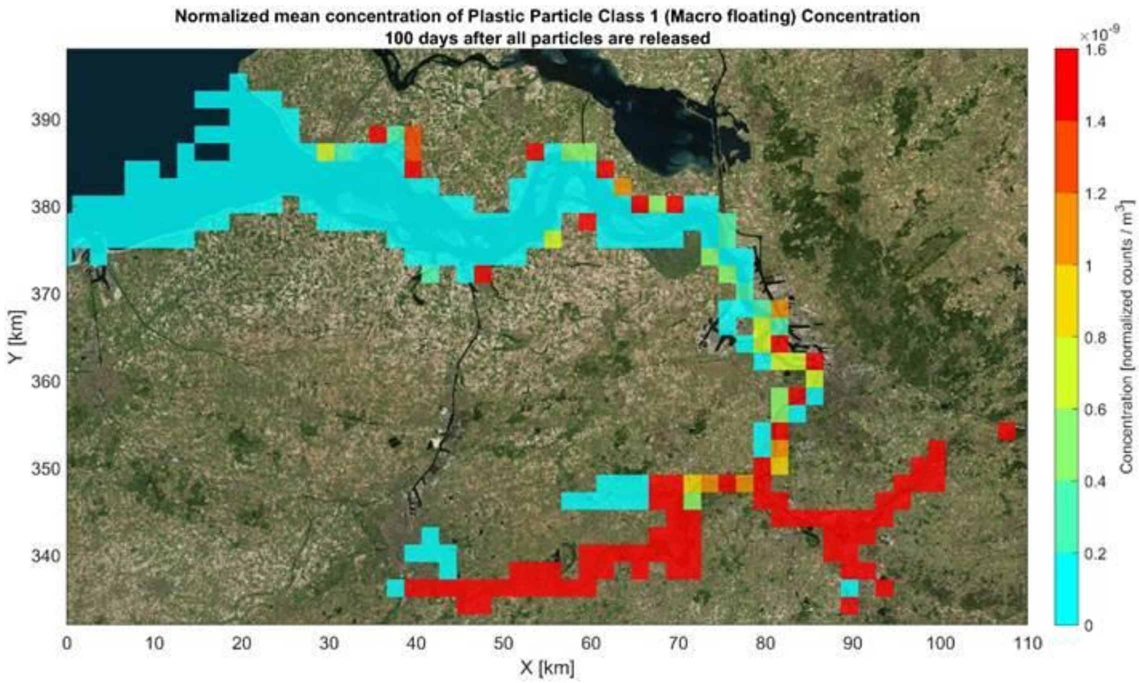
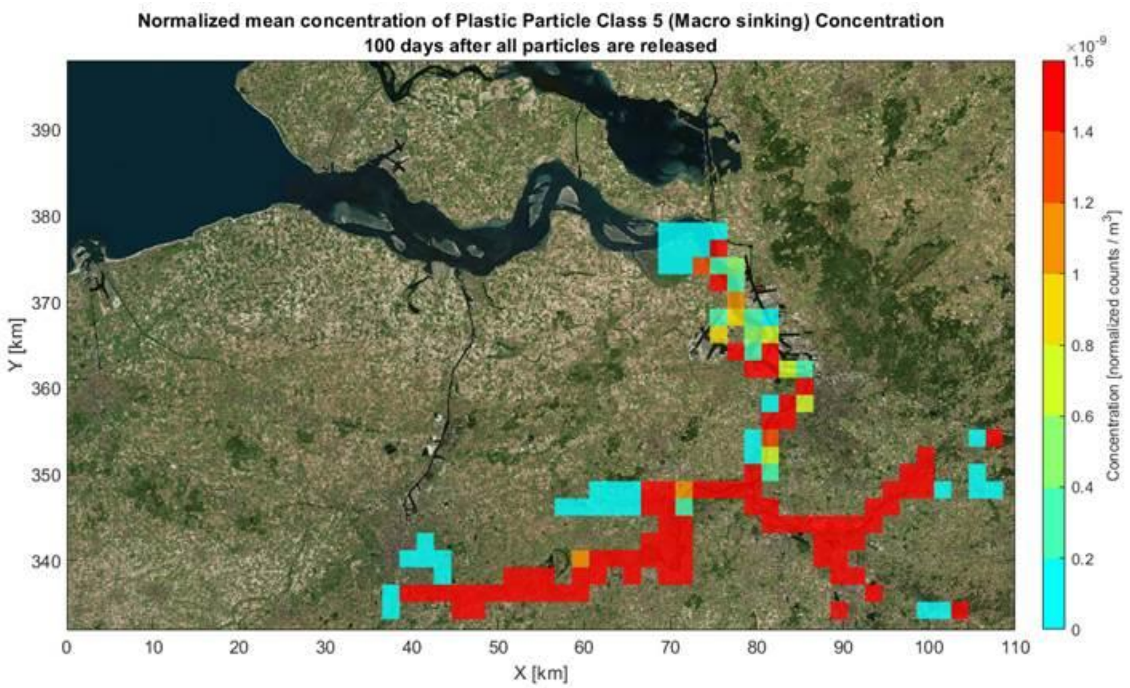


Fig. 18: 2 Plastic particle maps. *Maps of the plastic particles for the class of floating macro plastics at the beginning of the simulation and after 100 days.*



Normalized mean concentration of Plastic Particle Class 1 (Macro floating) Concentration
100 days after all particles are released
Y [km]
X [km]
Concentration [normalized counts / m³]
×10⁻⁹



Normalized mean concentration of Plastic Particle Class 5 (Macro sinking) Concentration
100 days after all particles are released
Y [km]
X [km]
Concentration [normalized counts / m³]
×10⁻⁹

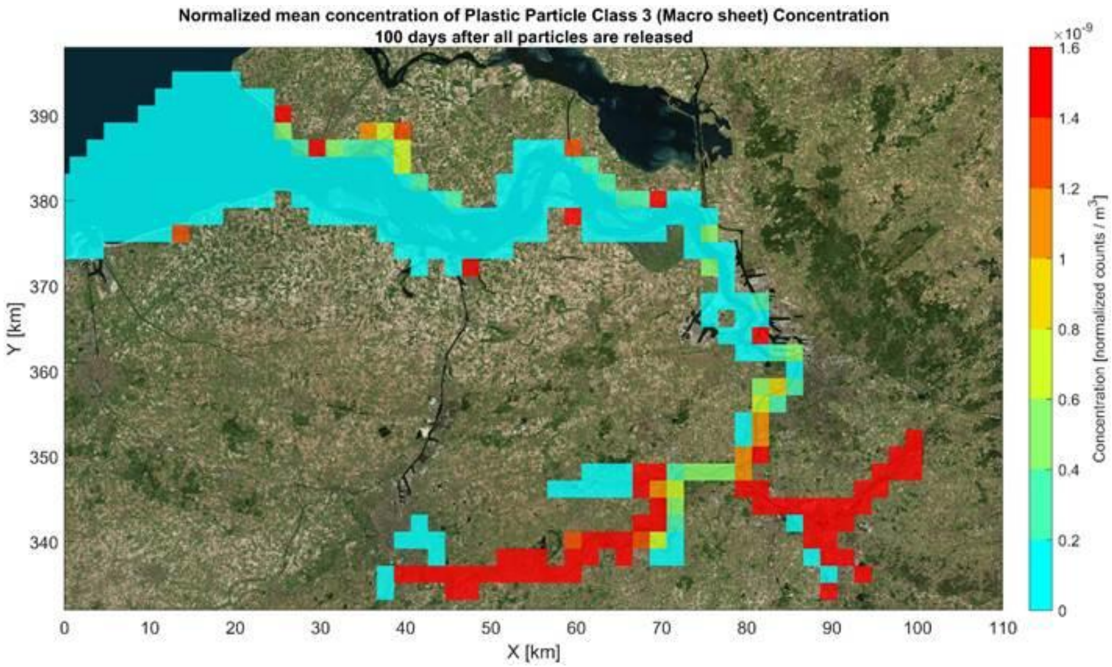


Fig. 19: Plastic number density maps. *Maps of the plastic number density calculated by the model for the different classes of macro plastics after 100 days.*

The normalised time series of the cumulative plastic fluxes are shown in **Figs. 20-22** for transects in Vlissingen (close to the mouth), Doel (halfway in the estuary close to the border) and Wintam (upstream). The location of the three transects could be found in the figure below (**Fig. 23**).

Table 10: *Percentage (%) of the released particles passing through the transect in the model after 100 days.*

	Cumulative Flux Wintam	Cumulative Flux Doel	Cumulative Flux Vlissingen
Floating (MESO)	4	12	8
Sheets (MESO)	1.3	16	15
Sinking (MESO)	0.9	2.8	0
Floating (MACRO)	3.5	10	6.4
Sheets (MACRO)	1.4	16	15
Sinking (MACRO)	0.4	1.5	0

The normalised flux is the net number of particles that have crossed the transect divided by the initial number of particles introduced in the model. This variable indicates the total amount of plastic that has crossed a transect, and its slope indicates the instantaneous flux with a higher slope denoting a stronger flux. For brevity, only the results for the macroplastics objects are shown. The results were determined once a day, meaning that short (tidal) time scale variation in the flux is not visible in the results. The results indicate that the suspended and floating plastics are much more mobile than the sinking ones. As already seen in the concentration maps, the sinking plastics do not reach the sea under normal conditions (Vlissingen). With respect to the mobility, it seems that the suspended plastics are more mobile as the floating ones, which more easily can get stuck on wetlands. This beaching processes is sensitive to the used parameters and therefore add to some uncertainty in the results. In the suspended plastics at Vlissingen, there is a wave pattern in the time series of the flux. This is because these particles tend to move in and out the estuary. A similar process can be seen at Wintam, where both the suspended and the floating plastics show a period in which there is downstream or upstream motion of the plastics.

A first estimate of the macroplastic flux in the Scheldt

Based on the available measurement data and model results, an estimation was made of the plastic flux in the Scheldt. There is a large uncertainty associated with this estimate, coming from model uncertainties and the very limited amount of available data thus making the model setup, calibration and validation very difficult, despite the huge efforts in collecting those data in this and previous projects. The nature of plastic observations is such that it is extremely hard to have a sufficient spatial and temporal coverage. This kind of measurement tends to show a large variability in the plastic concentrations, thus adding to the uncertainty in the results. In the following tables averages are presented taken over all available data in the 2025 dataset, without differentiating to different sampling locations and different measurements periods, to have the largest amount of data available.

The model results are summarised in **Table 10**, showing the percentage of the released particles that have passed the different transects after 100 days. This percentage was calculated for each class. This period was chosen, because an equilibrium occurs in the flux in this period. For the release to the sea, most important is the percentage passing through Vlissingen. From the model results, about 15% of the sheets and 6% of the floating macroplastics pass through this transect.

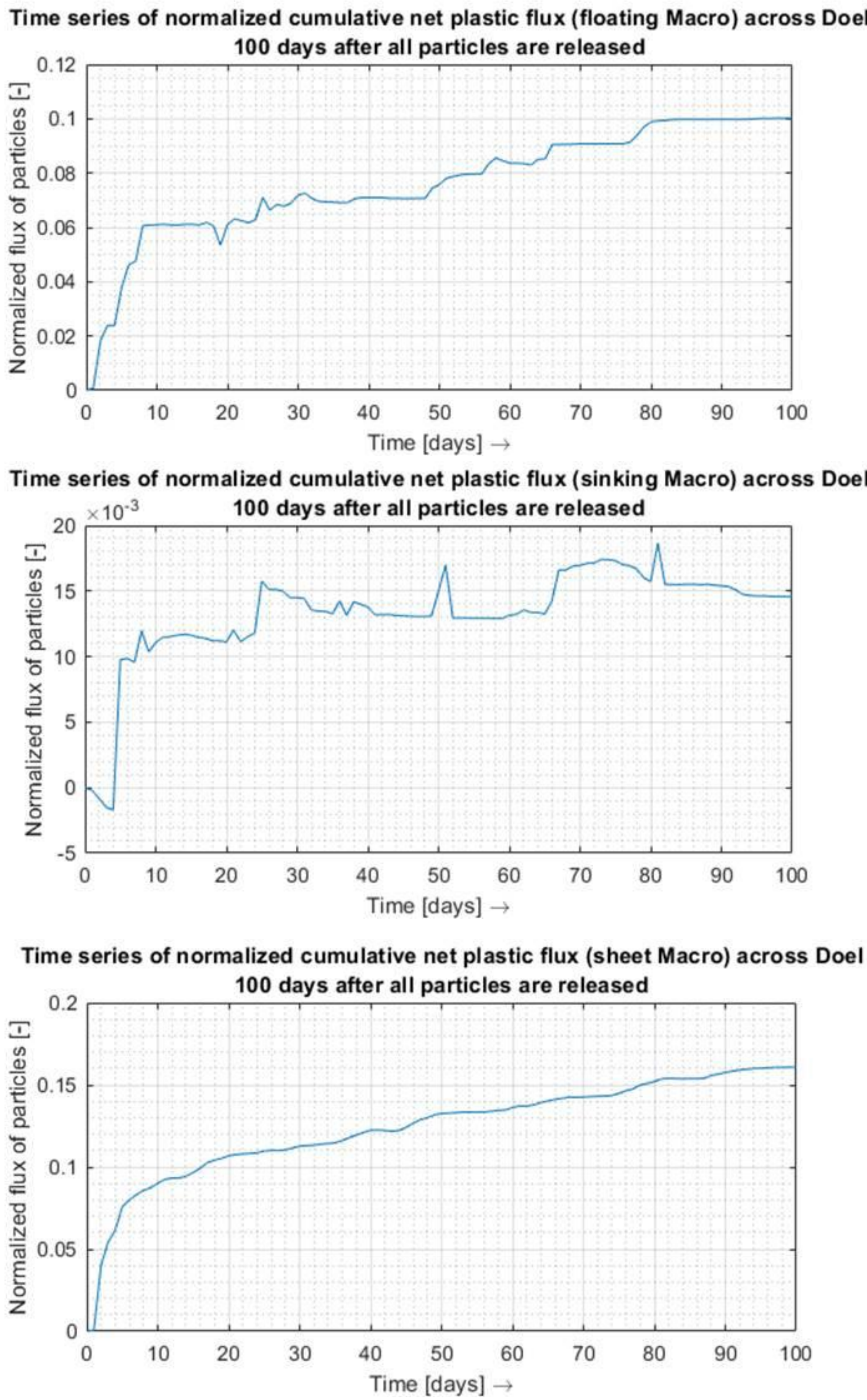


Fig. 20: Time series net plastic flux at Doel. *Normalised plastic flux in the model at Doel (near the border with the Netherlands) as function of time for three different classes of macro plastics. Warning: the axis scale differs for the different classes.*

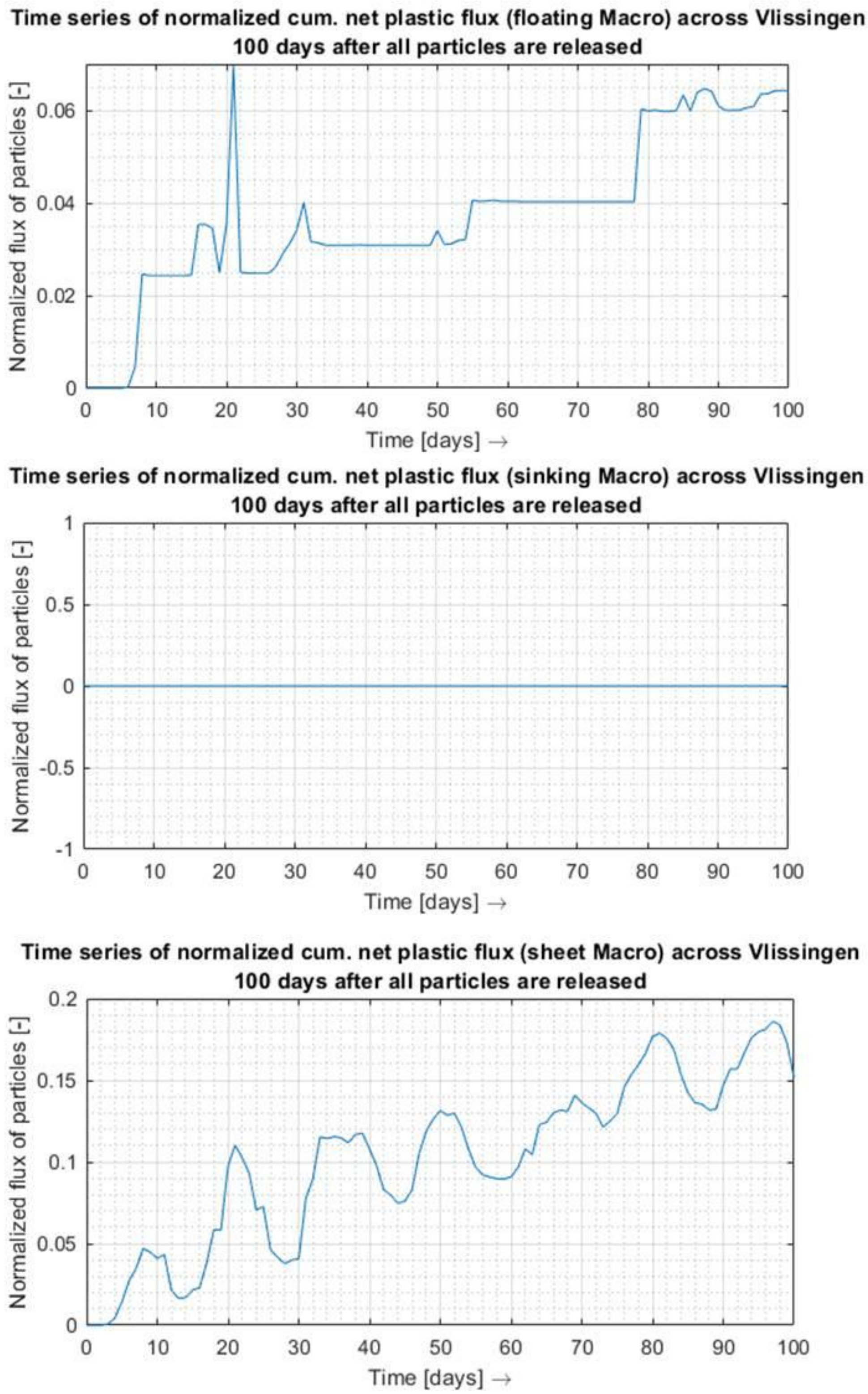


Fig. 21: Time series net plastic flux at Vlissingen. *Normalised plastic flux in the model at Vlissingen (downstream) as function of time for three different classes of macro plastics. Warning: the axis scale differs for the different classes.*

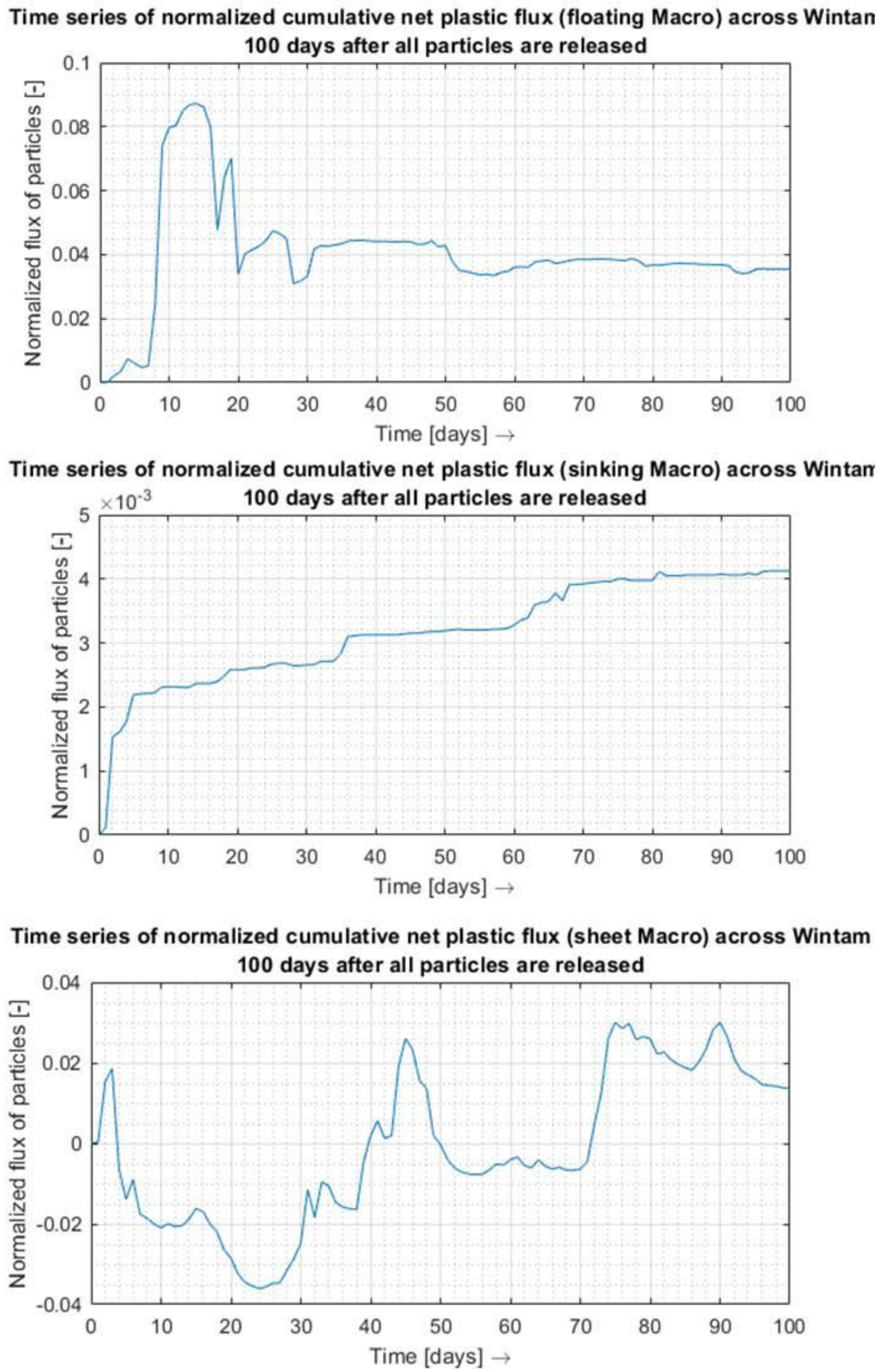


Fig. 22: Time series net plastic flux at Wintam. *Normalised plastic flux in the model at Wintam (upstream) as function of time for three different classes of macro plastics. Warning: the axis scale differs for the different classes.*

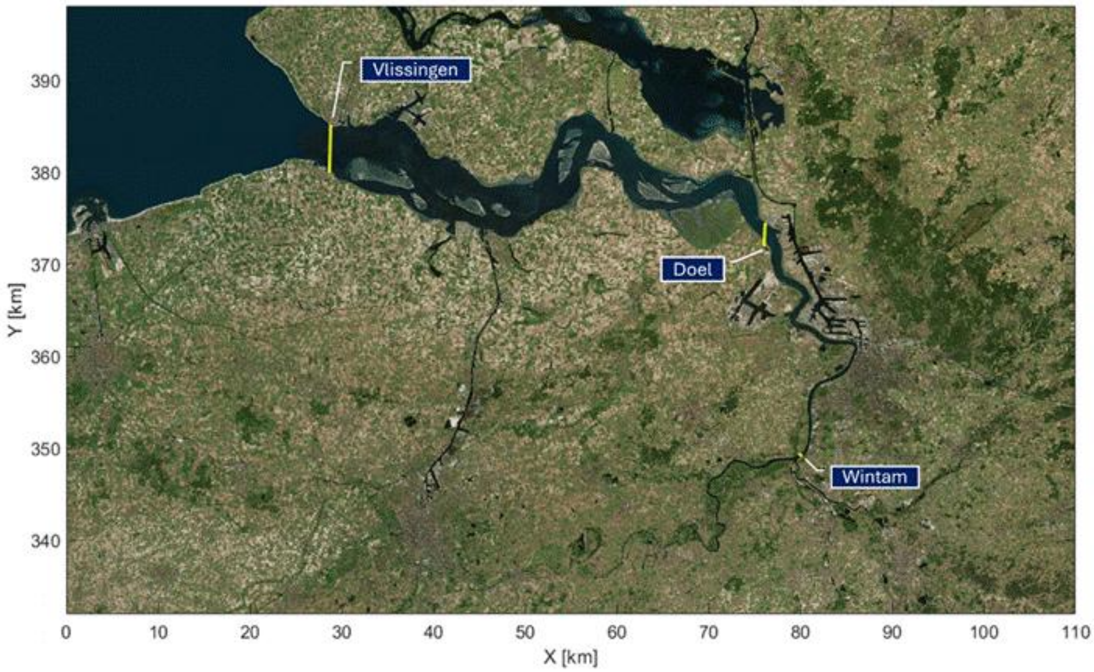


Fig. 23: Transect locations. *Location of the three transects to determine the cumulative plastic fluxes.*

The observed plastic concentrations are shown in **Table 11** for the different hydrodynamic plastic classifications. In generating this table, it was assumed that the particles in the near-surface nets from the measurements were floating ones, the ones in the bedload samplers (from the measurements) the sinking ones, and the other nets (from the measurements) the suspended ones and the corresponding weights were used from the datasets. A cross comparison with the characteristics of the individual plastics showed a similar distribution over the different classes. Based on the dimensions of the suspended nets and the bottom sampler cage deployed in the water column, together with the modelled flow velocities at the position of the different samplers, the corresponding total water volumes (necessary for calculating the concentrations) passing through each sampler could be derived for the respective sampling durations. From the measurement results, it appears that only a small part of the plastics (by mass) consists of mesoplastics (about 3%). Of the macroplastics, more than half of it (by mass) consist of sinking particles, which is probably due to the heavier weights of these plastics in the collected samples. This an interesting contrast to the previous project (2020-2022), where most of the report macroplastics were reported to be sheet like. However, the total plastic concentration (10 g per 1,000 m^3) is in line with the results reported from the 2020-2022 measurement campaign (between 1 and 10 g per 1,000 m^3). Given the uncertainties that lie in the observed concentrations these results can easily change to a factor of 10. To reduce these uncertainties more measurements are required.

Table 11: Observed plastic concentration [g per 1000 m³]

Plastic Class	Concentration [g per 1000 m³]	Mass Percentage
Floating (MESO)	0.12	1.2%
Sheets (MESO)	0.065	0.6%
Sinking (MESO)	0.11	1.1%
Floating (MACRO)	3.2	31.5%
Sheets (MACRO)	2.2	21.2%
Sinking (MACRO)	4.5	44.4%

An estimation of the total fluxes was obtained by estimating the total amount of plastic in the Belgian part of the Scheldt, using concentration and water volume for each of the plastic classes and multiplying it with the percentage of these plastics that crosses the transects in a hundred day period from the plastic model results and then rescaling to a full year period (**Table 12**). Note that the largest contribution of the flux to the sea comes from the suspended plastics (sheet-like object) and that sinking plastics, even though they seem to consist of the largest part of the plastics, are unlikely to reach the sea. It may be clear that this estimate has a large uncertainty, which is inherent to this type of research.

Table 12: Yearly plastic flux (metric tonnes per year) combined model results and observations

	Wintam	Doel	Vlissingen
Floating (MESO)	5.E-03	2.E-02	1.E-02
Sheets (MESO)	9.E-04	1.E-02	1.E-02
Sinking (MESO)	1.E-03	3.E-03	0.E+00
Floating (MACRO)	1.E-01	4.E-01	2.E-01
Sheets (MACRO)	3.E-02	4.E-01	4.E-01
Sinking (MACRO)	2.E-02	7.E-02	0.E+00
Total	2.E-01	8.E-01	6.E-01

Summary

The PLASTFLOW modelling results show that plastics do move through the Scheldt Estuary and into the North Sea, although the exact quantities remain highly uncertain due to limited measurements and measurement coverage in time and space, strong variability in observed concentrations, and remaining model limitations.

The model indicates that only a share of plastics is mobile enough to reach marine waters: approximately 15% of sheet-like plastics (valid for meso and macrolitter), 6% of floating macroplastics, and 8% of floating mesoplastics are estimated to cross the Vlissingen transect, while sinking plastics, despite being the dominant mass in measurements, largely remain within the estuary system. Combining modelling and monitoring data suggests that the total macro- and mesoplastic flux export to the North Sea is approximately 0.6 tonnes per year, though this value includes high uncertainty. These insights provide some first indication but underline the need for continued monitoring, expanded datasets, and further research to support informed progress toward the Flemish objective of reducing land-to-sea plastic leakage by 75%.

Drone Observations of Macro- and Mesolitter, and Pellets

Within the PLASTFLOW project, drone-based observations, done by VITO in collaboration with UAntwerp, were used to estimate the amount of macrolitter at a site also surveyed in situ by the University of Antwerp team. These observations serve as a potential proxy for assessing the abundance of plastic pellets and for quantifying terrain characteristics, such as slope, vegetation density, and vegetation height, that may influence pellet retention. The Galgeschoor site was selected because it is known to contain high concentrations of macro-, meso-, and microplastics, as well as diverse terrain features including stones, grass, and both low and high vegetation.

All drone operations adhered to standard flight protocols, which included flying at 12 m above take-off, maintaining an 80% lateral and longitudinal overlap, and setting a flight speed slow enough to ensure a maximum ISO of 400 was reached for each captured image. The surveys produced high-resolution visual data of the study area, enabling consistent and objective identification of visible litter items not obscured by natural cover. Two drone flights were conducted, each using a different payload: a high-resolution RGB camera (Zenmuse P1) and a 12-band multispectral camera (MicaSense Dual RedEdge-P). Flights were carried out at an altitude of 12 m above the roadside (**Table 13**), corresponding to 17 – 20 m above the Galgeschoor terrain, resulting in a Ground Sampling Distance (GSD) of approximately 0.25 cm for the RGB imagery and 1 cm for the multispectral data.

Table 13: Campaign specifications. *Summary of Unmanned Aerial Vehicle (UAV) flight campaign parameters, detailing the date, flight altitude, payload and number of spectral bands for each survey.*

Date	Time	Height (m)	Camera	Number of Bands
04/12/2024	11:46 - 12:26	12	Zenmuse P1	3
	12:47 - 13:33	12	MicaSense Dual RedEdge-P	12

Data processing

The collected drone imagery was processed and analysed through a structured workflow combining geospatial data preparation, AI-based object detection, and result aggregation.

Data Preparation and Quality Assurance

Raw drone images from each flight were processed using the MAPEO software, developed at VITO, to generate orthomosaics (i.e. geometrically corrected aerial images) provided as GeoTIFF files. Each orthomosaic underwent visual inspection to ensure image quality and GDPR compliance, with any identifiable personal data (e.g. people, license plates) masked or removed. The validated images were then georeferenced and clipped to the relevant spatial extent.

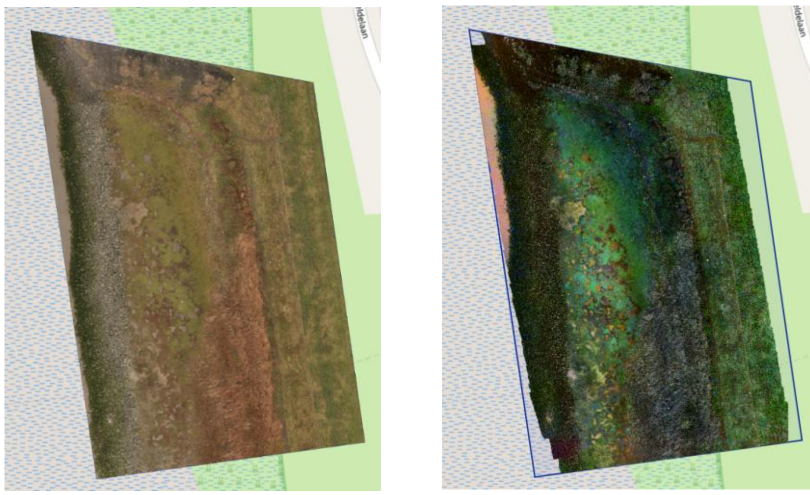


Fig. 24: Orthomosaics generated by stitching drone-captured imagery. *The left panel shows the high-resolution RGB orthomosaic, while the right panel displays the multispectral orthomosaic, visualised using a combination of three selected spectral bands for clarity.*

AI-Based Macrolitter Detection

The orthomosaics were used as input for an automated litter detection workflow (**Fig. 24**). To facilitate efficient processing, each orthomosaic was divided into smaller image tiles, which were analysed using the YOLOv11m object detection model. This lightweight neural network architecture was selected for its optimal balance between detection accuracy and computational efficiency. The YOLOv11m model was pre-trained using a knowledge distillation approach, where a larger Vision Transformer model (DINOv2) acted as a teacher network to enhance general visual feature understanding. This method improved the model's robustness and ability to generalize across varying environmental conditions. The model was subsequently fine-tuned using drone imagery collected from several sites along the River Scheldt to ensure accurate detection of visible litter items under diverse lighting and surface characteristics. Following detection, all outputs were recombined and mapped back onto the original orthomosaics. The results include bounding boxes indicating individual litter items, which can be further processed into centroids or heatmaps for spatial analysis of litter density (**Fig. 25**).

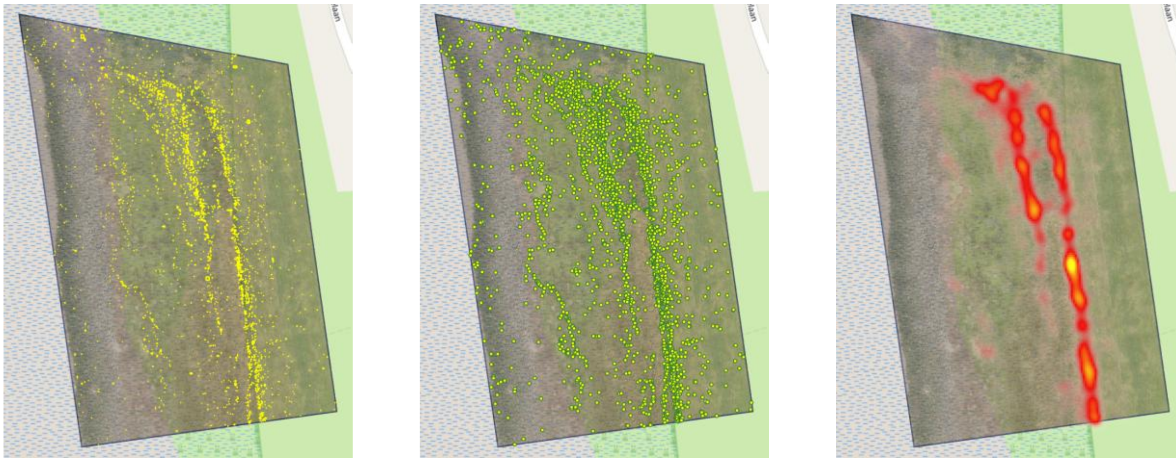


Fig. 25: Three representations of detected litter items*: (left) bounding boxes showing litter size and location; (middle) centroids indicating only the item positions; and (right) a heatmap, visualizing litter density and hotspots.*

On this site and day, between 3,000 and 3,500 macrolitter items were predicted, depending on specific AI model parameters. The spatial distribution reveals that litter tends to accumulate within and between vegetation located along the higher water lines. A comparison of the heatmaps in **Fig. 26** shows that only smaller items remain at the highest water line, whereas both small and large items are trapped along the lower water line.

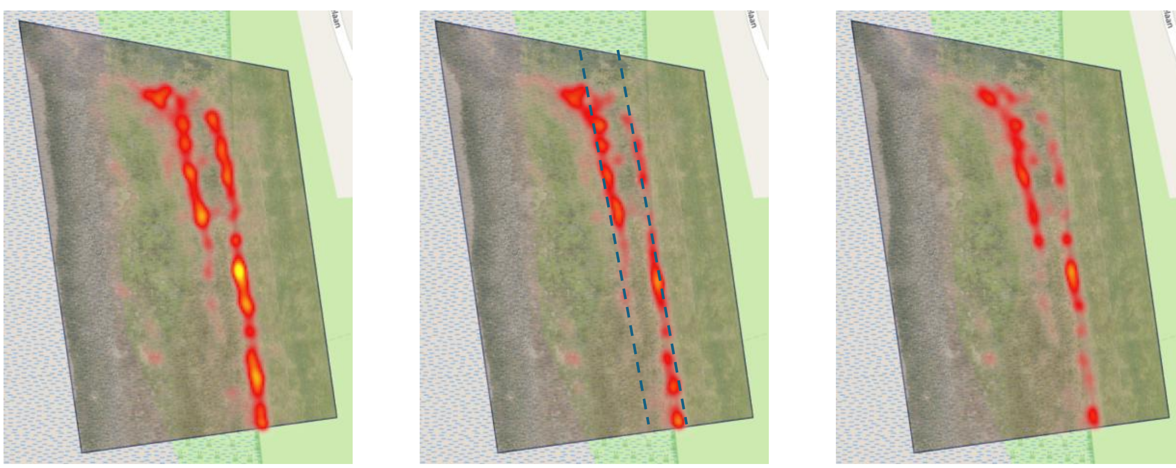


Fig. 26: Heatmaps of predicted macrolitter. *Warmer colours indicate higher litter density, while dashed blue lines mark the high-water levels. The difference from left to right reflects the item size thresholds applied in the model: the left panel includes even the smallest detectable items, whereas the right panel only accounts for larger objects.*

Pellet indicators

Three distinct terrain parameter maps (**Fig. 27**) were derived from the original orthomosaics of the RGB and multispectral datasets. The image on the left is based on RGB data and represents an estimation of surface structure height, including features such as boulders and vegetation. Such structural elements are assumed to obstruct litter on its way back to the river and may serve as accumulation zones. The central image shows the terrain elevation, also derived from RGB data. It is hypothesised that terrain steepness influences the aggregation of pellets and other small debris. The image on the right displays the NDVI (Normalised Difference Vegetation Index), which quantifies vegetation health by comparing the reflectance of red and near-infrared light. Higher NDVI values indicate greener, more vigorous vegetation. Although no direct relationship between NDVI and litter accumulation was observed in this study, this index may contribute to developing a broader site-specific indicator in future analyses.

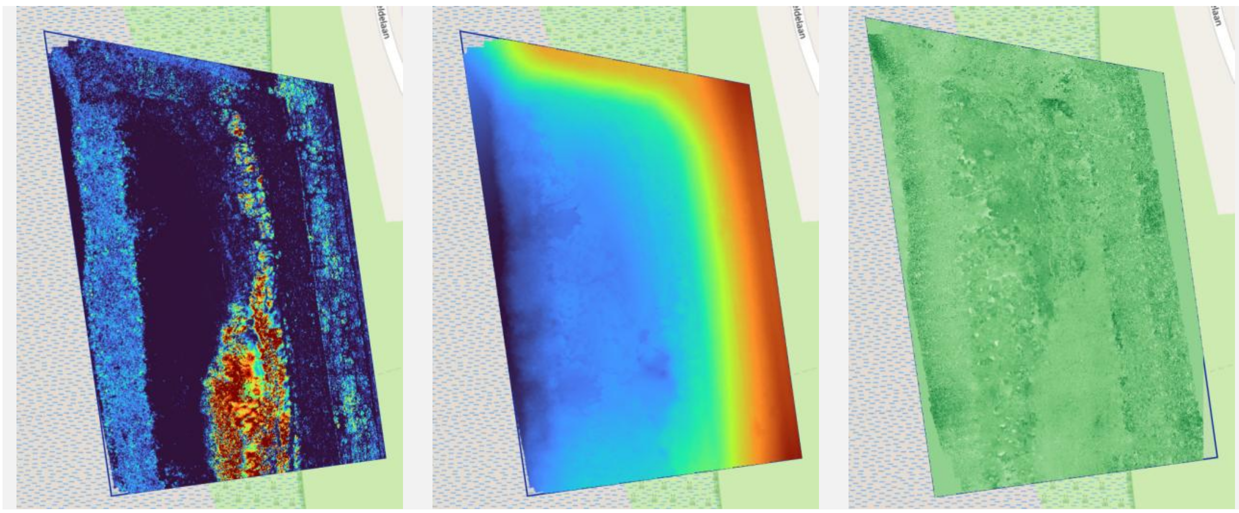


Fig. 27: Terrain parameter maps derived from RGB and multispectral data. *From left to right: surface structure height, terrain elevation, and NDVI. These parameters help characterize surface roughness, slope, and vegetation health, factors potentially influencing litter accumulation patterns.*

Summary

The high-resolution drone imagery serves as a proxy for quantifying plastic pellet abundance and assessing terrain characteristics (e.g., slope and vegetation density/height) that influence litter retention. Spatial analysis indicates that litter accumulation is concentrated within and between vegetation along higher and lower water lines. Specifically, only smaller items remain at the highest water line, while both small and large items are trapped along the lower water line. This distribution supports the hypothesis that terrain steepness influences the aggregation of pellets and other small debris. Although the Normalised Difference Vegetation Index did not directly correlate with litter accumulation in this study, it may be a valuable component for developing future site-specific accumulation indicators.

Microlitter

VLIZ has led the observations of microlitter in the water column and river sediment, with samples being analysed both by VLIZ and Ghent University. An overview map was produced showing all sampling locations, for which median microplastic concentrations were calculated based on all measurements taken (HSM, TCM, and SSM) across all sampling approaches: manta net (surface water), FerryBox sampler (water column), and Van Veen grab (riverbed sediment), yielding ranges of 1 – 26 particles / m^3, 0 – 125 particles / m^3, and 160 – 29,020 particles / kg, respectively (**Fig. 28**).

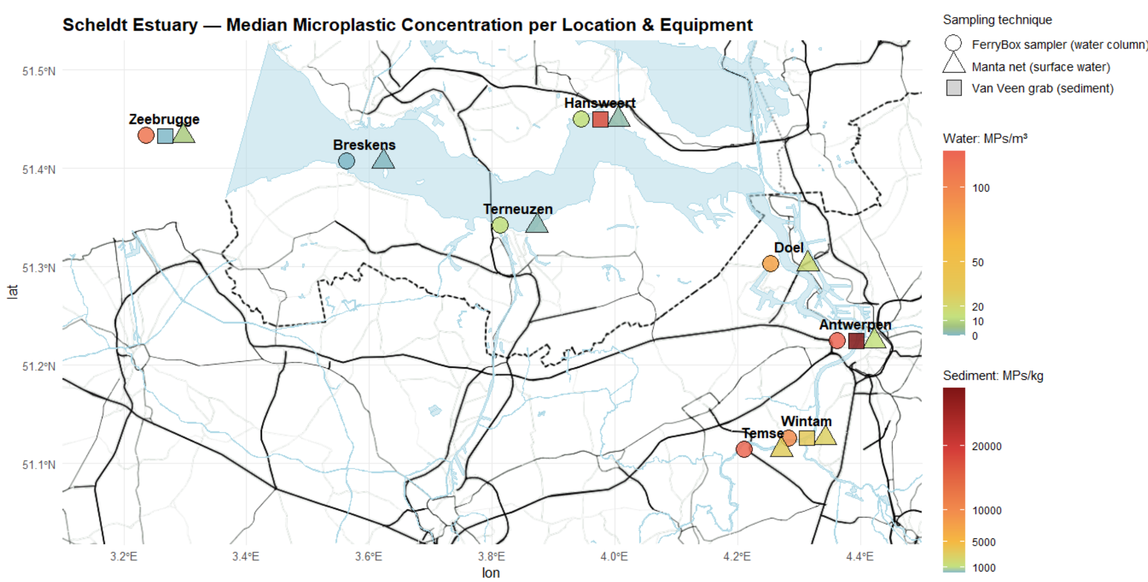


Fig. 28: Visualisation of median microplastic concentration along the Scheldt Estuary. *A map showing median microplastic concentrations in surface waters, the water column, and riverbed sediment for each location. Median values were calculated using all samples collected at each site.*

Overall, sites upstream of Doel exhibited higher microplastic concentrations in the water than those downstream, except for Zeebrugge. Temse and Wintam showed consistently higher levels across sample types, with surface and water-column concentrations within the same range (median 25 – 28 particles / m^3) and (median 93 – 122 particles / m^3), and sediment containing 3,501 particles / kg near Wintam. For Doel and Antwerpen, we observed comparable patterns, although Antwerpen showed the highest sediment concentration (median 29,020 particles / kg), likely reflecting inputs from the densely populated urban environment. These observations support our assumptions regarding potential microplastic accumulation locations. Downstream locations, i.e. Hansweert, Terneuzen, and Breskens, generally showed lower concentrations in the water column (median 0 – 14 particles / m^3), though sediment concentration remained relatively high (median 17,567 particles / kg at Hansweert), possibly due to hydrodynamic conditions such as reduced flow velocity near river bends that promote particle deposition. The higher concentrations at Temse and Wintam may also be related to their position in a narrower, more upstream part of the Scheldt, in contrast to the wider downstream areas where greater dilution can occur (Portillo De Arbeloa et al., 2024).

Microplastic levels at Zeebrugge were higher than at the downstream Scheldt sampling sites and comparable to Temse and Wintam in the water column (median 112 particles / m^3), despite slightly lower surface concentrations. These relatively elevated levels may be influenced by additional coastal or terrestrial inputs unrelated to the Scheldt, or by the nearby dredge disposal area, where previous work (Vanavermaete et al., 2023 has reported elevated macroplastic loads. The comparatively lower concentrations measured at Breskens and Terneuzen support the idea that the elevated levels at Zeebrugge are unlikely to originate from Scheldt outflow alone.

Fig. 29: Median polymer concentration per location in both matrices. *A visualisation of plastic polymer concentration per location, in water (left) (particles / m^3) and in sediment (right) (particles / kg). Median polymer concentrations were calculated based on all samples collected at each site.*

We also examined median polymer concentrations for each sampling location and matrix (**Fig. 29**). Polyethylene and polypropylene, together with polystyrene (PS), dominated in water across most sites, with medians for both groups ranging from 1 - 31 particle(s) / m^3 and 1 - 44 particle(s) / m^3 in water (medians), which is consistent with their global production volumes (Geyer et al., 2017). Their distribution in the studied compartments reflects expected patterns driven by their density (Frias et al., 2018): polyethylene/polypropylene (PE/PP) accounted for the largest share in surface waters (32–97%), in line with their low density (**Fig. 30**), and correspondingly showed lower proportions in sediments (4–17%), except at Zeebrugge, where all detected particles were PE/PP. Proportionally, PS was most prevalent in water column samples (14–69%), compared to the surface water (7–42%) and sediment samples (16–31%), and was present at nearly all sites along the Scheldt.

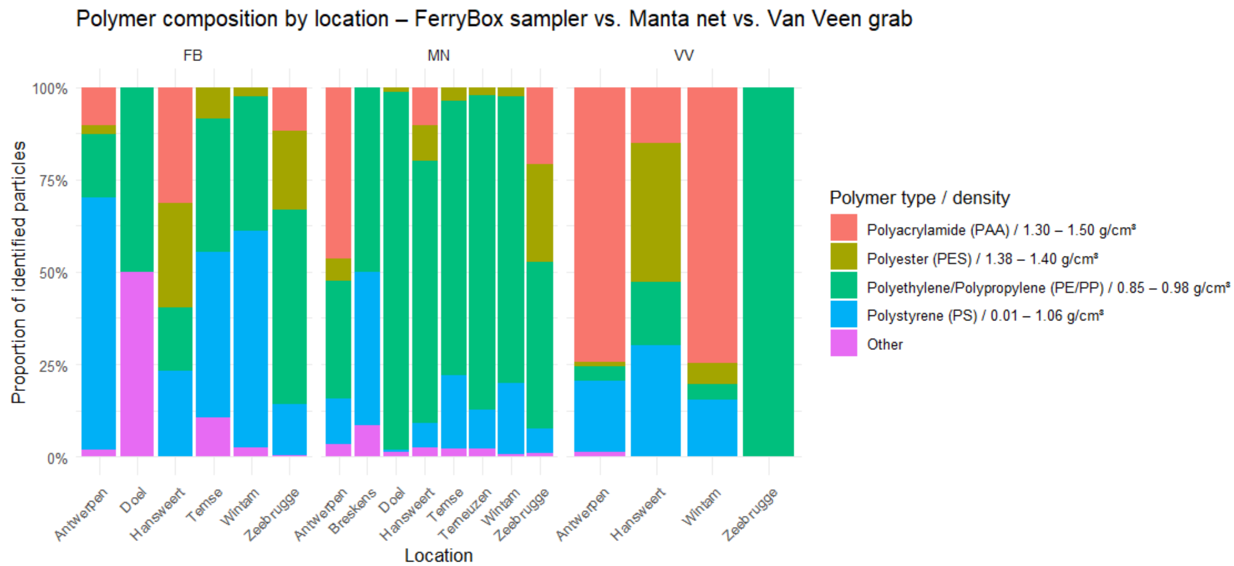


Fig. 30: Median polymer composition per location and type of equipment. *Median polymer composition was determined for each location and for each sampling device used: the FerryBox sampler (water column), the mantanet (surface waters), and the Van Veen Grab (riverbed sediment). A density range is provided for each polymer (Frias et al., 2018).*

Polyacrylamide (PAM) occurred at particularly high concentrations in sediment from Antwerpen (median 21,592 particles / kg) (63%), consistent with its higher density, i.e., a higher "weight" than water, which promotes its deposition (**Fig. 30**), and was also detected in surface and water-column samples (median 3 and 73 particles / m^3) from Antwerpen. Similarly elevated sediment concentrations were observed at Wintam and Hansweert (respectively 2,614 and 2,672 particles / kg) (medians). According to Xiong et al., 2018, PAM is often used in water and wastewater treatment, soil conditioning, and as a viscosity- and friction-reducing agent in enhanced oil recovery and hydraulic fracturing.

In addition, relatively high concentrations of polystyrene were detected near Hansweert and Antwerpen, with 5,311 and 5,537 particles / kg (medians), respectively. In contrast, 543 particles / kg (median) were found near Wintam, and no PS particles were detected near Zeebrugge. Polyethylene/polypropylene concentrations in sediment ranged from 160 particles / kg in Zeebrugge to 2,973 particles / kg in Hansweert (medians). Polyester (PES) was also frequently detected at nearly all locations, particularly in sediments (198 – 6,613 particles / kg) (6–38%) and throughout the water column (10 – 24 particles / kg) (3–29%), again reflecting its higher density (medians). Other polymers occurred only in minor proportions in water and sediment across the estuary, except at Doel, where this category represented 50% of detected particles (median 21 particles / m^3) in water, which could potentially be linked to the concentrated industrial activity in that area.

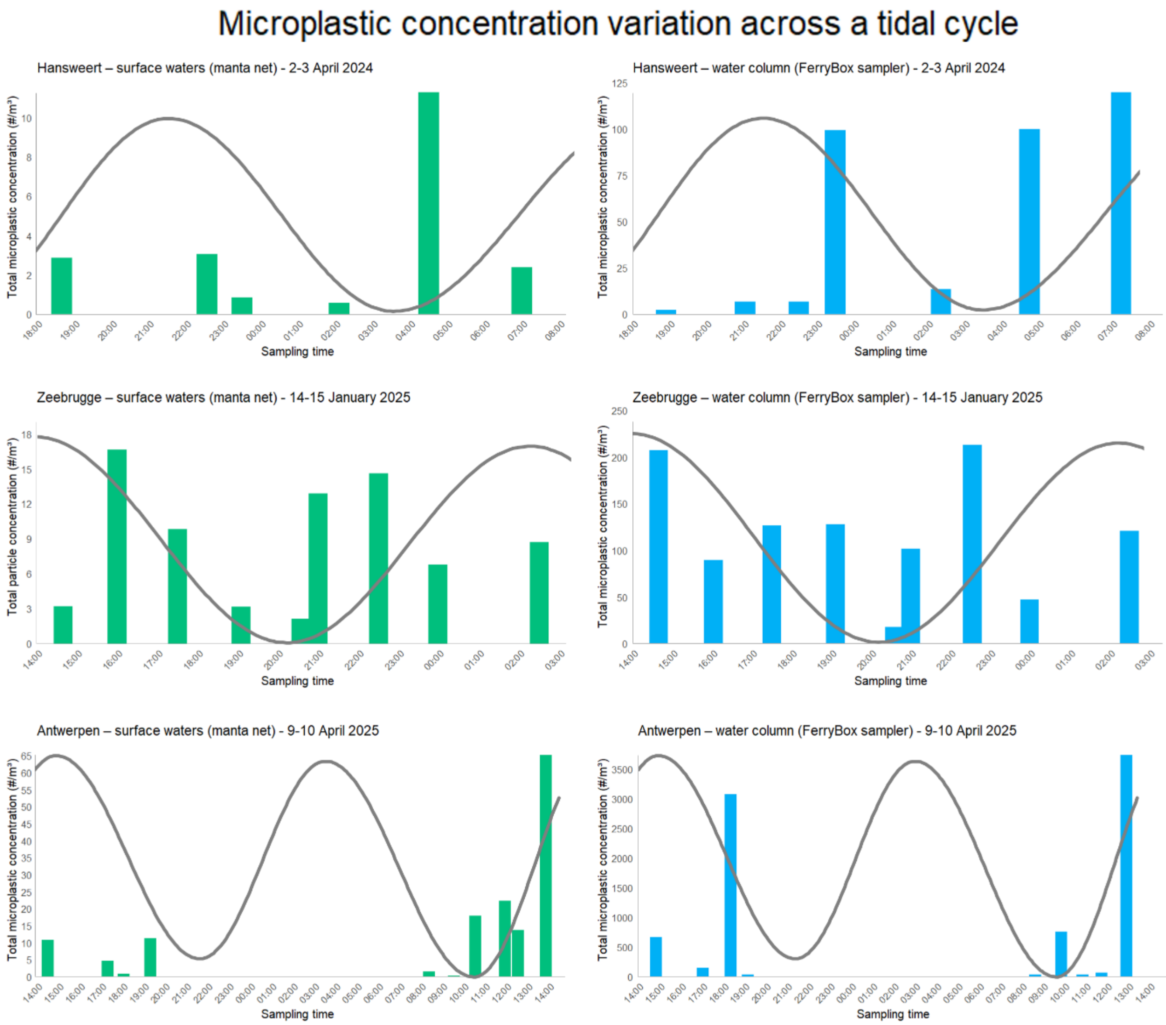


*Fig. 31: **Microplastic concentration vs. tide.** Microplastic concentration is shown during a full tidal cycle at Hansweert, Zeebrugge, and Antwerpen. Please note that the scale of concentrations (y axis) varies according to sampled site.*

When plotting microplastic concentrations as a function of tidal phase at three locations (Hansweert, Zeebrugge, and Antwerpen) (**Fig. 31**), concentrations seem higher during ebb and flood tide compared to the high and low tide moments. We hypothesise that increased water movement and mixing during tidal transitions might help explain this, as this may resuspend microplastics from sediments or distribute them more evenly throughout the water column. In addition, tidal flow can carry microplastics from upstream or adjacent areas and in this way temporarily increase local concentrations.

Table 14: Median microplastic concentrations across locations and matrices for this study (2024-2025) as well as for the baseline study (2020-2022) *(Everaert et al., 2022). The median microplastic concentrations were calculated per location based on samples from all seasons and campaigns, and this for surface water (manta net), water column (FerryBox) and sediment (Van Veen grab) samples. Number of samples analysed is given per calculated median concentration [n].*

Location	Sampling technique [lower mesh size used]	Median microplastic concentration in water [particles / m³] PLASTFLOW	Median microplastic concentration in water [particles / m³] BASELINE STUDY	Median microplastic concentration in sediment [particles / kg] PLASTFLOW	Median microplastic concentration in sediment [particles / kg] BASELINE STUDY
Antwerpen	FerryBox sampler [100 µm]	124.07 [12]			
	Manta net [200 µm]	12.43 [12]	17.67 [4]		
	Van Veen grab			29,019.61 [1]	1,841.38 [2]
Breskens	FerryBox sampler [100 µm]	0 [1]			
	Manta net [200 µm]	0.62 [1]	20.16 [3]		
	Van Veen grab				31,427.24 [3]
Doel	FerryBox sampler [100 µm]	78.28 [1]			
	Manta net [200 µm]	16.9 [2]	25.32 [4]		
	Van Veen grab				1,222.39 [1]
Hansweert	FerryBox sampler [100 µm]	13.31 [7]			
	Manta net [200 µm]	2.6 [6]	193.86 [1]		
	Van Veen grab			17,566.67 [1]	18,031.41 [1]
Temse	FerryBox sampler [100 µm]	121.94 [2]			
	Manta net [200 µm]	27.7 [6]	20.03 [3]		
	Van Veen grab				21,738.90 [2]
Terneuzen	FerryBox sampler [100 µm]	13.3 [1]			
	Manta net [200 µm]	1.77 [1]	80.06 [3]		
	Van Veen grab				9,843.14 [3]
Wintam	FerryBox sampler [100 µm]	92.84 [3]			
	Manta net [200 µm]	25.1 [3]	29.24 [4]		
	Van Veen grab			3,500.99 [1]	4,479.37 [3]
Zeebrugge	FerryBox sampler [100 µm]	111.1 [10]			
	Manta net [200 µm]	7.74 [10]	128.98 [1]		
	Van Veen grab			160 [1]	144,962.68 [1]

Table 14 summarises median microplastic concentrations across matrices and locations for both the current and baseline study. Overall, concentrations varied considerably across sites and over time: microplastic surface water levels were relatively stable at Doel, Antwerpen, Wintam, and Temse, but larger differences were observed at Zeebrugge, Terneuzen, Hansweert, and Breskens. Most concentrations however remained within the same two orders of magnitude (0 – 100 microplastics / m^3). Sediment concentrations were similar near Hansweert and Wintam, yet differed substantially near Antwerpen and Zeebrugge. The obtained results highlight the high spatial and temporal variability of microplastic pollution in the Scheldt Estuary. This variability, influenced by factors such as vegetation, rainfall, estuarine hydrodynamics, legacy plastics, and point sources (e.g. industrial activity near Antwerpen and dredge disposal activity near Zeebrugge), complicates the interpretation of our results, and consequently explains why the subsequent power analysis indicates that relatively large sample sizes are required to detect a reduction in microplastic pollution.

Power analysis

Based on microplastic concentrations collected during the PLASTFLOW project (2024-2025) and the baseline study (2020–2022) (**Table 14**), we performed a power analysis to estimate the number of water samples needed to reliably detect a reduction in microplastic pollution following management measures in the Scheldt Estuary. Concentrations were log1P-transformed to stabilise variance and make the data distribution more symmetric. We fitted the model *lm(Microplastic_concentration_log ~ Sampling instrument + Season + Location + Year, data = df)*, with 'Year' indicating either the baseline or current study. These fixed factors controlled for known sources of variation, providing a more accurate estimate of overall reductions. Analyses were conducted in R with α = 0.05. A small effect size (Cohen's d = 0.2; f^2 = 0.041667) (Cohen, 1988) was chosen to reflect the expectation that reductions may be subtle but even the small improvements should be detectable. Using the pwr.f2.test() function, we found that a total of approximately **440** samples would provide 80% power across all variables considered, which translates to an 80% probability of detecting this small effect, if existing. As a reference, 73 water samples were used for the analyses within the PLASTFLOW project.

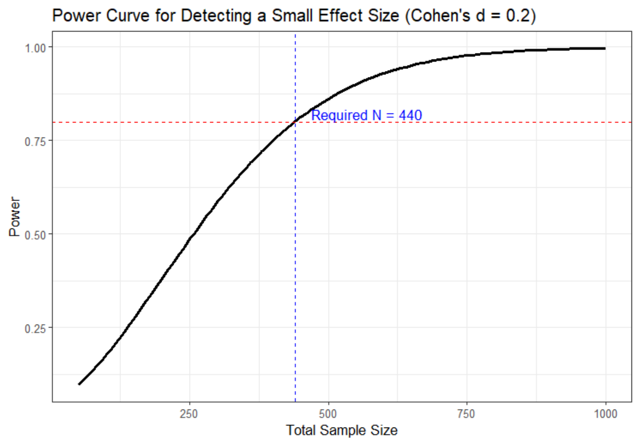


Fig. 32: Power curve to detect a small effect size of 0.2. *The power curve shows how power increases with sample size, and marks 440 samples as the minimum sample size needed to detect a reduction in microplastic pollution with 80% certainty. The optimal sample size for a power of 0.8 is indicated with a dotted line.*

Summary

Across the Scheldt Estuary, microplastic concentrations ranged from 0 to 125 particles / m^3 in water and 160 to 29,020 particles / kg in sediment. Upstream of Doel, microplastic concentrations in water were generally higher than downstream, with Zeebrugge as the exception. Antwerpen showed the highest sediment concentration, likely reflecting inputs from the densely populated urban environment. These results seem to confirm patterns from previous work (Everaert et al., 2022) regarding potential microplastic accumulations locations. Distribution patterns reflect density-driven behaviour: Polyethylene and polypropylene (PE/PP) were most prominent in surface waters (32 – 97%) and less abundant in sediments (4 – 17%), except at Zeebrugge, where all detected particles were PE/PP. Polystyrene was most prevalent in the water column (14 – 69%), followed by surface waters (7 – 42%) and sediments (16 – 31%). Polyacrylamide was dominant in sediment, particularly near Antwerpen and Wintam (both 75%). Hydrodynamic conditions near Hansweert, i.e., a river bend, resulting in a reduced water flow and associated sedimentation may have promoted local accumulation of microplastics in sediment, while slightly elevated levels near Zeebrugge may reflect additional coastal or terrestrial inputs or nearby dredge disposal. Microplastic concentrations were generally higher during ebb and flood tides than at high or low tides, likely due to tidal mixing of resuspending particles and transporting them from upstream or adjacent areas. Based on a performed power analysis, approximately **440** water samples are needed to be able to detect a small reduction in microplastic pollution with 80% certainty.

Microplastics transport modelling

Modelling of microplastics transport in the Scheldt Estuary was performed by KU Leuven.

The Belgian Coast–Scheldt Estuary modelling system was built in the TELEMAC–MASCARET framework (www.openTELEMAC.org) and integrated hydrodynamics, waves, sediment transport and microplastic dynamics into a coupled numerical simulation environment. The primary purpose of the system is to simulate microplastic transport across the estuary and assess fluxes between the riverine, estuarine and coastal zones. The model spanned the Belgian coastal waters and the full Scheldt Estuary, employing unstructured meshes and hydrodynamic forcing based on tides, meteorological conditions, temperature and salinity fields. This model is nested into a larger, coarse-resolution North Sea model, used to generate boundary conditions at the open sea boundary of the high-resolution coastal model. Boundary temperature and salinity are derived from CMEMS datasets and validated extensively using in-situ observations along multiple stations in the estuary and coastal domain.

A key component is the **Population Balance Equation (PBE)** microplastics model, which tracks microplastic size distribution (Shettigar et al., 2024). Although simplified in the current implementation, the PBE framework provides a numerical basis for evolving particle number concentrations at any space-time instance, and it is directly used for flux calculations across estuarine cross-sections.

The **sediment–microplastic coupling** was developed within the TELEMAC-GAIA environment, which includes formulations for deposition and erosion shear stress criteria, which have been adapted for microplastics. Microplastics interact with suspended sediments both in the water column and at the sediment bed. Deposition was governed by suspension capacity theory (Toorman, 2000) applied to the sediment mixture (mud-sand). Erosion followed a mixed-sediment criterion in which critical bed shear stress depends on local sand–mud mixtures: microplastics are resuspended with sediment when shear exceeds this threshold.

Material Flow Analysis (MFA) data (Schwarz et al., 2023) was used to derive estimates of microplastic concentrations since direct measurements are sparse. The MFA-based concentrations were mapped onto the model domain as **initial conditions**, ensuring the simulation starts from a realistic, mass-balanced microplastic distribution rather than arbitrary values. In the PBE microplastics model, concentrations were initialised with cumulative MFA estimates from 1950 up to the year of simulation. The PBE microplastic model redistributed the uniform initial concentrations to a stable spatial distribution after model warming-up time driven by tidal forces and local mixing.

Model simulations were designed to cover the PLASTFLOW field data timelines. The model simulation timeline is presented in **Fig. 33**. Also, the validation data is presented in the figure with black circles. The simulations of 30 days and 110 days, coinciding with the tidal cycle measurements (TCM) at Hansweert, Zeebrugge and Antwerpen, were with higher time resolution of model output at 10 min, compared to 270 days and 250 days model simulations which had a 1 hour time resolution. 30 days and 110 days model simulations were used in the model validation with TCM data. These 2 models were initialised with microplastics concentrations which were derived from last time step of the preceding model runs respectively, 270 days and 250 days model runs. All the locations where the model validations were performed are shown in **Fig. 34**.

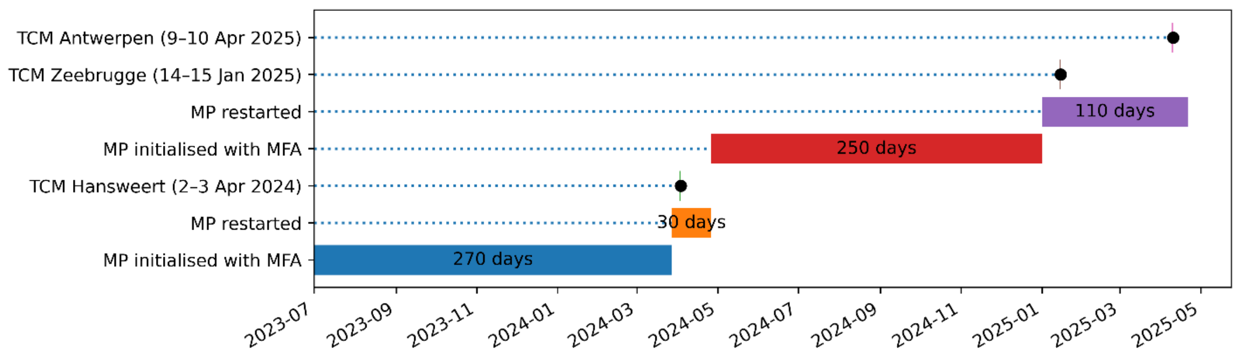


Fig.33: PLASTFLOW model simulation timeline. *The coloured bars show simulation periods. 30 days and 110 days simulations had higher time resolution (10 min) outputs, to have validation with the measurement data shown as black circles.*

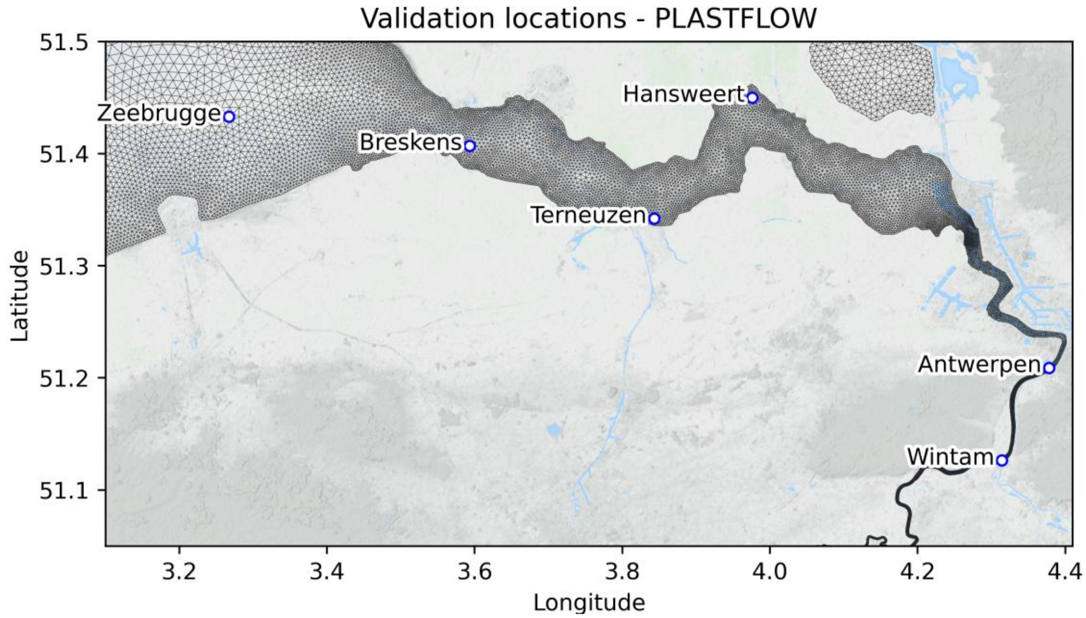


Fig. 34: Locations of measurements conducted in PLASTFLOW. *Microplastics suspension concentrations were measured at these locations and data is used for model validation.*

Results

Model validation was performed with two types of field data, namely acquired using the manta net and the FerryBox collection methods. The two methods use different mesh sizes i.e., 200 µm and 100 µm respectively. As a result, different size fractions of microplastic particles were captured in these collection methods. In **Fig. 35-36**, model results were compared with the TCM and spot sampling data collected in the month of April in 2024 using respectively the manta net and the FerryBox methods. In **Fig 37-38,** model results were compared with TCM data at Zeebrugge and Antwerpen respectively with manta net and FerryBox datasets.

Model validation using the April 2024 field data highlights clear and systematic differences in measured microplastic concentrations depending on both the sampling method and the hydrodynamic setting in which the data were collected. The tidal cycle measurements and spot samples were obtained using both manta net (200 µm mesh) and FerryBox (100 µm mesh), but the two approaches differ fundamentally in sampled water volume: the manta net typically filters ~15,000 L, whereas the FerryBox draws only ~150 L per sample. Because microplastics are highly heterogeneous in space and do not follow a linear concentration-volume relationship, extrapolating FerryBox counts to a standard unit volume (1 m^3) introduces substantial uncertainty. As a result, manta net samples - despite targeting a coarser size fraction - generally provide more statistically robust concentration estimates due to the much larger filtered volume and reduced sensitivity to small-scale patchiness.

The spatial patterns in both sampling datasets and the model emphasize the dynamic microplastics environment in the Scheldt system. The model resolves particles in the 1 - 5 µm size range, a fraction that is not efficiently captured by manta nets but is partially included in the FerryBox data, which further contributes to differences in magnitude between observations and simulations. The model reproduces the tidal phasing and overall spatial trend, but, as noted above, its magnitudes sit well below the FerryBox estimates because those values are strongly affected by the low sampled volume and the nonlinearity of particle distributions. Taken together, the results show that the model performs realistically relative to the more reliable manta net dataset, while the very high FerryBox concentrations should be interpreted with caution due to methodological limitations and the inherent variability of microplastic distributions.

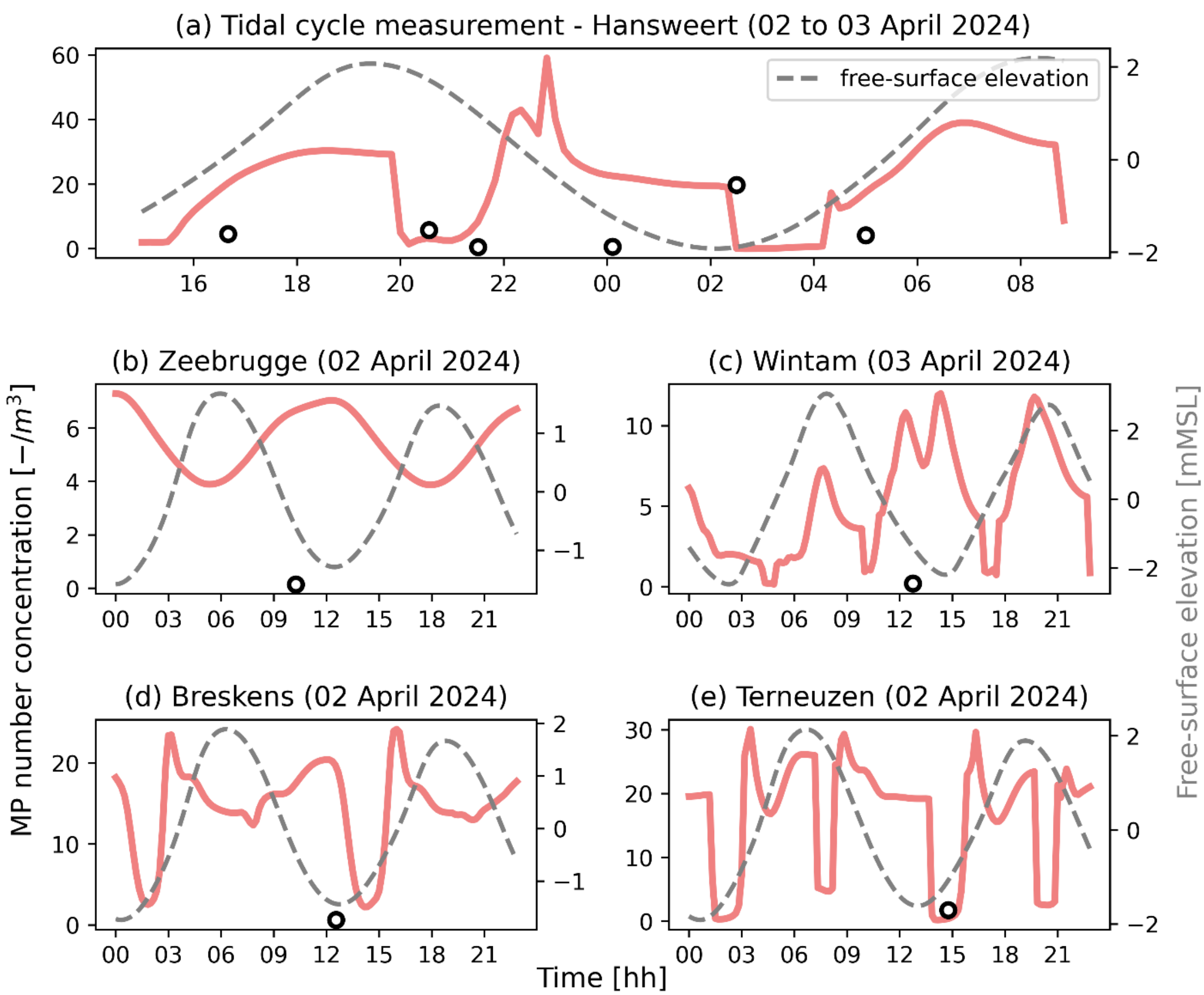


Fig. 35: Model validation – Manta net sampler. *Model validation with microplastics suspension concentration measured during a tidal cycle (a) and spot samples (b-e) using manta net collection method (200 µm mesh size). Red lines are modelled microplastics concentration (numbers per m^3), black circles are measured microplastic concentrations (numbers per m^3). Grey dash lines are modelled free surface elevations.*

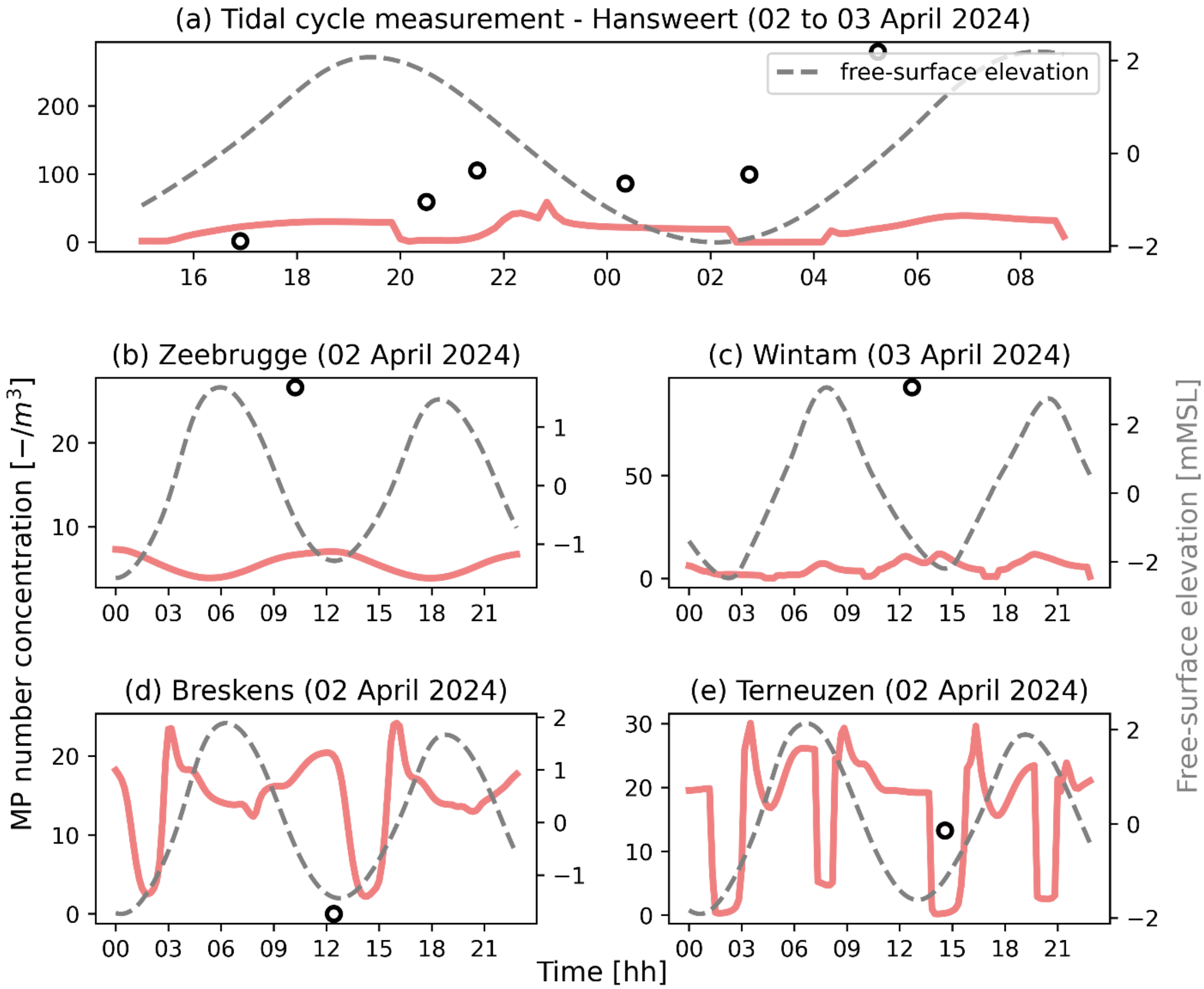


Fig. 36: Model validation – FerryBox sampler. *Model validation with microplastics suspension concentration measured during a tidal cycle (a) and spot samples (b-e) using FerryBox collection method (100 µm mesh size). Red lines are modelled microplastics concentration (numbers per m3), black circles are measured microplastic concentrations (numbers per m3). Grey dash lines are modelled free surface elevations.*

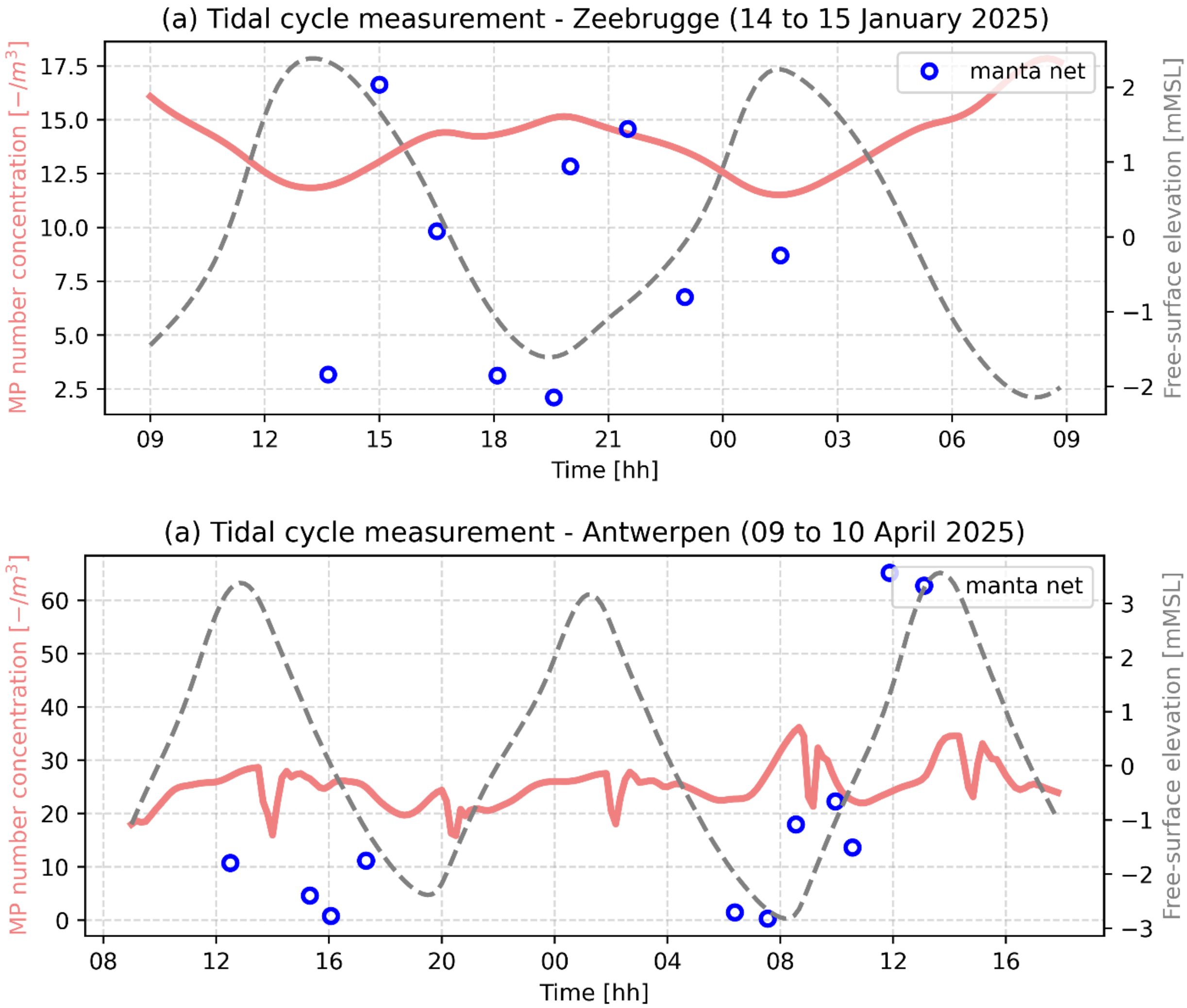


Fig. 37: Model validation. *Model validation with microplastics suspension concentration measured during a tidal cycle. Red line is modelled microplastics concentration (numbers per m³), blue circles are measured microplastic concentrations (numbers per m³) using manta net collection method (200 µm mesh size). Grey dash lines are modelled free surface elevation.*

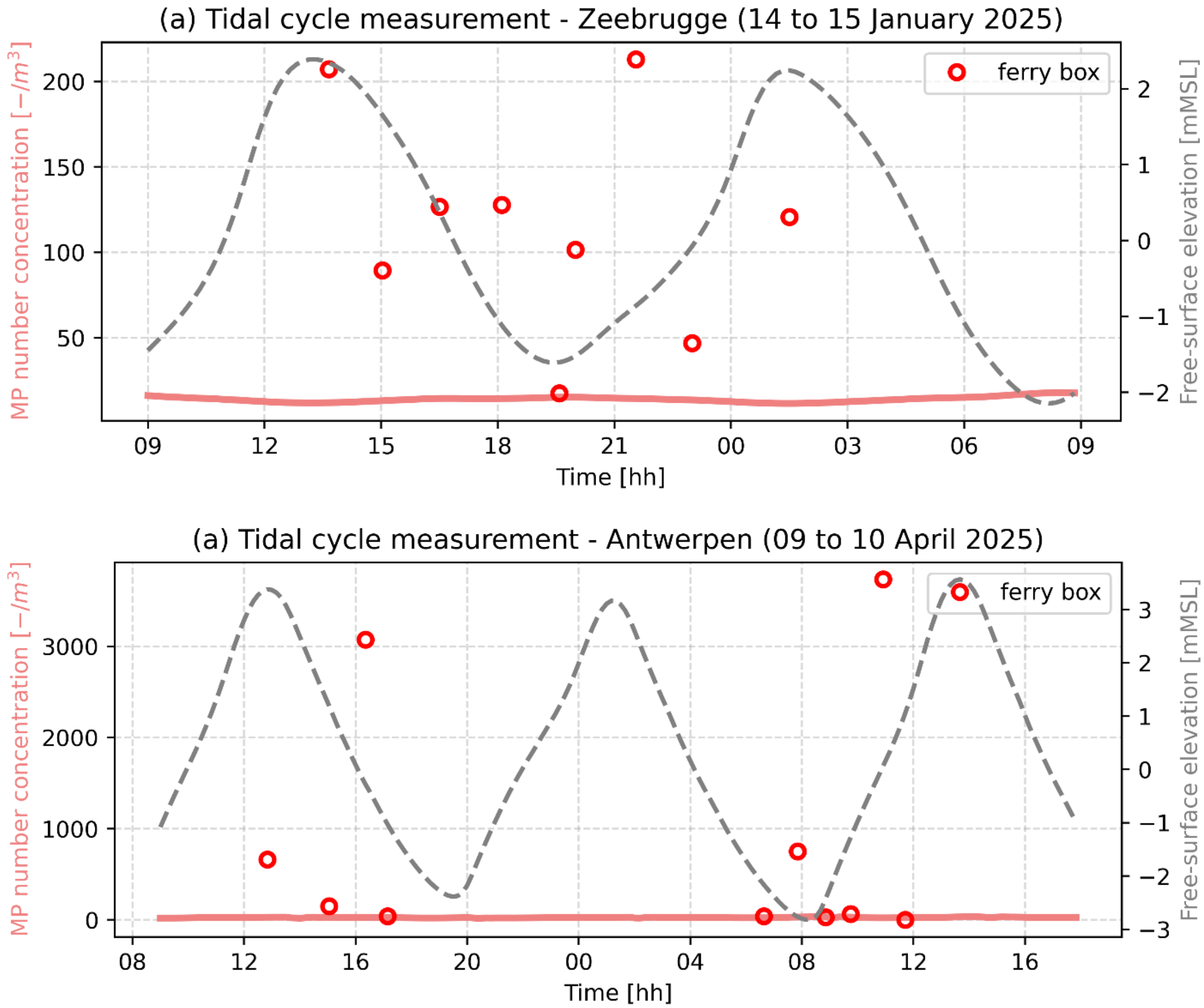


Fig. 38: Model validation. *Model validation with microplastics suspension concentration measured during a tidal cycle. Red line is modelled microplastics concentration (numbers per m^3), red circles are measured microplastic concentrations (numbers per m^3) using FerryBox collection method (100 µm mesh size). Grey dash lines are modelled free surface elevation.*

The mass fluxes of microplastics were analysed at three cross-sections, namely Vlissingen, Doel and Wintam, which are shown in **Fig. 39**, and the resulting fluxes are shown in **Fig. 40**. The modelled microplastic fluxes at the three cross-sections reveal clear spatial differences in both magnitude and directionality as the system transitions from the coastal boundary toward the upper estuary.

At Vlissingen, located at the mouth of the estuary, the flux signal is dominated by strong tidal oscillations with large positive and negative peaks, reflecting bidirectional exchange with the coastal North Sea. The cumulative flux shows a net positive trend, indicating that over the simulated 110-day period, the estuary exports more microplastics mass seaward than it imports.

Further upstream, at Doel, the magnitude of the instantaneous fluxes decreases substantially due to the constricted geometry and reduced cross-sectional area of the estuary. Here, tidal variability still drives alternating seaward and landward transport, but the cumulative signal climbs slower, suggesting a smaller net export compared to Vlissingen.

At Wintam, located in the upper Scheldt, the instantaneous flux is the weakest of all three cross-sections and displays a pronounced net imbalance between negative (landward-directed) and positive (seaward-directed) transport. The cumulative flux rises during the early part of the simulation but stabilises later, indicating temporary episodes of upstream retention rather than continuous export. **These patterns highlight a progressive shift from strong export at the estuary mouth to weaker, more storage-dominated behaviour upstream, implying that the upper Scheldt functions as a partial microplastics retention zone while the lower estuary remains an efficient conduit for microplastic export to the sea.**

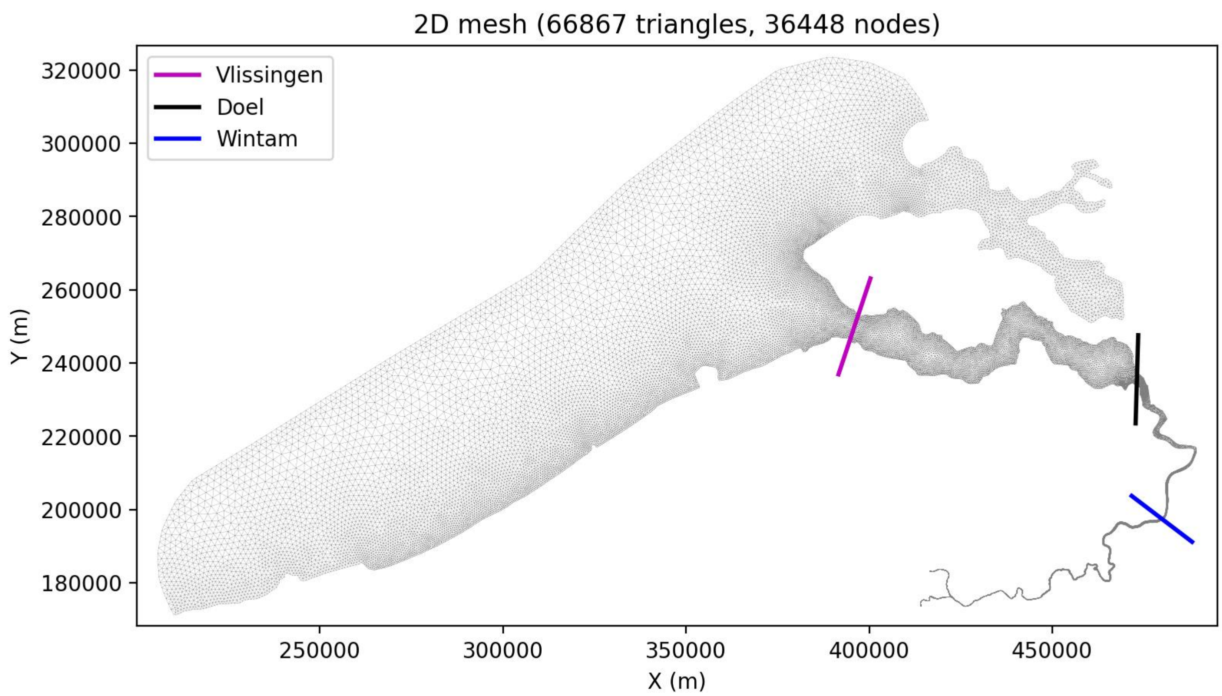


Fig.39: Cross-sections used. *Three cross-sections used for computation of fluxes of microplastics*

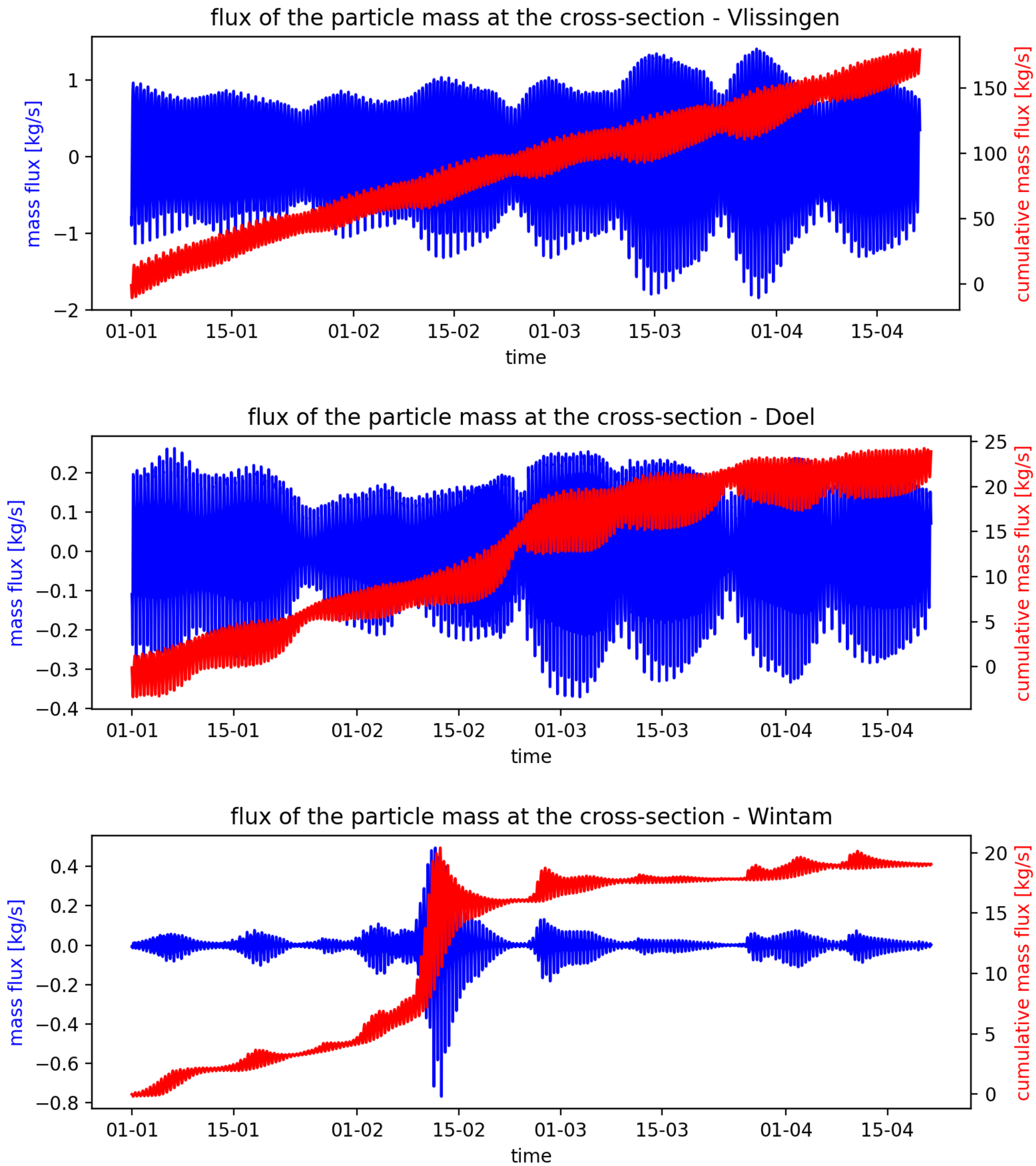


Fig. 40: Mass flux of microplastics. *At the three cross-sections Vlissingen (a), Doel (b) and Wintam (c) for a duration of 110 days of model simulations. Mass calculation at Vlissingen cross section is approximately 120 metric tonnes in 110 days or 32 metric tonnes in 30 days. For Doel and Wintam the estimate is 15 metric tonnes and 12 metric tonnes in 110 days, respectively. Note that for Vlissingen, the cumulative flux (red line) can flatten over a much longer period, reaching a stable value, resulting in lower net exported mass.*

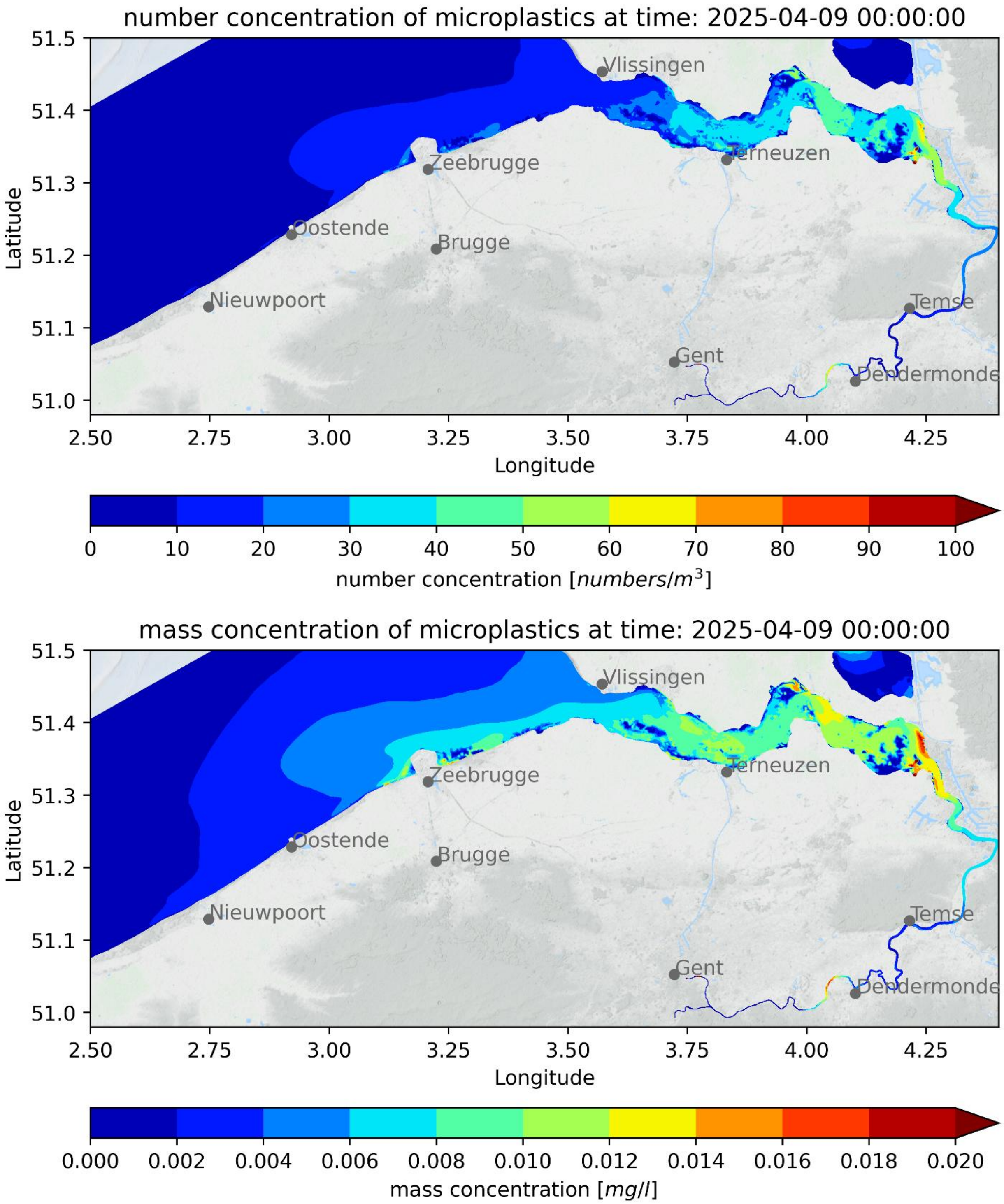


***Fig. 41: Model result of microplastics concentration**. Expressed in number concentration (a) and mass concentration (b)*

In **Fig. 41**, the spatial plots of microplastic concentrations in number and mass units are presented. The spatial patterns of microplastic concentrations in the model show hotspots that coincide with hydrodynamically constrained parts of the estuary. The highest number- and mass-based concentrations occur near Doel, where the estuary narrows and tidal currents accelerate, favouring the trapping and mixing of particles. The earlier flux analyses support this behaviour: fluxes at Doel are moderate, with both positive (seaward) and negative (landward) values remaining relatively small, suggesting that microplastics tend to be retained rather than flushed rapidly through this constriction. Tidal reach upstream of Dendermonde shows higher concentrations that can be mobilised as pulses. This upstream plume can periodically propagate downstream towards Wintam, where its arrival produces the pronounced, short-lived spikes in landward or seaward flux previously observed. Together, these patterns highlight how channel geometry and tidal dynamics shape both the spatial distribution and temporal flux behaviour of MP within the Scheldt system.

Earlier observations consisted of one TCM at Wintam using the manta net method with a 100 µm mesh and the model reproduced those concentrations well (Shettigar and Toorman, 2024). However, no comparable data existed at other locations. In contrast, the new monitoring campaign provides measurements at more stations, yet the sampling methods differ - the manta net with 200 µm mesh size and samples of ~15,000 L water per towing event, while the FerryBox system uses a 100 µm mesh size, but samples only ~100-200 L. FerryBox values must be extrapolated to m^3 of water volume from very small sample volumes and moreover microplastic concentrations vary strongly over space and time, these measurements are much less reliable, leading to model values generally being far lower than FerryBox data but higher than manta net data, evident from the tidal-cycle validations. Despite these limitations, the comparison demonstrates that the model initialised with cumulative emissions derived from the material flow analysis dataset (1950 to present), produces realistic concentration levels at multiple sites. As a result, any recent changes in microplastic inputs, removals or mitigation measures are unlikely to be detectable in coarse-resolution field data or short-term campaigns, because the system is still dominated by the long-term legacy pool of microplastic pollution rather than contemporary emissions.

Summary

The Scheldt microplastic transport model was validated against new 2024/2025 field data and showed that manta net measurements provide the most reliable concentration estimates, while FerryBox values are much less dependable due to their very small sampled volume and the strong spatial–temporal heterogeneity of microplastics, leading to model values generally being far lower than FerryBox data but higher than manta net data. The model captures tidal phasing and spatial trends well and reveals strong spatial structuring of microplastic dynamics: the estuary exports microplastics at Vlissingen, shows reduced but still alternating transport at Doel with notable retention, and exhibits weak, storage-dominated behaviour at Wintam. Spatial maps highlight hydrodynamic hotspots, especially near Doel, and importantly, the tidal reach upstream of Dendermonde exhibits elevated concentrations that can be mobilised as downstream pulses, driving short-lived flux spikes. Overall, the model, which was initialised with cumulative MFA-derived inputs, reproduced realistic concentration levels across sites and importantly indicated that the Scheldt Estuary remains dominated by a long-term legacy pool of microplastics, meaning recent changes in inputs or mitigation measures cannot yet be detected in short-term or coarse-resolution monitoring data.

Story Map

To support the transparent and widely accessible dissemination of the project's findings, the PLASTFLOW story map was developed by the VLIZ Marine Data Centre using the ArcGIS StoryMaps platform (https://storymaps.arcgis.com) and with support of all project partners. Story maps are online interactive multimedia tools, which integrate text, images, videos, and maps to present a narrative with a focus on geographical location. Information was compiled from project partners and adapted for general audiences in the creation of the story map. The PLASTFLOW story map describes the context of the project, the methodologies and results, the project timeline, and relevant references to related content. The story map can be publicly found via search engines and possibilities to link it on the website of ScheldeMonitor (https://www.scheldemonitor.be/en) will be explored. To access the PLASTFLOW story map, please visit the following website:

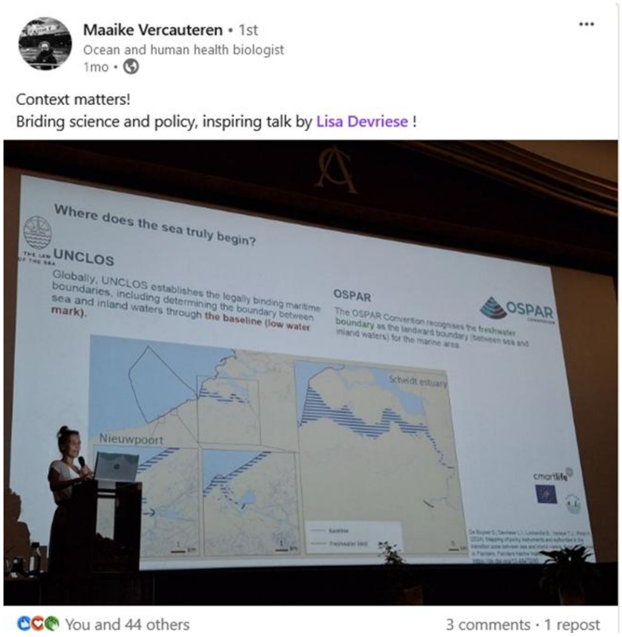
https://storymaps.arcgis.com/stories/bcc2983772b74d7abde9867ac8587d0c

More detailed information on the story map can be found in Annex IV of this report.

Policy brief

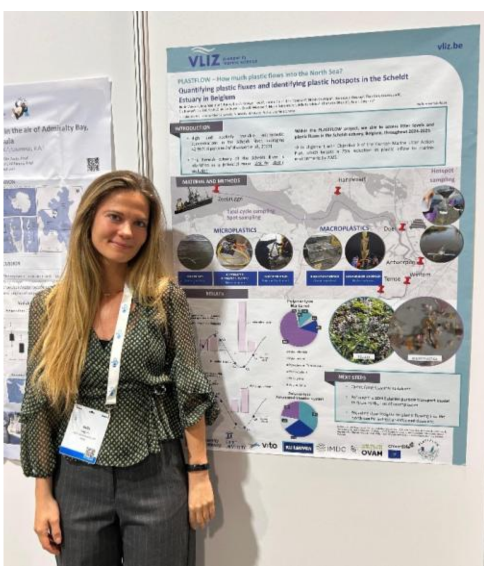
The PLASTFLOW policy brief (**D5.1**, Annex I) (Lalyer et al., 2025) was developed to translate the project's key findings into clear insights and a way forward for decision makers, stakeholders and the wider public towards reducing plastic pollution. It builds on the context of the Flemish Integral Action Plan on Marine Litter, which sets a key objective to reduce the flow of plastic litter from land to sea by 75% by 2025. In this framework, the brief also examines the demarcation of the marine environment and its implications for achieving this policy target, clarifying how governance boundaries affect the assessment of progress and the design of effective measures. The policy brief supports evidence-based decision-making for the Scheldt Estuary, highlighting the complexity of tackling plastic pollution, the importance of a source-to-sea management approach, and the priority areas for intervention based on the project's research results. Project partners shared their findings and expertise to build a shared understanding and to outline concrete next steps towards coordinated, data-supported action against plastics in the environment.

Main communications



Milestone 5.2 was successfully completed and refined the policy framework for the activities and outcomes of the PLASTFLOW project. The report outlines the boundary between inland waters and the Belgian part of the North Sea, and highlights the different approaches of UNCLOS and the Regional Seas Conventions (e.g., OSPAR). This work, including its insights on responsibilities across these interconnected water systems, was presented by Lisa Devriese (**Fig. 42**) at the MICRO2024 conference in Lanzarote.

Fig. 42: MICRO2024 conference – M5.2. *Lisa Devriese presenting the work done for M5.2 at the MICRO2024 conference in Arrecife, Lanzarote*.



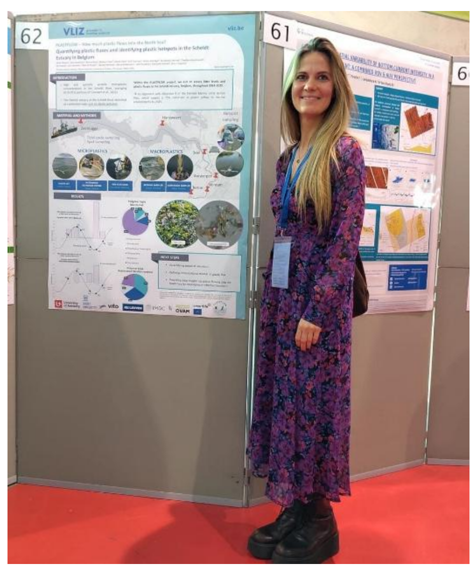


Fig. 43: SETAC and VLIZ Marine Science Day. *Nelle Meyers presenting the microplastics work done at the SETAC conference in Vienna, Austria, and at the VLIZ Marine Science Day in Bruges, Belgium*.

Nelle Meyers presented intermediary results of the PLASTFLOW project, focusing on the tidal cycle measurements taken at Hansweert, at the VLIZ Marine Science Day in Bruges (March 2025) and at the SETAC conference in Vienna (May 2025) (**Fig. 43**).

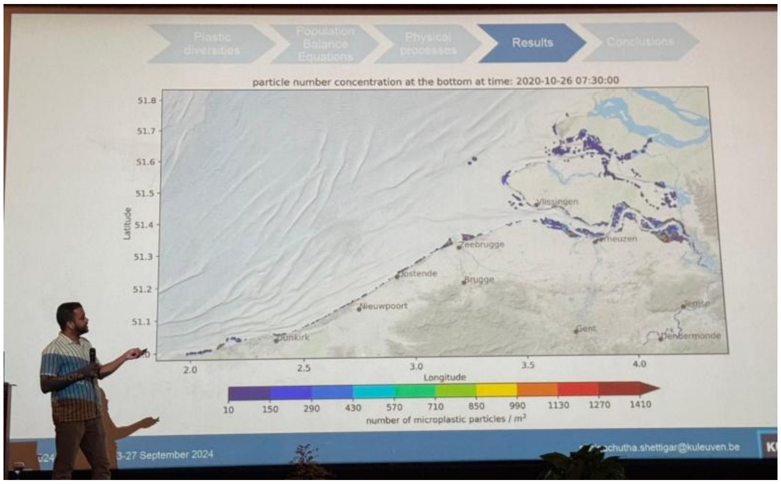


Fig. 44: MICRO2024 conference – microplastics modelling*. Nithin Shettigar presenting the microplastics modelling work done at the MICRO2024 conference in Arrecife, Lanzarote.*

Nithin Shettigar presented the microplastics transport modelling at MICRO2024 conference (23-27 September 2024) at Lanzarote with title "Size-dependent microplastics transport in a sediment rich environment" (**Fig. 44**).

Conclusion and perspectives

Plastic pollution poses well-documented hazards to aquatic ecosystems, estuarine and marine biodiversity, and potentially human health, underscoring the need for robust monitoring and targeted mitigation. In support of the Goal 9 of the Flemish Marine Litter Action Plan, which aims for a 75% reduction in plastic inflow to marine environments by 2025, the PLASTFLOW project established a comprehensive and consistent sampling framework. By building on baseline measurements from 2020-2022 and assessing concentrations in selected sampling locations in 2024–2025, the project provided reliable data to track temporal trends. In parallel, PLASTFLOW addressed additional objectives, including identifying and assessing pellet accumulation areas, and strengthening data management to ensure high-quality, FAIR, open-access datasets on plastic contamination in the Scheldt and its estuary.

This final report synthesizes the progress made across all project components: quantifying plastic fluxes from river to sea, improving sampling and data workflows, modelling the fate and accumulation of macro-, meso- and microplastics, and developing accessible communication tools such as the project story map. Together, these efforts have deepened our understanding of plastic distribution patterns and pollution dynamics in the Scheldt Estuary. The insights generated provide a solid scientific basis for future policy development, targeted mitigation, and continued monitoring aimed at reducing plastic emissions and protecting the health of estuarine and marine environments.

Key research findings

- **Litter accumulation hotspots** seem to be linked to **hydrodynamic features** such as river outer bends (like in Hansweert), physical barriers (bridges), and channel constrictions (like the narrowing at Doel) which enhance sedimentation. The found hotspot areas seem to be in line with the previous work from Everaert et al., 2022.

- **Vegetation** (on riverbanks and along waterlines) and **steep terrain** are critical in trapping litter, forming specific retention zones.

    - **Drone imagery confirms the physical processes observed in field sampling**, showing that vegetation, slope, and water-line position can create predictable retention zones for pellets and other small debris.

- **Macro- and mesoplastics** (typically from end-of-life waste) tend to accumulate near **urban areas**, while **plastic pellets** (from accidental releases) accumulate near **industrial areas**.

  - **Macroplastics seem to be the main source of mesoplastics due to degradation** (75% of macro- and 96% of mesoplastics were fragments) thus their origin remains unidentified.

  - The high sediment loads of microplastics at **Antwerpen** (highest sediment load) are explicitly linked to **dense urban inputs**, suggesting the upstream, urban origin of much of the litter.

- **Temporal dynamics, tidal and seasonal influence:** Riverbank observations of macro and mesoplastics note a **seasonal difference in plastic accumulations** (lower in August, higher in December). The microplastics model adds a crucial hydrodynamic layer: **tidal mixing and resuspension** are key drivers, as concentrations increase during both ebb and flood tides, indicating the plastic is constantly being mobilised and redistributed within the system.

- **Density-Driven Distribution:** The location of different plastic types is density-driven: **PE/PP** dominated surface waters, while **PAA** was strongly associated with **sediment**.

- Both the macroplastics and microplastics transport models show that the **Scheldt Estuary acts as a major trap** for plastics of all sizes, with limited export to the sea under normal conditions. However, this export may vary in case of extreme weather events and floods.

  - The **Macroplastic transport model** states that the Scheldt Estuary acts as a **trap** for plastics, with only a small portion (6 – 15%) reaching the North Sea, resulting in an estimated total flux of around **0.6 metric tonnes per year** to the North Sea. The flux should be taken with caution as there is high uncertainty.

  - The **Microplastic transport model** confirms patterns of **retention in the Upper Scheldt** and highlights that the **historical load stored and recirculating in the estuary remains large and dynamically active**, dominating over contemporary emissions.

- There is a **high uncertainty** associated with both microplastics and microplastics models due to scarcity of data and sampling limitations.

The study confirms there is an export of plastics to the sea, however, the estimated quantities remain highly uncertain due to limited measurement coverage in time and space, strong variability in observed concentrations, and model limitations. The estimated high number of **legacy plastics** already present in the environment makes it difficult to assess new emission reductions, preventing us from making conclusions on the evolution of plastic litter concentrations in the Scheldt over the recent years.

Future perspectives

Targeting accumulation areas for mitigation efforts, such as outer river bends, industrial zones, narrowing channels, and vegetated banks would deliver efficient results for plastic pollution reduction. Cleanup campaigns could coincide with periods of high seasonal accumulation and/or periods when low water levels or tidal cycles make access to accumulated litter easier. Even more, the frequent removal of macroplastics could reduce the in-situ breakdown into smaller items (meso- and microplastics), preventing the accumulation of microplastics in the Scheldt.

The findings clearly distinguish between pollution sources (end-of-life fragments) and industrial losses (pellets). Therefore, tackling pollution at the source is key in preventing plastics' entry into the environment. Supporting the industry to follow the new Plastic Pellet Loss Regulation (EU 2025/2365) would enable stopping releases at the source. Additionally, improving waste management, developing new materials and supporting a circular economy would help prevent plastics from urban sources.

Drone imagery proved adequate as a proxy for detecting small-item accumulation and terrain drivers of retention. Supporting drone-, satellite-, and AI-based monitoring will increase spatial coverage and reduce reliance on intensive field sampling.

Because model uncertainties remain high, broader temporal and spatial datasets to improve model accuracy are important, enabling better forecasting of plastic fluxes and improved evaluation of progress toward reduction targets.

Achieving the 75% reduction goal requires a holistic strategy that implements mitigation on the entire source-to-sea continuum, while clarifying how governance boundaries affect the progress of effective measures.

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Annexes

Annex	*Title*
Annex I	D5.1 Policy brief
Annex II	Model Description Macroplastic Flux
Annex III	D2.2 Updated Data Management Plan
Annex IV	D5.2 Story Map
Annex V	D2.3 Open and FAIR data

Annex I: D5.1 Policy Brief

Available as a separate document

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. 17 pp. https://dx.doi.org/10.48470/127

Annex II: Model Description Macroplastic Flux

Available as a separate document

Wang, L.; Breugem, W.A., Koutrouveli, T.; Decrop, B.; International Marine and Dredging Consultants (IMDC): Belgium; (2025): *Macroplastic Flux from river Scheldt to the North Sea.*

Annex III: D2.2 Updated Data Management Plan

Available as a separate document

Rondelez, J.; Dhondt, C.A.L.; Catarino, A.I.; Meyers, N.; Knaeps, E.; Shettigar, N.A.; Decrop, B.; Toorman, E.A. (2025). PLASTFLOW: Data Management Plan (Deliverable D2.2). Version 2. Flanders Marine Institute (VLIZ): Ostend. 14 pp. https://dx.doi.org/10.48470/124

Annex IV: D5.2 - Story Map

Introduction

Narrative cartography has received increasing recognition as a valuable strategy in storytelling. Through situating a story in a specific visualised place, audiences' imagination can be stimulated, enhancing engagement with the narrative (Caquard, 2013; Mukherjee, 2019) and potentially improving communication outcomes.

ArcGIS Story Maps is a leading tool for web-based narrative cartography in the form of "story maps," available as a feature of the commercial web-based GIS application ArcGIS Online. Story maps can be customised with interactive maps, text, images, videos, and more to convey place-based information. ArcGIS Story Maps is known for its relative ease of use, adaptability to a wide range of spatial narratives, and sophisticated graphic interface (Caquard & Dimitrovas, 2019). In addition, this software is already widely utilised in scientific communication of environmental data (Hackney, 2022). For this reason, this platform was selected to disseminate the project's activities and findings as part of WP5: *Policy framework and policy information*.

Story map structure and contents

The PLASTFLOW story map is structured sequentially in seven sections:

1. A brief introduction to the PLASTFLOW project ("**The project**");
2. A description of the geography, history, and other features of the Scheldt estuary ("**The Scheldt estuary**");
3. An overview of the global issue of aquatic plastic pollution, followed by a review of the state of plastic pollution in the Scheldt estuary ("**Plastics in the Scheldt**");
4. A brief state of the art on relevant Flemish and EU policies and directives on aquatic and marine litter, including emerging regulations and recommendations ("**Marine policy and the Scheldt**");
5. An illustrated description of the methodologies used in the project ("**What PLASTFLOW is Doing**");
6. A summary of the major results arising from direct field observations ("**Field results**");
7. A summary of the results from numerical models of plastic dispersion in the Scheldt, calibrated and validated with field observations ("**Modelling plastic flux**").

After section 7, an illustrated timeline of major events for the project, such as partner meetings and conference presentations, is provided. The story map concludes with a collection of links referring the user to related projects on aquatic plastic pollution: the Horizon Europe-funded project **INSPIRE** (http://inspire-europe.org), the Interreg North Sea-funded project **TREASURE** (https://www.interregnorthsea.eu/treasure), and the VLAIO-funded project **SSPIRIT** (https://vito.be/en/news/seabed-satellite-vito-leads-research-plastic-pollution-innovative-detection-technologies).

Developing the story map

The VLIZ Marine Data Centre took the lead in preparing the story map. The process began with the identification of a target audience. This was determined to be policymakers and interested members of the public. Afterwards, an initial text draft was created, and a media inventory of CC-licensed images was compiled. These were incorporated into the story map to vividly illustrate and describe plastic pollution in the Scheldt estuary. As needed, interactive maps were also prepared on ArcGIS Online and embedded in the story map. In most cases, the interactive maps were derived from project data (e.g. coordinates of sampling sites). Other maps were adapted from publicly available data. For example, the map of wastewater treatment plants in the Flemish Scheldt was derived from the HydroWASTE dataset (Ehalt Macedo et al., 2022).

Project partners were regularly consulted for information and supporting materials (e.g. photos, videos) regarding sampling methods and results. Throughout the process, partners also had the opportunity to provide feedback on initial drafts for the story map. Following the last batch of results from the PLASTFLOW project, the finalised version of the story map is estimated to be published in December 2025 and can be accessed via the following link: https://storymaps.arcgis.com/stories/bcc2983772b74d7abde9867ac8587d0c.

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Annex V: D2.3 – Open and FAIR Data

General metadata of the generated data and models are made publicly available via records in the searchable MarineInfo catalogue (https://marineinfo.org/search). Micro-, meso- and macrolitter sampling data and drone observation data (except the raw images) are archived on the Marine Data Archive for long term storage and public accessibility, and data files will be linked to the metadata records.

One dataset for microlitter (Meyers et al., 2025b) and one dataset for meso- and macrolitter (Diels et al., 2025) are published in open access, with a unique persistent identifier (DOI) and data usage licence (CC BY). These field sampling data are provided in harmonised and standardised (meta)data templates, previously created by VLIZ and adapted to the PLASTFLOW project in collaboration with the project partners. These templates consider currently existing international data management guidelines and best practices and controlled vocabularies, both general and litter specific. For the images taken by the drones, general metadata is published with a unique persistent identifier for each camera type (RGB camera and multispectral sensor) separately (Van Overloop et al., 2025c&d), but raw images will remain with VITO and will be available on request. For the data retrieved from the images, data end products are made publicly available with a unique persistent identifier and data usage licence for each camera type separately (Van Overloop et al., 2025a&b). Published data of the project will only be publicly available after a moratorium period that will last until the publication of scientific results in a report and/or research article.

Metadata information on the numerical modelling of transport and accumulation of microlitter and meso- and macrolitter in the Scheldt estuary will be made available but code will not be publicly accessible. Metadata of the microlitter transport model is published with DOI (Shettigar et al., 2025) but the actual model (code on GitLab) is still under (continuous) development and will only be provided upon request with KU Leuven. Data resulting from the macroplastic transport model, more specifically time series of plastic fluxes at three transects (Doel, Wintam and Vlissingen), are archived on the MDA and published with DOI and licence (Wang et al., 2025), but the actual model is not publicly available (code with IMDC). Results of the two numerical models are made available in the final project report (**D1.2**).

An overview of the data availability can be found in **Table 15**. After publication, the field sampling data for micro-, meso- and macrolitter will also be sent to EMODnet Data Ingestion to be shown in the EMODnet product catalogue (https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog. search#/home) For the numerical models, open access data of four different external sources were used. A brief overview can be found in **Table 16**. Metadata information of the data, models and reports will be linked to the project metadata record in MarineInfo (https://marineinfo.org/doc/project/5524) and to the relevant reports or scientific articles. The story map will link to the project record and vice versa. Thus, all metadata information will be connected to each other. More information can also be found in the PLASTFLOW Data Management Plan (**D2.1** and **D2.2**), the PLASTFLOW Sampling plan (**D3.1**) and the final project report (**D1.2**).

Table 15: *Overview of the available data.*

Data	Availability	Project partners	Environmental matrix
Microlitter sampling	MDA CC BY https://doi.org/10.14284/767	VLIZ + UGent	Surface water, water column, riverbed sediment
Meso- and macrolitter sampling (including pellets)	MDA CC BY https://doi.org/10.14284/768	UAntwerp	Water column, near-riverbed water layer, riverbank
Drone observations meso- and macrolitter – raw images	General metadata available. MDA Images restricted, upon request (VITO). 2 DOIs (RGB + multispectral sensor) https://doi.org/10.14284/772 https://doi.org/10.14284/771	VITO	Riverbank
Drone observations meso- and macrolitter – data end products	MDA CC BY 2 DOIs (RGB + multispectral sensor) https://doi.org/10.14284/770 https://doi.org/10.14284/769	VITO	Riverbank
Models	**Availability**	**Project partner**	**Model variables**
Microlitter transport modelling	General metadata available. Model: first version restricted (available upon request with KUL; case per case evaluation) GitLab https://doi.org/10.14284/766 Results: publicly available in final project report.	KU Leuven	• Microplastics concentrations in suspension and deposition • Flow variables i.e., water depth and velocity • Sediment (mud and sand) concentrations and sediment bed layer thickness

Macrolitter transport modelling	General metadata available. MDA https://doi.org/10.14284/773 Model: closed (IMDC). Results: publicly available in final project report.	IMDC	Time series of plastic fluxes (macro and meso) in three transects (Doel, Wintam and Vlissingen) https://doi.org/10.14284/773

Table 16: *Overview of the third-party data used for numerical modelling (transport and accumulation of plastics in the Scheldt estuary).*

Source	Availability	Parameters used	Temporal coverage used	Geographical coverage used
Copernicus Climate Data Store - https://doi.org/10.24381/cds.adbb2d47	CC BY	Meteorological data – Wind velocity components U and V	Depends on the model time period, which is overlapping with field measurements timeline (*)	North Sea and Scheldt model domain
TPXO global dataset - https://www.tpxo.net/global/tpxo10	Open access for non-commercial use (similar to CC BY-NC)	Astronomical tidal data – Tidal elevation; flow velocities	(*)	North Sea model boundaries
E.U. Copernicus Marine Environment Monitoring Service - https://data.marine.copernicus.eu/products (Global Ocean Physics Analysis and Forecast - https://doi.org/10.48670/moi-00016)	Similar to CC BY	Water state variables – Seawater temperature; salinity	(*)	Scheldt model domain
Waterinfo (Vlaanderen) - https://waterinfo.vlaanderen.be/	Similar to CC BY-NC	Hydrological data – Discharge; salinity; water temperature	(*)	Scheldt estuary boundaries

List of acronyms

CC BY Creative Commons Attribution 4.0 International (data usage licence) https://creativecommons.org/licenses/by/4.0/

DOI Digital Object Identifier (unique persistent identifier) https://www.doi.org/

FAIR Findable Accessible Interoperable Reusable https://doi.org/10.1038/sdata.2016.18

MDA Marine Data Archive (VLIZ) https://marinedataarchive.org/

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