



ADVANCING TOWARDS LITTER - FREE
ATLANTIC COASTAL COMMUNITIES
BY PREVENTING AND REDUCING
MACRO AND MICRO LITTER

Literature review - State of the art

Microplastic sampling methods in natural water bodies

WORK PACKAGE 2 Assessing and Monitoring micro and macro litter
contamination.

ACTIVITY 2: Improved microplastics monitoring,
TASK 1 Low-cost methodology to improve microplastics sampling in water



Work package	ASSESSING AND MONITORING MICRO AND MACRO LITTER CONTAMINATION.
Activity and task	IMPROVED MICROPLASTICS MONITORING, TASK 1 LOW-COST METHODOLOGY TO IMPROVE MICROPLASTICS SAMPLING IN WATER
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1. BACKGROUND

Microplastic (MP) pollution is an increasing concern for modern society due to the continuous rise in plastic production, disposal, and accumulation in aquatic environments (Horton & Barnes, 2020). Since 1960, annual plastic production has surged from 10 million tons to 368 million tons in 2019, excluding polyethylene terephthalate fibers, polyamide, and polyacryl (Pasquier, Doyen, Kazour, et al., 2022b). At this scale, a significant consequence is the vast amount of plastic waste entering the environment, particularly aquatic ecosystems. Marine litter, including MPs, is now a global challenge, and estimating the abundance and/or distribution of microplastics in water bodies has become internationally important (Michida et al., 2019). Microplastics are likely to affect marine ecosystems and are extremely difficult to recover.

Determining the current status of distribution and quantity of microplastics in the ocean is an urgent task (Michida et al., 2019). As interest in ocean microplastics grows, institutions worldwide conduct monitoring through diverse sampling and analysis methods, gradually accumulating data. A harmonisation and comparability of microplastics monitoring results across Europe is needed.

As global interest in ocean microplastics increases, institutions conduct diverse monitoring and analysis through diverse sampling and analysis methods, and highlight the need for harmonized and comparable results (Čerkasova et al., 2023). Sampling surface water for microplastic content requires proper equipment for accurate and representative results (Sharma et al., 2024). However, differences in methodologies based on survey goals, resources, and technical capabilities limit comparability across studies. Despite longstanding concerns about microplastics (MP) in the environment, techniques and best practices for sample collection and analysis of these particles and fibers are still very much evolving (ITRC, 2023).

While the increasing threat of plastic pollution in the ocean is undeniable, a key gap remains in the implementation of effective monitoring and sampling systems. To the present, it is based on *in-situ* visual census, which requires human effort and is time-demanding. Emerging techniques, not yet widely adopted, add further challenges to harmonisation and standardisation of procedures and data comparison globally (Michida et al., 2019). There is a need for innovative tools, specially mapping strategies to enhance coastal marine litter monitoring. These effective mapping and monitoring technologies can provide scientists and policymakers with valuable insights into the distribution, density, and sources of pollution, enabling the development of targeted, efficient, and sustainable mitigation strategies.



Significant challenges remain, such as the lack of standardization in MP sampling protocols in marine environments (Barceló & Pico, 2020), essential for obtaining reliable and comparable data. Currently, inconsistencies in methodologies—such as the type of sampling equipment, mesh size of nets, and processing techniques—lead to significant variability in results. Lv et al. (2021) critically reviewed the analytical methods of MPs, including sample collection, separation, identification, and quantification. Variability in methodologies, including differences in sampling equipment, net mesh sizes, and processing techniques, results in significant inconsistencies in microplastic research outcomes.

The abundance of microplastics varies with the detection method. The choice of the sampling method is not trivial when sampling MPs as it generally defines the lower MP size within the sample. A consensus has been reached regarding the larger size limit of MPs (5 mm), but not the case with the lower size limit (Defontaine & Jalón-Rojas, 2023). The smaller size limit is defined operationally by the size of the finer mesh, sieve or filter pore used during sampling. Trawling nets classically only capture MPs greater than 300 μm (lowest mesh size), while the lowest size collected with a pumping system or bottle sampling depends on the sieve size or filter pore, which can go down to 1 μm . Therefore, and although research methods on microplastics in the environment have been reported extensively, the data on microplastics obtained cannot be comparable due to the different methods employed. It is crucial to harmonize and standardize analytical methods for microplastics as soon as possible, as the lack of common optimized and validated methodologies continues to limit the comparability of data despite extensive research on environmental microplastics (Lv et al., 2021; Sharma et al., 2024). Additionally, the development of novel methods for nanoplastic analysis remains a pressing necessity.

Other key considerations are the design of sampling surface waters, including the size and hydrology of the water body, as well as potential microplastic sources. Another recent review (Sharma et al., 2024) details the analytical tools used for characterizing and quantifying microplastic concentrations and types across various environmental matrices. It underscores the need for a multidisciplinary approach that integrates advancements in sampling, separation, and characterization techniques to improve and harmonize methodologies for microplastic quantification. Without these uniform guidelines, it is difficult to accurately assess the scale and impact of MP pollution, which in turn affects policy and cleanup decisions. Therefore, there is an urgent need to prioritize harmonised guidelines to facilitate the comparison and integration of data from global research efforts, ensuring reliable assessments to address this worldwide issue and comparability across diverse ecosystems. Implementing these harmonised procedures would enable researchers to track trends over time and across regions, evaluate the effectiveness of mitigation measures, and gain deeper insights into the sources and distribution of microplastics. The Joint Group of Experts of Marine



Environmental Protection and regional bodies, such as those implementing the Marine Strategy Framework Directive, OSPAR Convention and Arctic Council, are making efforts to establish reporting methods and guidelines for better characterizing microplastic pollution. Monitoring programmes should incorporate common research themes covering the installation of common infrastructure and the use of harmonised guidelines to development comparable scientific outputs (Bakir et al., 2024).

As a summary, random or systematic sampling ensures representativeness, and appropriate sampling points should cover different areas, including potential contamination sources (Sharma et al., 2024). Clean, non-contaminating equipment is essential to avoid introducing external microplastics. Critical steps include collecting surface water to capture floating microplastics, ensuring sufficient sample replications, using blank control samples, and preserving collected samples appropriately. Periodic sampling at the same locations for long-term studies can reveal temporal and seasonal trends. Collaboration with experts and adherence to established guidelines ensure accuracy and reliability. Developing standardized methods and harmonised guidelines for microplastic processing and analysis remains a key area for improvement. Here, in the report, we assess the state of the art concerning microplastic sampling in surface waters, both marine and freshwater.

2. METHODS OF SAMPLING MICROPLASTICS FROM AQUATIC ENVIRONMENT

In general terms, the study of microplastics in aquatic environment can be done through various sampling methods to collect particles, and its abundance is contingent upon the specific sampling methodology employed (Poli et al., 2024). When comparing methodologies for MP field collection, simplicity and accessibility, accuracy, and comparability are all important elements to consider (Mogensen, 2024). Among the most common techniques are sampling nets, such as Neuston and Manta nets, which are used to capture microplastics in the ocean's surface layer. Additionally, pumps and in-situ filtration devices or bottles allow for the collection of water at different depths, and are also used to study the vertical distribution of MP. When combined, these tools provide a comprehensive view of the presence and concentration of microplastics in the aquatic environment.

Due to the relatively low concentrations in the aquatic environment, sampling of microplastic particles generally requires large sample volumes (Löder & Gerdts, 2015a, GESAMP, 2019; Löder & Gerdts, 2015b; MSFD Technical Group on Marine Litter, Galgani, F., Ruiz-Orejón, L. F., Ronchi, F., Tallec, K., Fischer, E. K., Matiddi, M., et al., 2023). The sampling of these large volumes of water can be easily sampled ensuring solid statistical data and reducing the impact of background contamination (Defontaine & Jalón-Rojas, 2023). The most frequently methods for sampling of microplastics in surface waters are



sampling nets (e.g. Neuston, Manta or other nets) (Ermolin, 2024a; Michida et al., 2019; Pasquier, Doyen, Kazour, et al., 2022a), that allow for sampling of this large volumes of water, from the surface to the bottom layer (Kang et al., 2015; Lima et al., 2014). They are the most used devices for MP sampling and their application occurs in 238 out of 298 cases (80%), analysed in this study, a literature review carried out from up to 2024 using databases (such as Scopus, Science Direct and Google Scholar) and selecting only research studies on MPs in aquatic systems. This is also corroborated by previous studies, e.g. by (Cutroneo et al., 2020), reporting an application in 76% of the cases analysed (56 out of 74 analyzed studies) (FIGURE 1), or by (Defontaine & Jalón-Rojas, 2023), who stated that it is also the most common technique used in estuaries.

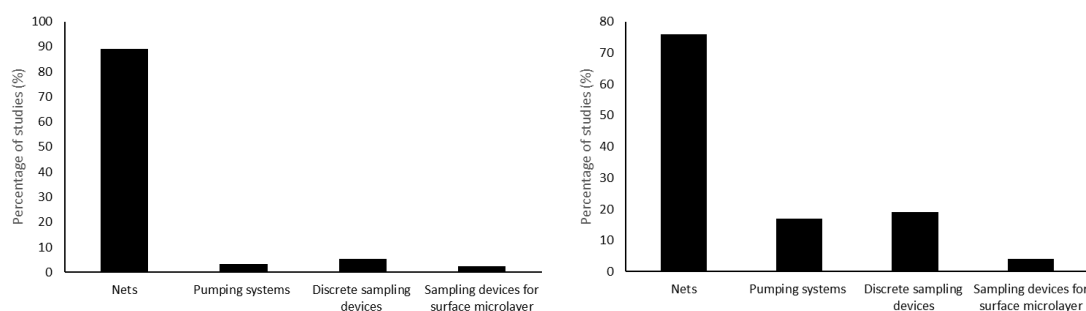


FIGURE 1. Number of reviewed studies expressed in percentage (%) in which different sampling devices are used a) reviewed in this reports and b) by Cutroneo et al., 2020 (Creative Commons BY 4.0 license).

The most commonly used mesh sizes between 300 and 390 μm (Hidalgo-Ruz et al., 2012; Li et al., 2020; Schönlau et al., 2020), an approach similar to plankton sampling, i.e., using nets of various mesh sizes to filter out particles of a certain size category (see Table 3).

In addition to neuston nets, pumps are utilized for microplastic sampling, allowing for the collection of samples from various depths, whereas neuston nets are limited to sampling the surface layer of water (up to 0.5 m) (Nayebi et al., 2023). These stationary or submerged pumps can be installed both onboard ships and onshore, pumping water through filters of different mesh sizes (Norén, F., 2007; Setälä et al., 2016; Zobkov & Esiukova, 2018), and therefore facilitating the simultaneous collection of multiple microplastic size fractions.

Although water collection using precleaned metal or glass bottles is the most straightforward method for sampling microplastics (plastic containers are not recommended to prevent contamination), and allows one to collect small microplastics fractions, one limitation of this method is the small sample volume, reducing representativeness. Alternative sampling methods include Niskin bottles (see



references in (Manbohi et al., 2021), or the use of buckets or scoops, where water is manually collected and then filtered through a sieve with the appropriate mesh size.

In-situ filtration devices consisting of a high-capacity pump associated with a filtration device (e.g. in-line steel filters, mesh bag) have shown promising results in sampling MPs. They can be equipped with a flowmeter and pressure sensor. However, such systems do not sample the surface microlayer (Defontaine & Jalón-Rojas, 2023). In this microlayer is where certain microplastics, such as polyethylene (PE) and polypropylene (PP), with a lower density than water, tend to accumulate. To specifically sample the surface layer (approximately 60 μm), a specialized rotating drum device is employed. This device collects a thin film from the water surface through surface tension forces but is only effective under calm weather conditions.

The representativeness of sampled water volume depends on the targeted MP size and concentration. For MPs larger than 300 μm , typically collected using net-based methods, when occur at low concentrations (e.g., <1 particle/ m^3), a large water volume than that collected by grab samples is necessary for representativeness (Poli et al., 2024).

Recently, new technologies have been developed to investigate microplastic pollution in a more automatic way. Automatic rosette water samplers or even ROV have been used for MP sampling in ocean waters as well as Continuous Plankton Recorder and continuous-flow centrifuges (Defontaine & Jalón-Rojas, 2023).

In Table 1, a comparison between different sampling methods for surface water sampling is summarized, while in Table 2, advantages and limitations of MP field sampling methodologies based on simplicity, accuracy and comparability are detailed (Mogensen, 2024).

TABLE 1: Advantages and disadvantages of sampling using nets, grab samplers, and pumps

Method	Advantage	Limitations
Nets	Able to analyze larger study areas and catch higher concentrations of MPs	Underestimating small particles, particularly fiber, which could easily escape
	Preferable when the MP detection is done through the naked eye	High risk of secondary MP contamination through exposure to air and net materials (nylon), e.g. from sampling vessel and tow ropes
	Low price and easy accessibility of nets with large mesh size (>330 mm)	
	Can be deployed from small to large vessels	
	Underway sampling	Less accurate reported sampling volumes due to inaccuracy of volume calculating through flow
	Use of flow meter to estimate volume	



	meters or mathematical operations Use is weather dependant Towing speed and time must be limited to avoid clogging the net and under-sampling surface waters; vessel speed may need to be restricted Under-samples material smaller than mesh size
Grabs	Could investigate the broader size of MPs by selecting smaller filters and sieves Small volumes of grabs cause high variability between samples Able to be used in an environment where net sampling is tough Able to be applied for sampling from deeper columns of water with Niskin bottles Decrease the risk of secondary pollution due to shorter contact time with the sampling compartment and using non-plastic containers Lower particle concentration compared to nets, culminating in more probable false zero reports Can be conducted by citizen science method, increasing the accuracy of sampling Appropriate reports of MP abundance in the precise volumes Non-plastic grab samplers could be heated up to 500 °C before sampling to eliminate any potential residues Difficulty in the transportation of large volumes of bulk samples to the laboratory Small volumes of grabs cause high variability between samples Lower particle concentration compared to nets, culminating in more probable false zero report Difficulty in the transportation of large volumes of bulk samples to the laboratory



	Require only one filtration, decreasing the risk of airborne contamination	
	High repeatability to assure volume accuracy	
		Risk of secondary plastic contamination through the materials of pumps, ropes, and filters
Pumps	Known volume sampled	Lower particle concentration compared to nets, culminating in more probable false zero report
	High repeatability to assure volume accuracy	
	Could investigate the broader size of MPs by selecting smaller filters and sieves	High risk of the clogging of limited filters area when a large amount of water is investigated
	Able to be used in an environment where net sampling is not applicable	Fragmentation of MPs to nanoplastics due to shear stresses caused by pumps blade

Adapted from GESAMP, 2019; Nayebi et al., 2023)

The issue of sample representativeness is indeed important from the viewpoint of analytical chemistry, and still requires special attention from researchers (Ermolin, 2024a). In general, nets provide a relatively simple and effective method for collecting large-volume water samples (over 0.5 m³), though they require a boat and have this limitation in the inability to capture smaller microplastics, particularly those less than 0.3 mm in size (Ermolin, 2024a).

TABLE 2: Comparison of the advantages and disadvantages of two microplastic field sampling methodologies (nets, grabs and pumps) based on simplicity, accuracy and comparability (adapted from Mogensen, 2024)

Field sampling	Nets	Grab	Pumps
Simplicity and Accessibility			
Flexible sampling collection	-	+	-
Low cost equipment	-	+	-
Widely available materials	-	+	-
Conductive for citizen science	-	+	-



Accuracy			
Standard sample volume	-	+	+
Comprehensive particle size range	-	+	+
Comprehensive particle morphology	+	-	+
Less susceptible to environmental variation	+	-	+
Less susceptible to secondary contamination	+	-	+
Comparability			
Broad comparability across studies	+	-	+

Another method for sampling microplastics from natural waters is continuous flow centrifugation, efficiently separating various types of microplastics ranging in size from 1 μm to 1 mm and densities from 0.94 to 1.63 g/cm³, and effective for sampling nanoplastics (less than 1 μm) (Ermolin, 2024a). However, this method requires the use of complex and expensive equipment, limiting its widespread application.

Other techniques are occasionally used for assessing MP concentrations in the water column are bulk sampling with subsequent filtration, direct *in situ* filtration (see references in (Bergmann, 2015)) or using screening Continuous Plankton Recorder (CPR) samples (Thompson et al., 2004). A highly promising technique, currently under development, is the use of direct fractionated pressure filtering of large (>1 m³) volumes of water through a filter cascade (developed by -4H-JENA engineering GmbH) (Löder & Gerdt, 2015b). This approach theoretically allows for the simultaneous sampling of different size fractions of microplastics down to <10 μm and thus enables a more comprehensive resolution of the size spectrum of microplastics (Löder & Gerdt, 2015b).

Several studies have compared manta trawl, a specific net, sampling with pump-based methods (such as plankton pumps) and bulk sampling, highlighting key differences in the concentration and types of MPs captured. The grab sampling method revealed a concentration of MPs per water volume up to two, three or four orders of magnitude higher compared to that obtained with the commonly used zooplankton methods (Manta, bongo, neuston and plankton nets). De-la-Torre et al. (2022) highlight that recent studies typically employ either surface trawling or bulk sampling methods for sampling surface MP. In surface trawling, netting bags are dragged horizontally through the water, capturing floating microplastics (MPs) larger than the mesh size while filtering large volumes of water. Conversely, bulk sampling involves collecting a large water sample, often using a container such as a 10-liter bucket with known dimensions. In general, comparisons concluded that bulk studies and *in situ* pumps report MP



concentrations thousands of times higher than trawl, while trawl studies report higher abundance of larger MPs (1–5 mm) than bulk methods (De-la-Torre et al., 2022; Schönlau et al., 2020).

Also (Poli et al., 2024) highlight this discrepancy when comparing two sampling methods (net and grab) using the same mesh size. This comparison revealed notable differences in MP concentrations. Grab samples, analyzed with a hypothetical 300 µm cut-off, showed a concentration significantly higher than the Manta net samples with 300 µm mesh size. They stated that this discrepancy arises because even a single MP in a grab sample results in a high concentration due to the smaller sample volume, whereas the Manta net samples larger volumes, making the concentration appear lower. To achieve comparable results, they suggest that grab sample volumes would need to be much larger, concluding, in agreement with comparisons of (Du et al., 2022; Montoto-Martínez et al., 2022) that grab sampling is not suitable for collecting MPs at this mesh size. However, accuracy depends on specific study needs, and using both methods strategically can improve results. Adjustments, such as modifying trawl size or increasing grab sample volume, can enhance the reliability of both approaches (Mogensen, 2024).

Shi et al. (2023) compared different common sampling devices, including a Manta trawl net, shallow-water plankton pump (SPP), deep-water plankton pump (DPP), and submersible pump with on-site filtration using 50 and 330 µm aperture size meshes, to sample MP in natural coastal water. They observed that Manta trawl and plankton pumps produced similar MP abundance ($2.0\text{--}6.0\text{ n m}^{-3}$). However, the MP characterization was significantly different, with fibers being the dominant MP in plankton samples (>70%) and only 14.2% in Manta trawl samples. Their study also highlighted the key factors that impact MP abundance and characteristics as well as the challenges to harmonizing MPs sampling methods in aquatic environments, which is also helpful for data compilation across studies.

Also (Du et al., 2022) compared a manta trawling and two newly custom-built pump filtration systems, namely, a trawl-underway pump combination system coupled in conjunction with an *in-situ* filtration device (Y-shaped filter, New Type I) and a stationary onboard pumping coupled to Y-shaped filter (New Type II). While the trawling-based systems (Manta Trawl and New Type I) covered large areas during sampling, the New Type II operated at a fixed location. The new systems enabled fractionated filtration of MPs on-site and prevented airborne contamination, and the detachable stainless-steel filters can be adjusted for specific mesh sizes. These authors highlight that the manta trawl mainly collected MP fragments, whereas the new systems primarily collected fibers, concluding that the new systems beat the manta trawls concerning capability in harvesting small items (0.1-0.3 mm) and fibers, price and performance. Similar conclusion were obtained by (Barrows et al., 2017), when comparing the effectiveness of a 0.335 mm neuston net tow with a 1 L surface grab, finding that grab samples captured three orders of magnitude more microplastics per unit of water than the neuston net tow, and minimizes contamination through proper laboratory and field



procedures. Grab sampling involves collecting a water sample in a vessel, followed by filtration under a vacuum filter, enables the detection of smaller microplastics that may not be captured by manta trawl tows (Barrows et al., 2017).

Also studies by (Barrows et al., 2017), (De-la-Torre et al., 2022) and (Schönlau et al., 2020) showed that pump-based and bulk sampling methods report significantly higher concentrations of MPs compared to trawling. However, (Zheng et al., 2021) and (Setälä et al., 2016) indicate that while pump-based methods report higher concentrations, they do not always offer the same representativeness regarding the physical characteristics (e.g., shape and size) of the MPs. Manta trawls tend to capture fragments of MPs, often larger ones (Du et al., 2022; Shi et al., 2023), while pump-based methods and surface sampling systems predominantly capture fibers, with fibers making up over 70% of the MPs in plankton samples, compared to only 14.2% in manta trawl samples (Shi et al., 2023). (Zheng et al., 2021) concluded that the choice of sampling method should be based on specific research objectives and sampling conditions, emphasizing that larger water volumes tend to provide more representative results. However, they also acknowledged that no single method is suitable for all scenarios, and a combination of methods may be necessary to achieve comprehensive results. (Yuan et al., 2022) highlight that in-line filtration methods reduce contamination risks and produce more consistent results compared to in-laboratory filtration, suggesting that in-line filtration can be an effective way to reduce contamination in water samples, though it remains a labor-intensive method. However, the significant variability in microplastic concentrations across small scale samples makes it difficult to report environmentally relevant microplastic abundances. This variability is less of an issue with manta trawls, which cover larger areas and offer better representativeness in terms of the water volume sampled, as discussed by De-la-Torre et al., 2022 and Schönlau et al., 2020.

In summary, while different sampling methods, including trawl nets and pumps, vary in efficiency and representativeness, no single method can be considered universally applicable. Manta trawls are ideal for capturing larger MPs and covering larger water volumes, while pump-based systems excel at capturing smaller MPs and fibers. As a result, manta trawls continue to be the selected method for sampling microplastic pollution in large volumes of surface waters (Gerber, 2017). The use of multiple methods in parallel may offer a more comprehensive understanding of microplastic pollution in aquatic environments, and it is hoped that issues with small-size sampling will be resolved in future studies, leading to improvements and harmonisation of protocols and guidelines (Lv et al., 2021).

The work of (Pasquier, Doyen, Carlesi, et al., 2022a) introduces an innovative approach using aquatic drones for microplastic sampling, comparing their performance with a manta net and in-situ pump filtration across aquatic environments. Their results show that drones provide better reproducibility and more accurate sampling of MPs, similar



to the performance of pump filtration methods, suggesting that drones could offer a viable alternative to traditional methods, especially in difficult-to-reach environments, while covering large areas similar to manta trawls, and therefore support the interest in using the aquatic drone that could be included in harmonised protocols for MP sampling in aquatic environments.

3. NETS FOR MICROPLASTIC SURFACE SAMPLING

Different kinds of nets can be used for sampling MP, including neuston net, plankton net, manta net, continuous net, and manual net (Cutroneo et al., 2020). Choice of net is usually determined by the intended size of the microplastic and vertical height of the water column.

For sampling floating microplastics at the ocean Surface, Neuston nets or Manta nets are most commonly used method (Bergmann, 2015; Gago et al., 2016; Gerber, 2017; Hidalgo-Ruz et al., 2012; Löder & Gerdts, 2015b) (see Table 3). As seen previously, their use allows for large volumes of water to be rapidly sampled while retaining a volume-reduced sample (Gago et al., 2016; Gerber, 2017), and is the method generally recommended in sampling guidelines, although differences between net mesh openings and towing methods have been observed between past studies (Michida et al., 2019).

TABLE 3: Methods of sampling microplastics from seawater using nets

Type of sampler	Lower size limit (µm)	Water sampled	Reference
Mazur Sampler	330 µm	Samples surface water with flow meter	NOAA, U Tacoma Washington (USA) http://www.noaa.gov/
Regular plankton or neuston nets (continuous plankton recorders)	330 µm	Samples surface water at 10 m depth	U. Plymouth (UK) http://www.plymouth.ac.uk/staff/rcthompson#
Algalita manta trawl	333 µm	Samples surface water, approx. 500 to 3000 m ³ per trawl (normally	Algalita (USA), Cefas (UK) http://www.algalita.org/index.php



		expressed by Algalita in km-2)	
Bongo plankton net	333 µm	Samples mid-depth water column samples	Lattin et al., 2004 (USA)
Plankton net	80 µm	Samples surface water 0-0.3 m depth,	Norén, 2007 (Sweden)
Zooplankton net	450 µm	Samples surface water at 0- 0.3 m depth; sampling volume 10 to several 100 m3	North Sea Foundation (NL)
Manta trawl	52 µm	Samples surface water	Kazour et al., 2019
Manta trawl	150 µm	Samples surface water	Schmidt et al., 2021)
Manta trawl	200 µm	Samples surface water	Zayen et al., 2020; Digka et al., 2018
Manta trawl	300 µm	Samples surface water	Tesán Onrubia et al., 2021; Gajšt et al., 2016; Atwood et al., 2019; Berov and Klayn, 2020
Manta trawl	308 µm	Samples surface water	UNEP/MAP, 2015; Palatinus et al., 2019
Manta trawl	330 µm	Samples surface water	Caldwell et al., 2020; Caldwell et al., 2019; Faure et al., 2015; Baini et al., 2018; Fagiano et al., 2022; Güven et al., 2017; Vianello et al., 2018; Zeri et al., 2018; Capriotti et al., 2021
Manta trawl	333 µm	Samples surface water	Ruiz-Orejón et al., 2019; Ruiz-Orejón et al., 2018; Collignon et al., 2012; Ruiz-Orejón et al., 2016; Constant et al., 2018; de Lucia et al., 2018; Gündoğdu et al., 2017; Gündoğdu et al., 2018; Gündoğdu and Çevik, 2017; van der Hal et al., 2017; Güven



			et al. 2017; Gündoğdu 2017; Tuncer et al., 2018
Manta trawl	335 µm	Samples surface water	Compa et al., 2020
Manta trawl	500 µm	Samples surface water	de Lucia et al., 2014
Manta trawl	780 µm	Samples surface water	Schmidt et al., 2018
Neuston net	200 µm	Samples surface water	Pedrotti et al., 2016; Suaria et al., 2016; Pojar et al., 2021; Aytan et al., 2016; Pojar and Stock 2019; Cózar et al., 2015
Neuston net	300 µm	Samples surface water	Oztekin and Bat, 2017
High-speed manta traw	330 µm	Samples surface water	Fossi et al., 2017
WP2	200 µm	Samples surface water	Collignon et al., 2014; Lefebvre et al., 2019; Fossi et al., 2016; Panti et al., 2015; Fossi et al., 2012
WP2	333 µm	Samples surface water	de Lucia et al., 2018

(adapted from Leslie et al., 2011; M., Baini et al., 2022, where cited references are detailed).

In general, the principal difference between the nets consists in the height of the sampled water layer: A Manta net (due to its floating parts, 'wings' or floats) is typically suited for sampling from the near-surface layer at depths of 15 - 25 cm, whereas a neuston net can operate at depths of up to 50 cm (Ermolin, 2024b; Pasquier, Doyen, Kazour, et al., 2022b). These nets are towed behind boats, and while advancing in the water surface, generally moves up and down and remains semisubmerged, collecting all microplastics larger than the mesh size of the net. According to (Michida et al., 2019), each type of net has its own features:

(1) Neuston nets can capture the ocean surface layer in wavy conditions. However, it is difficult to estimate the volume of water filtered accurately because the net's immersion depth changes constantly.



(2) Manta nets is best used in calm waters to prevent hopping on waves and damage to the device. They can maintain a constant immersion depth at the sea surface. Filtered water volume can be estimated fairly accurately providing there are no waves on the sea surface and the net maintains position. If the wave height exceeds a certain level, the net tends to jump and skip on the water surface. The floating parts are usually the main difference between different models of Manta nets outside of its dimensions. While 'wings' can provide a better stability, 'floats' can be adaptable towards the position of the Manta net in water (Pasquier, Doyen, Kazour, et al., 2022b), determining the net's submersion percentage.

(3) Moreover, for sampling at open seas, even with high waves, a Catamaran net is recommended, with shape somewhere between the Neuston Net (with a slim aluminium) and na Manta net. The catamaran is 3 m long which helps to tow it very straight through the water. The fact that the two bodies are very slim and almost completely submerge into the water avoids "jumping" on the waves. It can be operated with greatest stability even under rough conditions. The maximum speed is rated to 4 knots. The net has a relatively large opening of 40 x 70 cm. Results obtained by a Catamaran net, the shape of which lies somewhere between Neuston nets and Manta nets, were comparable to the results obtained by a Neuston net when the particle diameters were 1 mm or larger (Michida et al., 2019).

(Michida et al., 2019) recommended to report weather and sea conditions at the time of sampling along with net immersion dept assuming that either a Neuston net or Manta net will be selected based on the respective advantages and limitations to suit the purpose of the survey and conditions in the target sea area optimally. According (Kovač Viršek et al., 2016) the Manta Net is in fact an enhanced version of the Neuston Net.

Trawling speed depends on weather conditions and currents, and usually lies between 1 and 5 knots. Trawling time depends on seston concentrations and lies between a few minutes up to several hours (Gago et al., 2016; Löder & Gerdt, 2015b). Typical Neuston trawls are limited to relatively calm sea conditions and slow tow speeds.

The All-purpose Velocity Accelerated Net Instrument (AVANI) described by (Eriksen et al., 2018) was specifically designed to withstand rough seas and high speeds, which often destabilize other neuston nets, e.g. DiSalvo neuston net or Manta, causing them to leap above or descend below the sea surface. The AVANI trawl provides comparable results to traditional trawls, but functions efficiently across a wider range of environmental conditions, higher sea states and longer sampling durations. Unlike traditional trawls, restricted to sampling at speeds of 2-4 knots, the AVANI trawl can be used for long, continuous sampling at speeds of up to 8 knots by (Eriksen et al., 2018) and at rougher sea conditions than the manta and DiSalvo neuston trawls. When towed at 5 knots for 60 minutes the AVANI trawl covers approximately 1300 m², a greater surface that the 1130 m² and 1482 m² sampled by the Manta and DiSalvo nets



respectively, when towed at 2 knots for 15 minutes, being therefore recommended as an efficient tool for high-speed surface sampling (Eriksen et al., 2018).

As a simpler alternative to the Manta net, (Coyle, C. et al., 2016) designed the Low-tech Aquatic Debris Instrument (LADI), a smaller, less affordable, and easy to build alternative of the Manta Trawl, which is expensive and large. The high price and size of the Manta Trawl limits its use to funded researchers; In contrast, LADI provides the same type of data while being accessible to a broader range of users, including professional scientists but to citizen scientists.

The majority of fabricators offer designs that feature large frames with areas 900cm² according to the nets available for order compared by (Mogensen, 2024). While the frame opening is fixed by design (and problems associated with lack of harmonization will be later discussed), the net opening can vary based on the mesh size and net length, influencing the efficiency and selectivity of microplastic capture.

In addition to the previously mentioned designs, there are also do-it-yourself (DIY) options, specifically designed for educational purposes, such as those found in the webs <https://www.testingourwaters.net/> or <https://civiclaboratory.nl/methodological-projects/>.

4. LIMITATIONS OF THE MANTA TRAWL

Net-based methodologies face challenges in accurately quantifying and ensuring the representativeness of the sampled water volume (Poli et al., 2024). Manta trawls, while widely used for surface MP sampling, presents several limitations that affect precise quantification of the sampled water volume due to variable tow speeds, turbulence, and mesh clogging, which can alter water flow dynamics. Additionally, these methods may not adequately represent the true distribution of microplastics, as factors such as wind-driven surface accumulation and particle buoyancy can influence sampling efficiency. These constraints highlight the need for standardized calibration techniques and complementary approaches to improve data reliability.

4.1. Uncertainties in sampled volume estimates

In surface trawling, nets are dragged horizontally capturing floating MPs larger than the mesh size while filtering large volumes of water. Recording the exact volume of water filtered by the sampling net is a crucial aspect of quantifying the concentration of microplastics per volume unit, as nets usually travel semisubmerged. This semi-submerged position of the net at the air-water interface is a critical factor, and the uncertainty in filtered volume determination is probably the biggest unreliability in



sampling with a trawl, being an area where there is room for innovative approaches to measuring it more accurately (Montoto-Martínez et al., 2022).

Currently, the filtered water volume is usually determined using a current meter or by calculating the product of the trawl opening area and the distance towed (De-la-Torre et al., 2022). However, this approach assumes the absence of surface currents, and the direction and velocity of ocean currents are dynamic variables that can influence the actual water flow through the net. The use of commercial flow meters, often attached to a manta or neuston net, can partially mitigate this issue, telling the observer how much water has passed through the net. With this distance estimate and the width of the trawl, the “true” portion of area sampled can be estimated (GESAMP, 2019), by:

Area of water filtered:

$$A = \alpha W N_R$$

Where:

A = Area of the water filtered (m^2)

α = Flowmeter calibration factor

N_R = Number of revolutions (read from the flowmeter)

W = Width of the mouth of the net (m)

The formula for flow meter calibration:

$$\alpha = d_1/NR1 + d_2/NR2 + \dots + d_n/NRn$$

Where

$d_1, d_2, \dots, d_n$ = distance of trawling of the net for n number of tows

$NR1, NR2, \dots, NRn$ = Number of flow meter counts, for n number of calibration tows.

(Source: https://www.niot.res.in/img/tech/osstech/edited_Ocean_Best_Practice_Marine_plastics_samping_in_Open_Ocean.pdf)

The actual depth of the sampled water layer cannot be determined at any given moment as the net travel semi-submersed and weather conditions, such as waves and wind, continuously affect the height of the water layer entering the sampler (Razeghi et al., 2021), leading to significant uncertainties in estimation of filtered volumen (Poli et al., 2024).

Additionally, vertical movements of the net relative to the water surface, as well as pitching, flapping, or lateral rolling motions, can alter the effective amount of filtered water, creating discrepancies between the recorded and actual volume. Even incorporating a flowmeter, its position in the net frame does not allow the precise



volume of water filtered by the net to be measured, but an estimate must necessarily be made based on the size of the mouth of the structure, its degree of immersion and a theoretical factor, as explained in (Liu et al., 2021) and (Suteja et al., 2021).

Flowmeter placement within the net frame often leads to inconsistent volumes between replicates, reducing repeatability (Poli et al., 2024). In fact, in some of the studies where the Manta net is used with the built-in flow meter, the results are still reported per area covered (see refs in (Montoto-Martínez et al., 2022)). Besides these limitations, the use of flowmeters has spread thoroughly in recent years, being e.g. an incorporated element in 66 % of the articles analysed by (Montoto-Martínez et al., 2022), or in 47.5% of marine MP pollution studies reviewed by (Shim Won Joon et al., 2022). Even when incorporating a flowmeter, the estimates of the filtered volumes can be very disparate between replicates, and the repeatability of the volumes reported when carrying out a monitoring study can be a disadvantage of using trawls (Montoto-Martínez et al., 2022). Consequently, estimations based on flow meter data that do not account for these variables result in particle concentration calculations—whether for microplastics or neustonic plankton—that do not accurately reflect the reality of the aquatic ecosystem.

Moreover, some studies recommend to combine both sampling techniques, bulk and trawling, with differences in terms of efficiency and representativeness of the sampled area, to avoid underestimation of MPs pollution in surface water (De-la-Torre et al., 2022): if the studies aim to provide comprehensive MPs data in terms of size distribution, abundance, and morphology (bulk methods are more appropriate to achieve this) in representation of a large body of water or area (trawl methods to achieve this).

4.2. Variety of frame size

The frame of a manta net is typically made of stainless steel or aluminium to ensure that the aperture remains constant during sampling. However, the dimensions of the opening vary significantly across different studies, highlighting the absence of harmonized sampling protocols (see e.g. (Mogensen, 2024)).

The most commonly used net aperture sizes (mouth opening of net) range between 0.03 - 2 m² (Gago et al., 2016; Gerber, 2017). We explore the scientific database (Scopus®), where we made queries using the keywords “manta + microplastics” and “manta + microplastic”, and the scientific article browser (Google Scholar®), to collect articles published up to December 2024 (**Supplementary Table S1**). Articles were conserved if the Manta net was directly used in the study for sampling MPs in aquatic environments. We observed that the most common aperture size was 60 cm in width and 15 cm in height, with the width of the mouth ranging from 30 cm up to 120 cm and the height varying from 10 to 75 cm (FIGURE 2). In this way, we expand the previous review by



adding 81 papers published in the last two years to the 95 listed by (Pasquier, Doyen, Kazour, et al., 2022b) for the previous decade. Both analyses highlight the abundant literature that is being produced on this subject, which makes it even more urgent to find comparable methodologies.

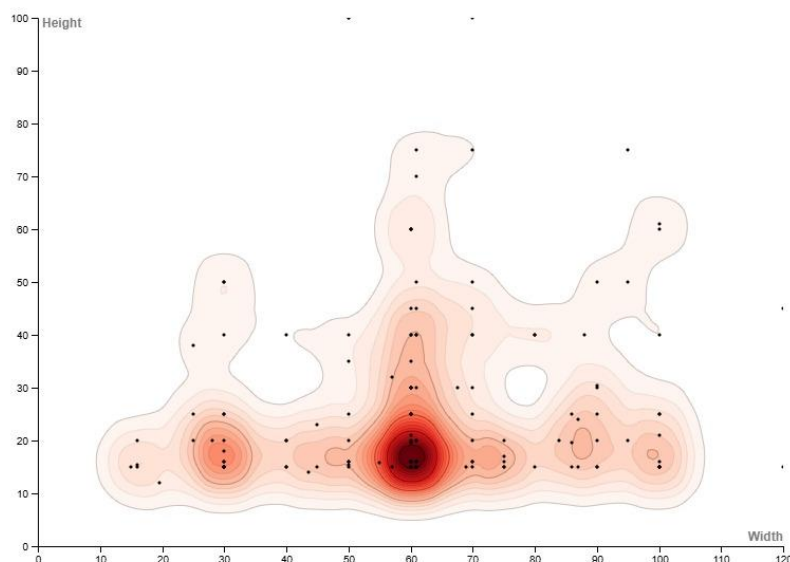


FIGURE 2 Distribution of manta height and width in the reviewed literature, including studies of both saltwater and freshwater environments.

There is significant variability among analyzed studies, along with some inconsistencies (see Supplementary Table S1). When analyzing the dimensions of commonly used sampling mantas, it is often unclear which measurement corresponds to the height and which to the width, leading to ambiguity in text interpretation. This lack of standardization has resulted in inconsistencies in the literature, e.g. as identified in the review by (Pasquier, Doyen, Kazour, et al., 2022b). For instance, this review states that (Liu et al., 2021) used a manta with dimensions of $61 \times 16 \times 300$ cm. However, upon verifying the original source, it is confirmed that the configuration used is a manta trawl with a $61 \text{ cm} \times 16 \text{ cm}$ opening and a 3 m long net, following the $W \times H \times L$ (Width $\times$ Height $\times$ Length) scheme. In contrast, when analyzing the reference to (Pan et al., 2021), (Pasquier, Doyen, Kazour, et al., 2022b) reports dimensions of $60 \times 100 \times 300$ cm using the $H \times W \times L$ scheme, as in the original publication, highlighting inconsistencies in the order of the reported variables.

Another example of this issue is found in (Aliabad et al., 2019), who reviewed various sources regarding the depth at which microplastics are collected. They cited that in (Sadri & Thompson, 2014) samples were taken at a depth of 50 cm. However, upon reviewing the original paper, it is confirmed that the manta used had dimensions of 0.50



m × 0.15 m, with the photo provided in the publication suggesting that 15 cm corresponds to the height of the device. Furthermore, the image included in the study suggests that the manta could sample at different heights, as observed in the photograph on the left.

Therefore, this lack of standardization in reporting manta dimensions underscores the need to establish uniform criteria in the literature to avoid confusion and ensure the comparability of studies, highlighting the necessity of harmonised protocols where these issues are clearly indicated.

4.3. Variety of mesh

Important parameters to be considered in selecting nets are a) mesh size, b) net aperture and c) length (Man Thaiba et al., 2023). There is a wide range of options available, and currently, no standardized methodology exists to ensure full comparability of microplastic studies. The mesh size of the net is one of the most restrictive elements of trawling nets. The use of a net for microplastic sampling is limited by the net's mesh size and often results in underestimations of MP particles smaller than the mesh size (Defontaine & Jalón-Rojas, 2023; Green et al., 2018).

The mesh size is the primary factor also influencing MP sampling with a Manta net (Pasquier, Doyen, Kazour, et al., 2022b), and greatly affecting the quantity of the collected microplastics. As the mesh size used for sampling decreases, the concentration of MPs in the sample increases. Therefore, direct comparisons between different studies that adopt varying minimum cut-offs in terms of mesh size of nets or filters, may lead to potentially significant errors in the evaluation of MPs pollution (Poli et al., 2024).

The most commonly used net mesh size is >330 µm in most surveys (De-la-Torre et al., 2022; GESAMP, 2019; Mogensen, 2024). More than 80% of field studies focus solely on sampling microplastics larger than 300 µm. Consequently, smaller microplastics—including 95% of cosmetic microbeads, synthetic microfibers, and secondary microplastics with diameters under 300 µm—are excluded from datasets and therefore, current estimates of marine microplastic pollution is being vastly underestimated (Lindeque et al., 2020).

A smaller mesh size increases resistance, which can create challenges when towing at sea or even when the ship's engine is off in the presence of strong water currents. However, one key advantage of sampling smaller fragment sizes is the collection of a toxicologically relevant fraction of macromolecular plastic material, contributing to particle toxicity assessments. Additionally, observations indicate that including smaller size ranges results in a higher particle concentration per cubic meter (particles/m³), effectively lowering the detection limits in a beneficial way (Mogensen, 2024). Conversely, the use of smaller mesh sizes may result in net resistance, clogging with



organic matter and particles suspended in the water and potential ripping of the mesh, leading to underestimates of microplastic abundance and limiting the volume of the sampled water (Ermolin, 2024b; European Commission. Joint Research Centre., 2022; Gerber, 2017).

Also (Michida et al., 2019) highlighted the importance of mesh size as a factor affecting a MP sampling. Comparing two different nets in MPs sampling, stated that, with the same mesh size, there was no statistically significant difference in the responses. (Kovač Viršek et al., 2016) provided guidelines for sampling MPs in surface waters using a Manta net and highlighted the risk of net clogging during sampling. To mitigate this issue, the authors recommended a 300 μm mesh size as the most suitable option, that was the size used by 90% of the authors according to (Pasquier, Doyen, Kazour, et al., 2022b). (Defontaine & Jalón-Rojas, 2023) recommended to deploy fine mesh trawling in relatively clear waters. In our update, with maximum and minimum values of 505 and 90 respectively (**Supplementary Table S1**) range from 300-335 was also the preferred size, being used by 81% of the studies. Although this size of mesh has been proven to underestimate the amount of MPs in both surface and subsurface water, from the viewpoint of harmonizing monitoring methods, using a net with mesh openings of about 300 μm is recommended as it is currently most commonly used method (Eriksen et al., 2018; Michida et al., 2019).

In the analysis of the risk of underestimating MP pollution when using different mesh sizes, a 100 μm mesh can collect 2.5 times more MPs than a 300 μm mesh and 10 times more than a 500 μm mesh (Lindeque et al., 2020). Comparing grab sampling versus size-selective net-based methods, the obtained stark difference in MP concentrations is explained by the size spectrum theory, or Sheldon spectrum, which states that smaller particles are more abundant in the aquatic environment due to the fragmentation of larger plastics. Grab sampling techniques target smaller MPs, which are more abundant, requiring smaller volumes to maintain sampling effectiveness. For instance, (Poli et al., 2024) reported that manta trawl sampling recorded an average of 0.24 particles/ m^3 , whereas grab sampling yielded 4050 particles/ m^3 , highlighting the smaller volume required for grab sampling. This suggests that net-based methods significantly underestimate MP concentrations, as supported by numerous studies, e.g. (Poli et al., 2024), facing challenges in accurately quantifying and ensuring the representativeness of sampled water volumes. Notably, 75.9% of MP studies rely on net tow methods, and 80% focus only on polymers larger than 300 μm , highlighting a major limitation in accurately assessing MP pollution.

Despite their challenges, manta trawls are widely used and offer better comparability across studies, which is essential for regional and global assessments. While discrete grab sampling is simpler and more accessible, manta trawls provide better comparability (Mogensen, 2024). Accuracy depends on specific study needs, and using both methods



strategically can improve results. Adjustments, such as modifying trawl size or increasing grab sample volume, can enhance the reliability of both approaches (Mogensen, 2024).

The sampled volume cannot be considered representative for the application of a 300 µm cut-off, or alternatively, grab sampling is not a suitable sampling method for larger MPs (Poli et al., 2024).

Although grab samples collected three orders of magnitude more microplastics per volume of water than a neuston net tow, the large variances of microplastic abundances between grab samples does not allow for the environmentally relevant microplastic abundances to be reported, and manta trawls remain the standard data collection techniques for surface water microplastic pollution sampling (Gerber, 2017).

Other limitation related to the mesh when sampling using trawl techniques is that these methods can cause sample contamination due to instrument and procedure design (Lv et al., 2021). The sampling device is composed by various plastic polymers, including monofilament polyamide mesh, synthetic fibers, and reinforced fabrics, which may cause contamination of the sample. Furthermore, that frames, connectors, and encode ends often contains hard plastic components, such as polyethylene, polypropylene, or polyvinyl chloride, which were frequently considered sources of contamination. Additionally, the mesh integrity must be checked frequently (Cerasa et al., 2021).

4.4. Additional factors influencing microplastic sampling

Beyond the primary considerations in microplastic sampling, other aspects related to trawling can influence the results. Specifically, variations in towing direction relative to the wind, differences in tow duration, and the position of the tow—such as conducting it at the stern—may impact sample collection (Michida et al., 2019). Net length, boat speed and the weather and sea conditions during the sampling can affect the MPs sampling and, therefore, should be noted (Manbohi et al., 2021). Additionally, data sheets generally record the start and stop time, location (latitude and longitude), wind and wave conditions during sampling, vessel speed and direction, and general details about the vessel and observer. It is highly recommended to include information on wind and wave conditions before sampling to better estimate the extent of vertical mixing in near-surface waters. These factors should be considered to ensure more accurate and representative data, and all this information could be included in published studies to enable more accurate comparisons.

Reference volumes for net-based methods are typically calculated based on trawling time and speed, with guidelines like (GESAMP, 2019) recommending 15–30 minutes at 2-3 knots, maintaining a steady linear course at a constant speed during the trawls (Kovač Viršek et al., 2016). According to these authors the ship has to sail at speed less than 2 knots, but it is dependent on wave height, wind speed and sea currents: It is



crucial to continuously monitor the manta net during sampling, and if it begins to hop, the trawling speed should be reduced. Most studies average a 20 ± 5 -minute trawling time. Studies analyzed in this work showed values ranging from 3 to 360 minutes and mean minimum and maximum values of 22 ± 1.55 and 28.4 ± 3.01 minutes, respectively (check **Supplementary Table S1**). Speed values also showed variability (check **Supplementary Table S1**), ranging from 0.2 to 5 knots with mean minimum and maximum values of 2.03 ± 0.07 and 2.50 ± 0.06 minutes, respectively. To improve representativeness and comparability of studies, future research should identify optimal water volumes tailored to sampling locations (e.g., open sea vs. high-pollution areas) and standardize methodologies for consistency across studies.

To ensure comparable results, surveys should be conducted under calm sea conditions, avoiding situations with strong winds, waves, or high plankton abundance. Half of the manta net opening should be submerged during sampling, and sea conditions influence the performance of manta nets or neuston tows, as rougher seas can cause the nets to move above or below the water's surface, leading to an unknown portion of the sampling area being missed. Besides the effect of water turbulence from waves in the volume of filtered water across time, wind and boat movement on the determination of net submersion, resulting in significant uncertainties in volume estimates. Wave action and weather conditions also affect at sea affect the suspension of the microplastic particles, and thus the results of surface water microplastics sampling: Density of microplastics at the ocean surface decreased in situations where both wind speed and wave height increased during sampling, probably due to the enhanced mixing of the ocean surface layer caused by changes in the sea conditions and the dispersion of microplastics to a certain depth. In a study carried out in the USA, the quantities of microplastics detected were different at different wind speeds (Proskurowski et al., 2010 in Leslie et al., 2010).

Therefore, sampling should be conducted in relatively calm sea conditions (Manbohi et al., 2021), with a wave height less than 0.5 m (GESAMP, 2019), or wind speed less than 2 or 3 Beaufort (<10 knots) (Kovač Viršek et al., 2016 and GESAMP, 2019, respectively). This might not be practical in areas prone to elevated wind conditions. In such situations, metadata such as wind speeds and significant wave heights should be recorded to allow comparisons with other survey results (Michida et al., 2019).

The sea state also affects surface abundance of MP by causing wind-driven vertical mixing of surface waters, downwarding flux of plastic particles deeper than the height of the manta net frame. The multilevel trawl used by (Reisser et al., 2015) to investigate the depth profile and physical properties of buoyant plastic debris, showed that plastic concentrations drop exponentially with water depth, and decay rates decrease with increasing Beaufort number.



To account for the vertical distribution of plastic particles, In cases of >10 knots, a correction factor on the MPs field data should be applied following the model described by Kukulka et al. (2012) (in Adamopoulou et al., 2021). Factors such as particle buoyancy, size, and water viscosity play a crucial role in this process (GESAMP, 2019). Also related with this, and since the manta trawl is typically towed horizontally alongside the ship using a rotatable spinnaker boom assembly, to ensure accurate sampling, it is recommended to deploy the trawl outside the wake zone. At < 4 meters away from the ship's hull turbulences can temporarily submerge floating plastics, potentially leading to an underestimation of plastic concentration (Kovač Viršek et al., 2016). On the other hand, and also vessel-related, contamination can arise from various sources, such as paint chips, fibers, or unwashed nets, potentially leading to overestimates of particle abundance. Paint chips from the vessel deck or hull are caught often while sampling, so collecting a few chips of ship paint for comparison is useful (GESAMP, 2019).

Together with wind speed, it is relevant to record different environmental parameters during the sampling such as water turbidity or wind speed, a useful form of metadata to collect when sampling surface layers of seawater (in (Leslie et al., 2011). In addition to avoiding unfavorable sea conditions, unsuitable conditions for sampling derived from high densities of natural particles or organisms, i.e. algae and plankton blooms, should also be carefully considered (Kovač Viršek et al., 2016). Seston can occasionally clog the manta net. If this occurs, trawling must be stopped immediately to prevent the loss of microplastic particles and potential damage to the net. In fact, it is recommended that the water turbidity be measured before each sampling campaign in order to adjust the Manta trawling time or distance and avoid clogging problems (Pasquier, Doyen, Kazour, et al., 2022b). When conducting a survey under unfavorable conditions is unavoidable due to characteristics of sea areas, it is desirable to consider appropriate methods such as shortening the tow duration accompanied with repeated towing, and frequently washing towing nets (Michida et al., 2019). Moreover, to enhance the precision of sample site selection and improve sampling efficiency, incorporating other environmental data—such as salinity levels, surface water temperature, currents, and bathymetry—along with a thorough understanding of potential litter sources, including tourist beaches, shipping routes, fishing grounds, and river inflows, will yield valuable results (Dhaka et al., 2022).

The necessity of reliable microplastic (MP) monitoring in aquatic environments remains a topic of debate, particularly regarding the importance of proper replication. Aquatic environments are constantly in motion, affecting the distribution of microplastics, which are small, light, and buoyant. This leads to high variability in local conditions. Discrete grab samples, due to their small volume, show significant variance in microplastic abundance, necessitating increased sample volume and more replicates for accuracy. In contrast, manta trawl samples showed greater relative variation but lower overall variability in microplastic concentration, making them less impacted by sampling



inconsistencies (Mogensen, 2024). Barone et al., 2024, also highlighted methodological weakness in surface water MP research, providing practical recommendations to enhance the reliability of environmental MP data, and underscoring the need for a robust sampling approach through sample replication, concluding that at least three replicate trawlings should be performed per site to obtain representative results (Sharma et al., 2024). To properly address and optimize this collection of replicates, the manta net could be towed from both sides of the ship simultaneously (Lebreton et al., 2019) or with paired manta as done with bongo nets or twin rigs.

5. FINAL THOUGHTS

When comparing methodologies for microplastic field collection, we saw that simplicity and accessibility, accuracy, and comparability are all important elements to consider (Mogensen, 2024). For advancing MP research, ensuring the reliability and comparability of data collected across different studies, a key objective is the establishment of joint databases that adhere to the principles of Findability, Accessibility, Interoperability, and Reusability (FAIR) is essential to inform policy and mitigation strategies (Jenkins et al., 2022).

Future directions in improving sampling methods should focus on addressing the uncertainties and the lack of harmonized protocols that currently exist. The sampling methods should be selected based on the research objectives. In this sense, it is recommended to combine sampling procedures to obtain comprehensive data (as suggested by (De-la-Torre et al., 2022)). The use of multiple methods in parallel may offer a more comprehensive understanding of microplastic pollution in aquatic environments, and it is hoped that issues with small-size sampling will be resolved in future studies, leading to improvements and standardization of methods (Lv et al., 2021). Additionally, the development of novel methods for nanoplastic analysis remains a pressing necessity.

Working with microplastic research experts and following established guidelines from environmental agencies or scientific organizations may ensure the accuracy and reliability of data collected during surface water sampling for MP, and develop harmonised protocols for microplastic sampling, processing and analysis (Sharma et al., 2024).

Aquatic environments are constantly in motion, affecting the distribution of MPs, which are small, light, and buoyant. This leads to high variability in local conditions. Manta trawl samples, due to the greater relative variation but lower overall variability in MP concentration, are less impacted by sampling inconsistencies than other sampling methods (Mogensen, 2024). Nevertheless, (Sharma et al., 2024) suggest that at least three replicate trawlings should be performed per site to obtain representative results.



The harmonization in MP sampling protocols in marine environments is essential for obtaining reliable and comparable data. Inconsistencies in methodologies—such as the type of sampling equipment, mesh size of nets, and processing techniques— should be solved to avoid significant variability in results, being recommended that they are clearly mentioned in harmonized protocols that take in consideration the specificities of the geographical location for instance.

The most commonly used methodology for sampling MP in aquatic surface are manta nets, considered to be the standard method for sampling microplastic pollution in large volumes of surface waters (Gerber, 2017). Smaller, less affordable, and easy to build alternatives with the same structure can be built as low-cost alternatives.

Another reason for this preferred use is that this method have been found to contain a greater morphological diversity of plastics, and sampling the full-range of morphological types may be an important component to identify sources of contamination of MP, as can be an important indicator of plastic origin (Mogensen, 2024). Manta trawl samples are therefore less vulnerable to environmental variation and contamination, two areas in which MP research is particularly susceptible (Defontaine & Jalón-Rojas, 2023).

The most common aperture size mouth opening was 60 cm width 15 cm height, followed by 30 vs. 15 cm, with a net mesh size is $>330\text{ }\mu\text{m}$ in most surveys. Take into account that when analysing the dimensions of commonly used sampling mantas, it is often unclear which measurement corresponds to the height and which to the width, so, when reporting manta dimensions, a uniform criterion should be used (e.g. always width vs. height), an indication that harmonised protocols should include.

Sampling smaller fragment sizes would permit the collection of a toxicologically relevant fraction of macromolecular plastic material, contributing to particle toxicity assessments and a higher particle concentration per cubic meter ($\text{particles}/\text{m}^3$), effectively lowering the detection limits in a beneficial way. However, a smaller mesh size increases resistance, which can create challenges when towing at sea or even when the ship's engine is off in the presence of strong water currents, clogging particles suspended in the water and potentially ripping the mesh, leading to underestimates of microplastic abundance and limiting the volume of the sampled water.

Manta trawls allow for a much greater volume to be collected. But one of the most significant sources of uncertainty lies in the determination of filtered volume, which represents a major source of unreliability in trawl sampling, which can influence a wide range of factors relating to sample accuracy. This is an area that offers considerable potential for innovation, with the development of more accurate methods for measuring filtered volume being a key priority for advancing the field (Montoto-Martínez et al., 2022).



When sampling microplastics, some good practices need to be applied to avoid sample contamination, as plastic particles from clothing and equipment can affect results. Trawling nets should be rinsed carefully between tows to reduce background contamination, ensuring that the rinse is done from the outside of the net and not through the net opening (Defontaine & Jalón-Rojas, 2023). In small samples, contamination can significantly distort findings. Blanks should be used to account for this. Moreover, to minimize this impact, large sample volumes are also recommended to differentiate true microplastic presence from background contamination (Mogensen, 2024). Not only in the field, it is also crucial to prevent background contamination in laboratory environments. Laboratory tools, ideally be made of glass or metal, must be thoroughly rinsed with pure water and covered with aluminum foil to avoid airborne contamination. Researchers should avoid wearing synthetic clothing when handling samples, with cotton clothing being preferred to reduce the risk of contamination (Defontaine & Jalón-Rojas, 2023).

Trawling speed depends on weather conditions and currents, and usually lies between 1 and 5 knots. Typical manta nets are limited to relatively calm sea conditions and slow tow speeds, although adaptations can be made to withstand rough seas and high speeds (e.g. AVANI). Collecting data on different oceanic and meteorological conditions, should be considered as it can be crucial for understanding the stability of the water column and, therefore, the vertical dispersion of MPs.

Another good but uncommon practice is to collect a wide range of physical parameters simultaneously to MP samples. MP abundance and distribution alone are very difficult to interpret and compare which may lead to biased conclusions. So it is highly recommended collecting additional data such as water levels, current intensity, water properties (e.g. salinity, turbidity, organic content) and weather forecast (e.g. rainfall, wind, waves) (Defontaine & Jalón-Rojas, 2023).

In addition, databases should include raw data, metadata, supplementary materials, and detailed protocols and methodologies, facilitating data sharing and integration among researchers, enabling more comprehensive analyses, fostering collaboration, and supporting the development of harmonized monitoring approaches on a global scale (Čerkasova et al., 2023).

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