Effects of microplastics on bivalves: are experimental settings reflecting conditions in the field?

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Abstract

Bivalves are the focus of experimental research as they can filtrate a broad size range of microplastics (MPs) with negative consequences on their physiology. Studies use a range of MP shapes, materials, sizes and concentrations raising the question on whether these reflect environmental observations. We review experimental studies on MPs effects on marine bivalves and contrast the MP characteristics used with corresponding data from the environment. Mussels were the most common bivalve across experiments which reflects their high abundance and broad distribution in the field. Although fibres are the dominant shape of MPs in coastal systems, most studies focus on spherules and beads whereas MP concentrations are often orders of magnitude higher than environmental levels. For higher relevance of experimental findings we recommend that maximum experimental concentrations of MPs are in the range of 100-1000 particles/L, that there is more focus on microfibers and that concentration is reported in particles/volume.

Key words: bivalves, polyethylene, polypropylene, fibres, coastal systems

Introduction

Mainly due to their small size (<5mm) (Barnes et al., 2009), widespread use and improper disposal or leakage, microplastics (MPs) are currently regarded as one of the most widespread forms of pollution (Napper and Thompson, 2019). Aquatic environments, and coastal ecosystems in particular, are especially prone to MP pollution due to intense anthropogenic activities, e.g., inflows from wastewater treatment plants, coastal landfills, industrial outfall and coastal fisheries (Garcia-Garin et al., 2019; Kazour et al., 2019; Xue et al., 2020). Investigating the effects of MP pollution on marine biota *in situ* poses many challenges associated with the effects of confounding factors that are difficult to control in the field (Lebreton et al., 2017). For this reason, the bulk of evidence on the impacts of MPs on marine organisms comes from experimental studies under controlled laboratory conditions. A focal group for such investigations are marine bivalves due to their susceptibility in ingesting MPs while filter feeding (Ward et al., 2019) and because of their importance in coastal ecosystem goods and services (van der Schatte Olivier et al., 2018a). However, to assess the impact of MP pollution on coastal marine bivalves, it is imperative to understand how relevant the conditions used in laboratory MP exposure studies are to the conditions and species observed in marine systems.

Bivalves play an essential role in ecosystem function (Dame, 1993) providing invaluable services including carbon sequestration, nutrient remediation and coastal defence (van der Schatte Olivier et al. 2018). However, different taxonomic groups can have different contribution to ecosystem goods and services. For example, mussels have the greatest potential for bioremediation as they remove the most nitrogen and phosphorus per tonne of shellfish produced (van der Schatte Olivier et al., 2018). On the other hand, clams, oysters and scallops amount to the highest percentages of global marine bivalve aquaculture (31%, 27% and 23% respectively) (FAO/ICAC, 2018a). It is thus essential to understand whether the choice of species -and studied responses- in MP exposure studies, reflects their importance to ecosystem goods and services, or is instead based on ease of accessibility and experimentation in laboratory settings.

The relevance of experimental MP exposure studies should also be assessed with respect to the characteristics of the MPs used. Field studies have shown that certain MP shapes and types tend to be more dominant in marine systems (Baldwin et al., 2020; Ekvall et al., 2019; Galaiduk et al., 2020; O'Connor et al., 2020). For instance, although a range of shapes can be found in marine ecosystems (e.g. spherical, pellets, grains and irregular fragments), fibres are the most common (Henry et al., 2019) accounting for up to 91% of all MPs in the water (Barrows et al., 2018). This is concerning as fibres are longer than they are wide, therefore, they can enter the digestive system of the bivalves when penetrating through the narrower width, avoiding the mechanisms of the bivalves to filter out particles larger than ~100μm (Sendra et al., 2021; Ward et al., 2019). Establishing whether fibres are well represented in experimental studies on the effects on bivalves is thus crucial.

It has been shown that certain bivalve species can distinguish, in the pre-ingestion level, between particle size, density and physicochemical properties (Brillant & MacDonald 2000, 2002). Similarly, oysters and mussels can reject particles depending on their surface properties (Rosa et al., 2013). In the case of MP pollution, such selective mechanisms could moderate the potential effects of MPs on organisms (Sendra et al., 2021). For experimental inference to be environmentally relevant, it is imperative that the MP material used in bivalve exposure studies is related to what is encountered as the dominant material in the field. This is particularly important because, although some polymer types seem to be dominant globally, (e.g., polypropylene and polyethylene), others have a more localised presence. For instance, additional to polypropylene and polyethylene, polystyrene is dominant in the Mediterranean whereas nylon is dominant in the North-Western Pacific (Pan et al. 2019).

Another vital information on the design of environmentally relevant MP exposure studies on bivalves is the MP size and concentration. Bivalves preferentially select and feed on particles between 1μm and 40μm in diameter (could reach up to 400μm in length) (Beecham, 2008). Particles of different sizes have a different ingestion and retention rate (Møhlenberg and Riisgård, 1978), consequently resulting in a differential response by bivalves. Bivalves also display sensitivity to the suspended particle concentration, for determining their filtration rate and pseudofaeces production (Riisgård, 2001), which could also lead to differences in their behaviour and particle selection capacity (Rosa et al., 2018). Thus the use of environmentlally relevant MP sizes and concentrations in experimental studies is critical in understanding plausible impacts of MPs on coastal bivalves.

The aim of the present review is to assess whether experimental settings reflect realistic exposure conditions faced by bivalves in the field. This will help determine whether our understanding of the effects of MP pollution is biased by potentially unrealistic study designs. To address this issue, we performed a systematic review of experimental studies assessing the impact of MPs on bivalves and extracted data on the species of bivalves used, the characteristics of MP tested, and the responses monitored during exposure. Furthermore, we carried out a meta-review (review of review papers) of the MP characteristics observed in aquatic systems; the findings were compared with the MPs used in experimental designs and the relevance of the later is discussed. Findings and recommendations from this study provide a framework for driving future work on the environmental consequences of MPs, towards settings that are more relevant to the actual exposure risks to organisms, including both bivalves and other aquatic organisms.

Methods

Extracting information from experimental MP exposure studies on bivalves

To conduct a comprehensive review on the effects of MPs on bivalves, databases and repositories were searched for relevant studies published in the period between 1989 to 2021 using keywords and applying the Boolean logic. The electronic databases used were: Web of Science, ScienceDirect and Dissertation Abstracts Online. The search was carried out by using the following progression of terms: TS= (Microplastic*OR microfiber* OR nanoplastic* OR polystyrene*) AND TS= (effect* OR impact*) AND TS= (mussel OR bivalve* OR filter feeder OR mollusc OR scallop OR clam OR oyster) AND TS= (marine system OR marine environment*) (Figure 1). The search was conducted in March 2020 and updated in September 2020 and February 2021. While we are aware of the potential publication bias towards statistically significant findings in any area of science, extending the literature search to unpublished research in a systematic fashion is challenging, in its own right, and not attempted here.

The search resulted in 378 publications on effects of MPs on bivalves which were filtered in different phases, following inclusion criteria (schematically illustrated in Figure 1). In the first phase, after dropping duplicates, titles and abstracts were screened fulfilling the first three relevance criteria (see criteria 1-3, Fig.1). The screening procedure was carried out by using the R metagear package (Lajeunesse, 2016). In the second phase, publications selected were thoroughly read and analysed, ensuring that there was a comparator and inclusion criteria 4-5 were met (see criteria 4-5, Figure 1). In the end, 68 studies which fulfilled all selection criteria were included in this review (Table S1). For each publication included in the review, the following data were extracted: year of publication (11 years), journal ID (68), organism (4 taxonomic groups), species (22), MP concentration (classified in five groups), MP size (classified in four groups), MP type (12 levels), MP shape (7 levels), and responses (217). In the case where studies investigated the combined effects of MPs with other pollutants, only the main effect of MP was included, omitting interactions with other pollutants.

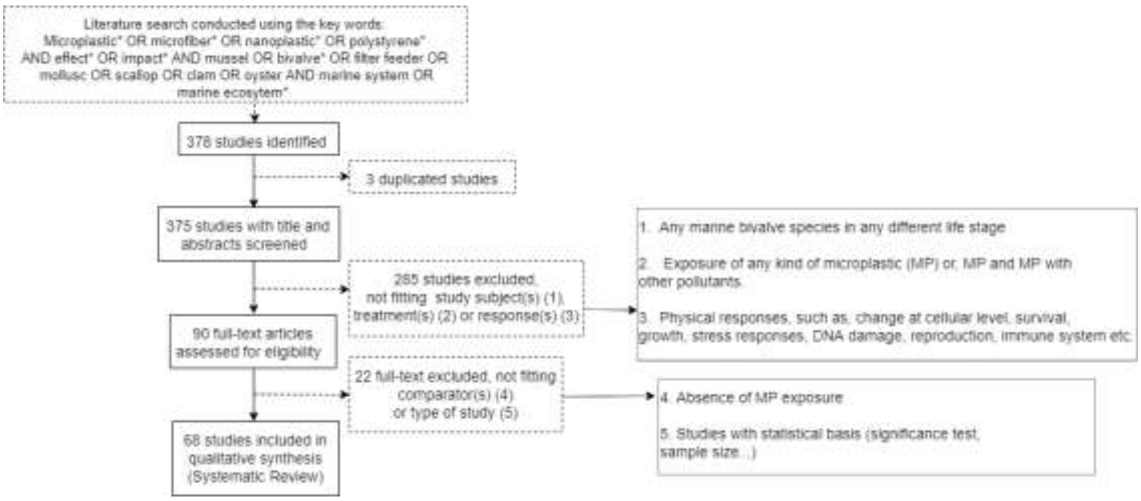

Figure 1. Schematic representation of the selection process. Numbers in brackets represent the requirements for inclusion criterion summarized on the right.

Upon extraction of the information from the selected studies, the reported 217 responses were categorised in 18 broader groups for clarity: oxidative damage, immunotoxicity, antioxidant capacity, feeding behaviour, genotoxicity, structural damage, growth, neurotoxicity, apoptosis, mortality, bioaccumulation, larval development, metabolism, fecundity, behaviour, homeostasis, microbiota and malformations (Table S2). As MP concentration was reported in particles/volume or weight/volume, a comparison between the two units of measure was not possible. However, to enable interpretation of findings, the MP concentrations of each unit type were transformed to MP/L and mg/L as appropriate and were classified in five groups (<1; 1-100; 100 to 10^4; 10^4 to 10^6; > 10^6).

This review presents the number of publications for each focal variable: bivalve species, the characteristics of microplastics tested and the responses recorded after exposure. Some studies tested the impact of MPs using multiple species, responses, and MP characteristics. As a result, the mentioned publications include multiple data entries identified with the same code.

Meta-review on environmental MPs

To enable a representative comparison and discussion on the relevance of MPs in experimental studies and MPs observed in the marine environment we conducted a literature search on review studies reporting environmental MPs published during the period 2016-2021. The reason we focused on a meta-review of existing reviews on environmental MPs was due to the high number of original research papers on the topic as well as the fact that these have already been summarised by a high number of reviews in a manner that provided useful baseline info on MP characteristics for our study (eg info on shape, size, material, concentration). The search was carried out in Web of Science using the following progression of search terms: TS= (Microplastic*) AND TS= (size OR shape OR abundance* OR composition*) AND TS= (marine environment). The search resulted in 196 reviews, from which 13 were selected according to the following criteria: (1) reviews needed to include marine surface or seawater studies and (2) reviews had to include studies on marine systems reporting MP abundance values in particles per volume. After selecting the reviews, the following data were extracted: number of publications per review, number of publications per environment within a given review, highest MP concentration (MP/L) and corresponding geographical location reported within a review, dominant polymers, shape and size range (μm) reported within a review. It has been demonstrated that most of the marine MPs are coming from riverine inflows (Lebreton et al., 2017; Meijer et al., 2019; Schmidt et al., 2017). In reviews on environmental MPs, using studies from both marine and freshwater systems, the highest concentrations reported are often from rivers. We have reported these concentrations in our meta-review table since they provide an indication of the upper threshold that MP concentration can reach in the coastal environment.

Results

Data from MP exposure studies on bivalves

The analysis of the responses of bivalves to MP exposure was assessed with a group of 68 publications out of which 67 were published from 2008 onwards (Figure 2).

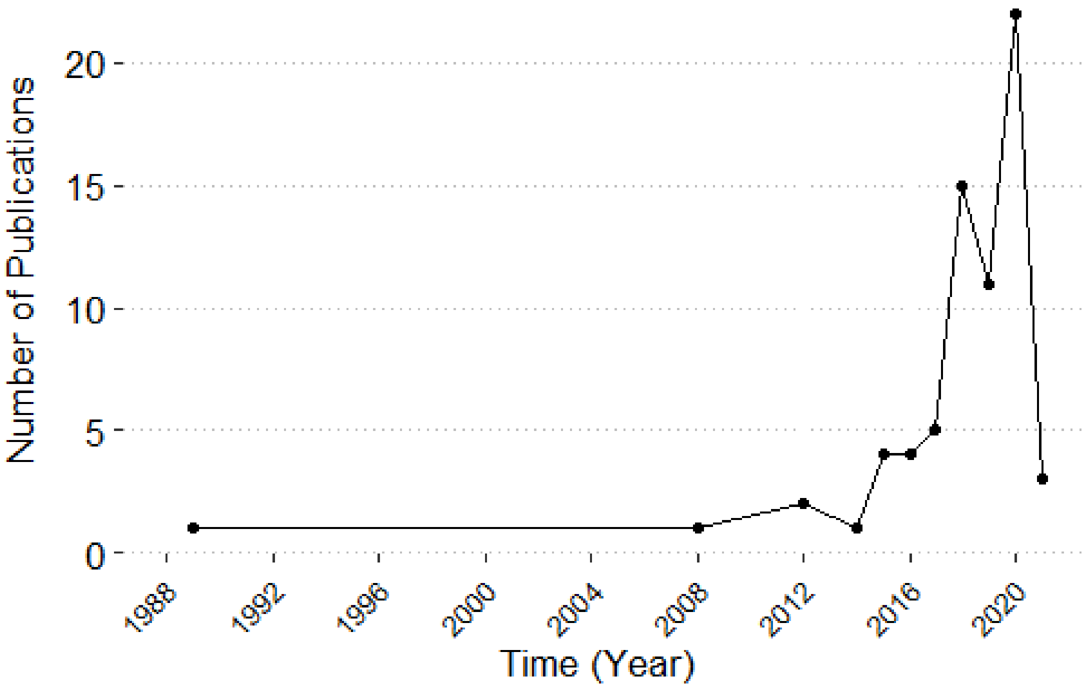

Figure 2. Number of publications included in this review that investigate the effects of MPs on bivalves in laboratory settings from 1989 to 2021.

The most frequently used taxonomic group in experimental studies were mussels (n=42, 62%) followed by oysters (n=13, 19%), clams (n=11, 16%) and scallops (n=3, 3%). Overall, 22 species, from the 4 taxonomic groups were used in the experiments. Specifically, 36.4% of species were mussels, 31.8% clams, 18.2% oysters and 13.6% scallops (Figure

3). The most abundant species within each group were the mussel *Mytilus galloprovincialis*, oyster *Crassostrea gigas*, clam *Tegillarca granosa*, and scallops *Chlamys farreri, Argopecten irradians* and *Pecten maximus*.

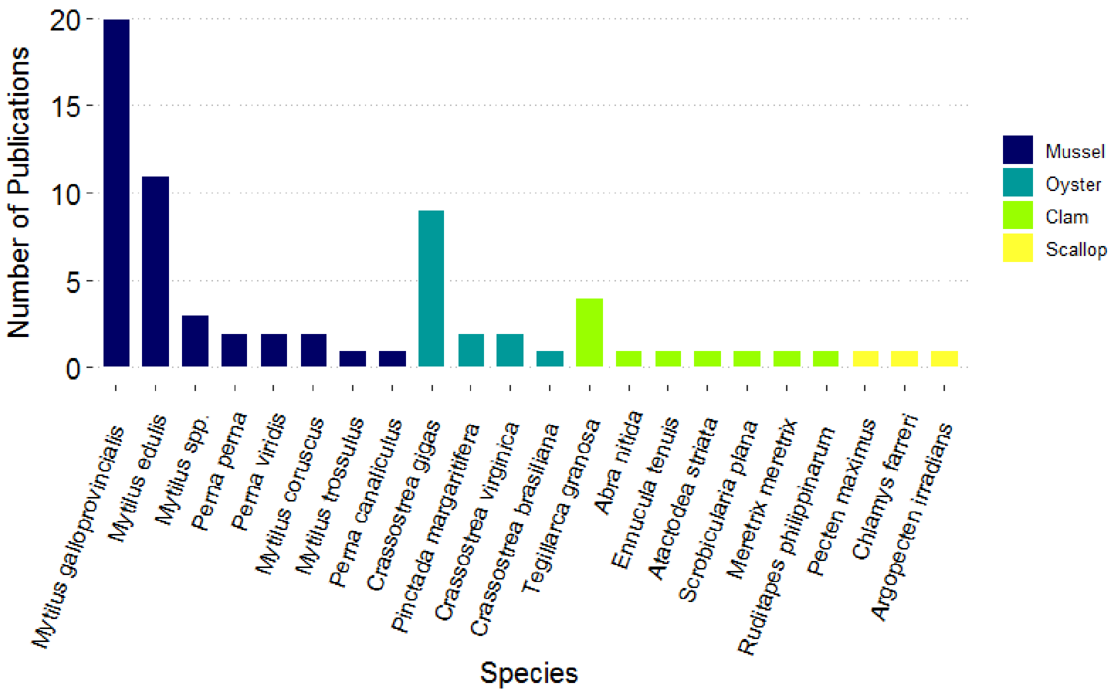

Figure 3. Number of publications, from 1989 to 2021, investigating the effects of MPs on bivalves in laboratory settings across the different bivalve species used in the experiments.

Bivalve responses to MP exposure that were more frequently investigated included immunotoxicity (n=25), oxidative damage (n=23), genotoxicity (n=21), structural damage (n=19) and antioxidant capacity (n=19). Mussels were the most dominant taxonomic group across the different response groups (Figure 4). Regarding the other bivalve taxonomic groups, clams were used to study 12, oysters 13 and scallops 7 out of the 18 response groups (Figure 4). Six out of the 18 response groups have been tested with all bivalve taxonomic groups and these were growth, genotoxicity, antioxidant capacity, oxidative damage, structural damage and immunotoxicity.

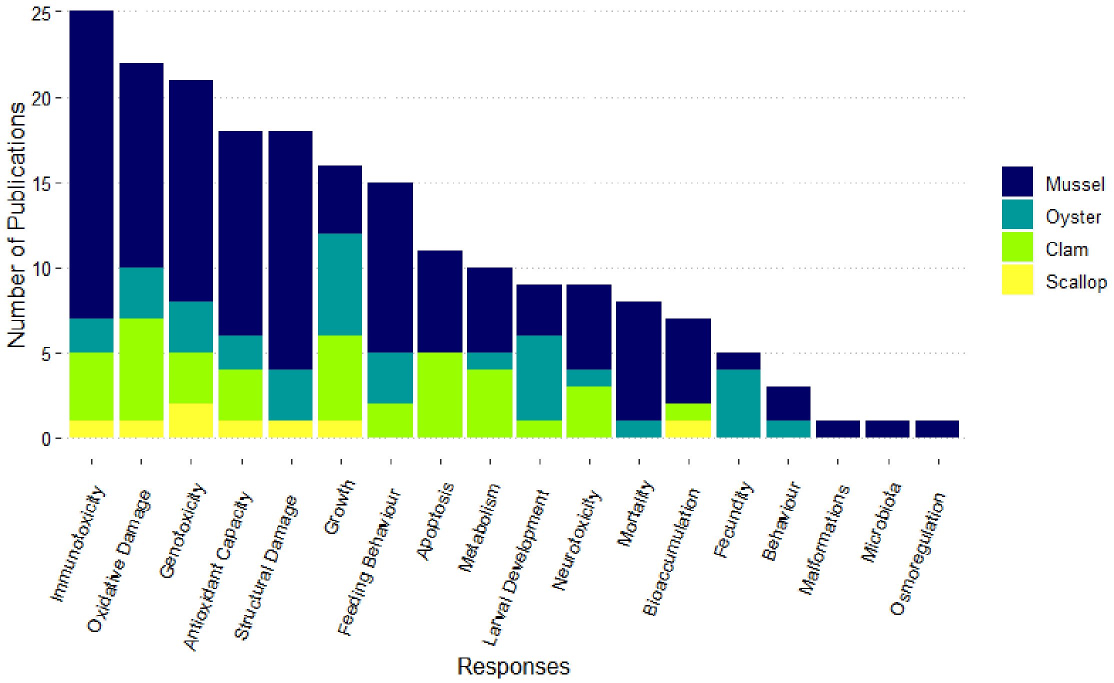

Figure 4. Number of publications, from 1989 to 2021, investigating the effects of MPs on bivalves in laboratory settings corresponding to the responses of bivalves to MPs, categorised in 18 groups, and the preponderance of different bivalve taxonomic groups that the responses were studied on.

In terms of the MP used in exposure experiments, bead/spherules (n=33) and unknown shapes (n=23) were the most used, whereas only 4 trials used fibres (Figure 5A). Regarding the composition of the MPs used, polystyrene (PS, n=36) and polyethylene (PE, n=15) were the most common types (Figure 5B).

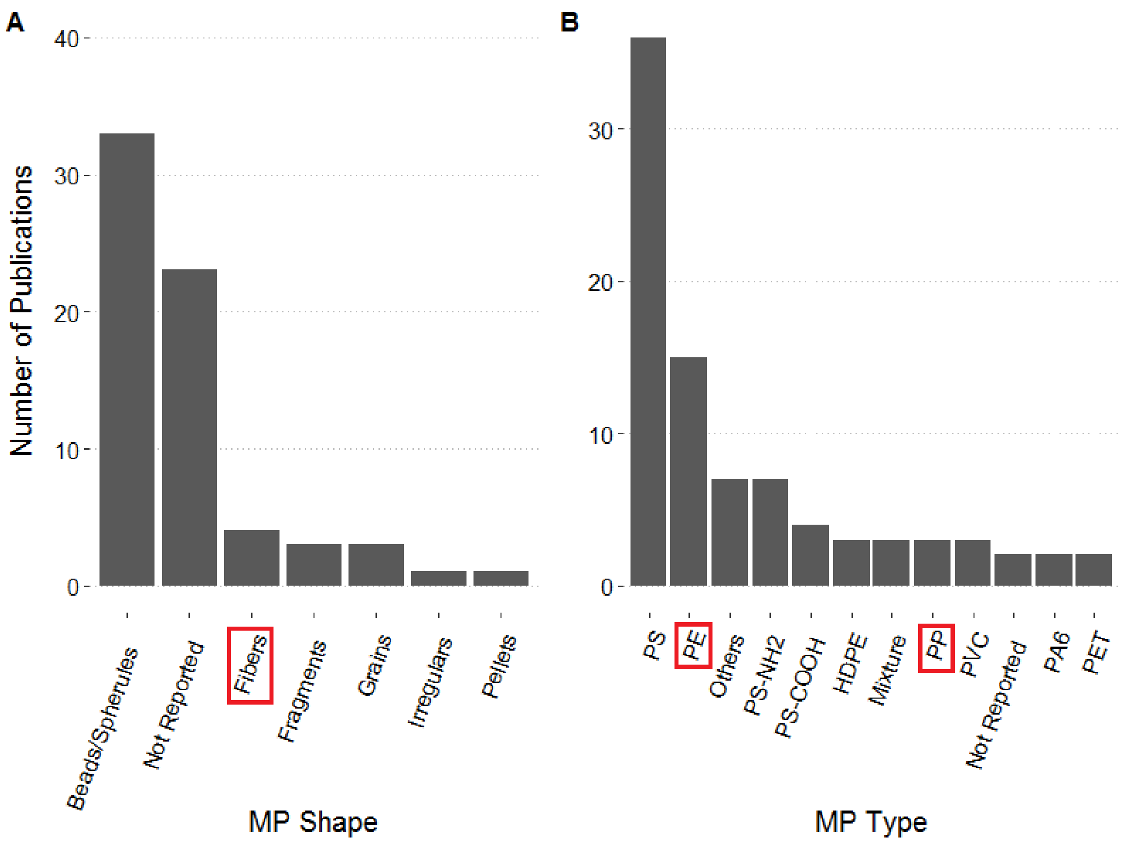

Figure 5. Number of publications, from 1989 to 2021, investigating the effects of MPs on bivalves in laboratory settings by microplastic shape (panel A) and material (panel B). Red rectangles represent the dominant MP groups in the marine environment based on our meta-review (see Table1). Meaning of acronyms: polystyrene (PS), polyethylene (PE), amino-functionalized polystyrene (PS-NH2), carboxyl-functionalized polystyrene (PS-COOH), high-density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC), Nylon 6 (PA6), polyethylene terephthalate (PET).

The most common size group of MPs used in laboratory studies was <10µm (n=41) from which 13 were nanoplastics (0.002-1µm). Only a single study exposed bivalve to particles >500µm (Figure 6A). Experimental studies reported concentration of microplastics in two different ways: particles per volume (n=27) or weight per volume (n=67), which prevent direct comparisons between them. In relation to particles per volume, most studies used concentrations between 10^4 to 10^6MP/L (n=12) whereas the next most used concentration group was that of the lower range, 10^2 – 10^4MP/L (n=8). The most used concentrations of weight per volume were <1mg/L (n=33) followed by 1 to 100mg/L (n=18) (Figure 6B).

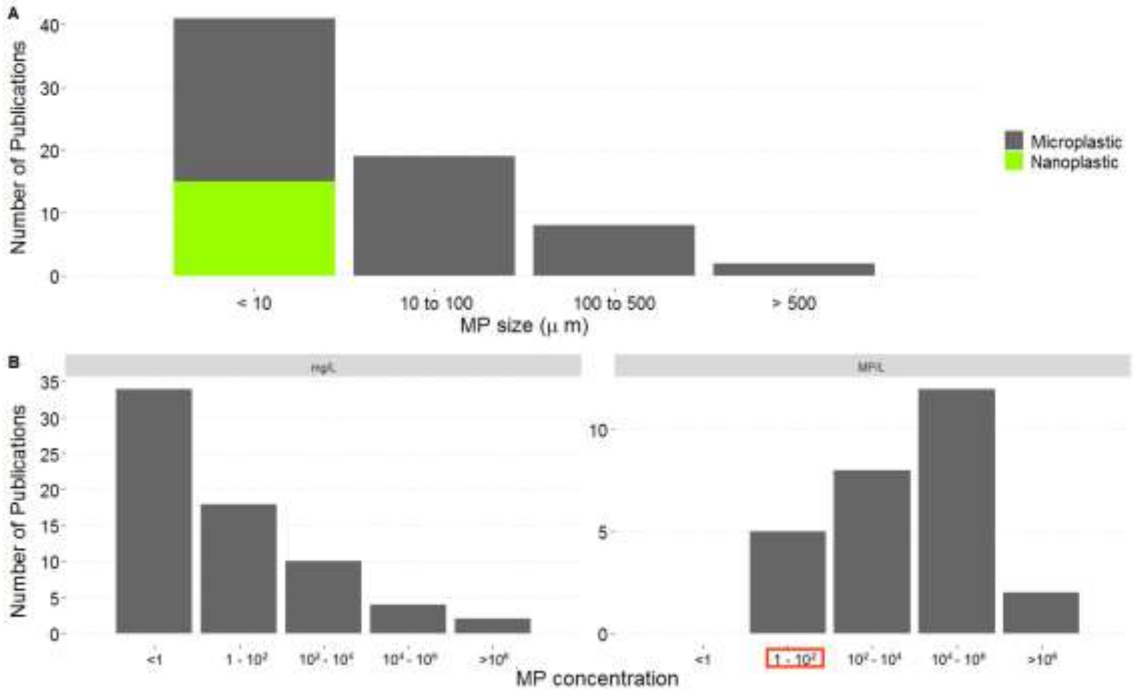

Figure 6. Number of publications, from 1989 to 2021, investigating the effects of MPs on bivalves in laboratory settings by MP size (panel A) and concentration based on both units (mg/L and MP/L) reported in articles (panel B). Red rectangle in panel B represents the dominant MP concentration class in the marine environment based on data compiled from our meta-review (see Table 1).

Data from review papers on environmental MPs

In terms of MPs presence in the natural ecosystems, a summary of the meta-review articles revealed that the most common MP polymers found in marine systems were polypropylene (PP) and polyethylene (PE). Regarding shape, fibres were the dominant group in marine ecosystems (Table 1). In terms of the MP dominant size, this varied from 1.2 to 5000µm (Table 1). With respect to the abundance of MPs in the environment reported in these reviews, the highest MP concentration was 102 items/L located in Stenungsund Harbour, Sweden (Table 1).

Table 1. Summary of different MPs characteristics reported within the 13 review papers selected from our systematic meta-review. Location refers to the place where the highest MP concentration [MP] was found. Polymers, shape, and size range refer to the dominant MP group(s) identified by each review. Note that highest concentrations

reported for a freshwater system e.g., a canal, indicate the upper threshold of concentration of marine papers examined within the same review.

Nº of publications per review	**Nº of publications per ecosystem**		**Highest [MP] (MP/L)**	**Geographical location of highest [MP]**	**Polymers**	**Shape**	**Size range (µm)**	**Reference of review paper**
	Marine	**Freshwater**						
59	9	6	1.215	South Easter bays of South Africa			1.2-5000	(Alimi et al., 2021)
18	7	-	0.0035	Bay of Biscay, Spain	PE>PA>PES	Fibres	250-2000	(Mendoza et al., 2020)
12	6	-	6.6	Yangtze Estuary, China		Films>Fibres		(Tang et al., 2020)
>61	23	38	21.839	Rhine-Ruhr, Germany	PP>PE>PVC>PS >PTFE	Fibres		(Xu et al., 2020)
>200	<113	<57	8.369	Lake Yenogoa, Africa	PE>PP>PS		1.2-5000	(Akdogan and Guven, 2019)
180	-	-	100	Canals of Amsterdam				(Cunningham and Sigwart, 2019)
12	7	-	6.6	Yangtze Estuary, China				(Laskar and Kumar, 2019)
38	12	12	102	Skagerrak, Norway/Denmark	PE>PP>PS	Fibres>Fragments		(Wu et al., 2019)
109	58	10	100	Canals of Amsterdam	PE>PET>PA>PP >PS>PVC>PVA	Fibres>Fragments>Beads>Spherules>Films>Foam		(Burns and Boxall, 2018a)
52	43	-	2.4	Swedish West Coast	PP>PE		500-1000	(Gago et al., 2018)
>70	-	-	2.8	Hong Kong	PE>PP>PS			(Shahul Hamid et al., 2018)
13	13	-	10.2	Yangtze Estuary, China		Fibres>Fragments>Beads		(Salvador Cesa et al., 2017)
-	-	-	102	Stenungsund Harbour, Sweden				(Norén, 2017)

*PE – polyethylene; PA – polyacrylamide; PP – polypropylene; PVC – polyvinylchloride; PS – polystyrene; PET - polyethylene terephthalate; PES- polyester; PVA – vinyl alcohol; PTFE– polytetrafluoroethylene.

Discussion

This is the first systematic review evaluating the environmental relevance of laboratory studies assessing the effects of MPs on bivalves. Our findings and suggestions draw an outline for future, environmentally meaningful, studies on the impact of MP on bivalves. Moreover, this review identifies issues, such as unit disagreement between published works and the lack of reported information when reporting results, which limit our ability to evaluate the extent of the marine bivalves' vulnerability to MP pollution as well as hinder our ability to interpret and compare results between studies.

Relevance of bivalve species and responses tested in exposure studies

Our findings show that 62% of the reviewed studies were focused on assessing the impacts of MP on mussels. Within this taxonomic group, species from *Mytilus* and *Perna* genera predominated in experimental studies. Preference for this group was also evident in the responses to MP exposure tested as mussels were the only bivalve taxonomic group present in all responses. Moreover, 17% of the responses were investigated solely on mussels. We can consider the use of mussels as environmentally relevant since they are the most dominant bivalve group in marine ecosystems globally (Gosling, 2003) and were shown to have the greatest potential of bioremediation (van der Schatte Olivier et al., 2018). Species of the genus *Mytilus* predominate in communities with cool water in the northern and southern hemispheres whereas species of the genus *Perna* have a tropical to subtropical distribution in the southern hemisphere (Gosling, 2003).

After mussels, oysters and clams were the most common bivalve groups in studies, used in 72% and 61% of all responses tested, respectively. Effects of MPs on growth were tested on both organisms, while oysters predominated in larval development and fecundity testing. This is presumably because of their greater economic importance (Gosling, 2003), as in 2018 it was estimated that the aquaculture of marine oysters and clams together was worth $7.27 billion (FAO/ICAC, 2018b). Despite the great economic value of scallops - $5.84 billion in 2018 (FAO/ICAC, 2018b) - they were the least studied group, present in 39% of all responses tested. A reason for their lower presence could be that most scallop species are found at depths between 10 and 100m in bays and open coast sites (Gosling, 2003) and are thereby harder to access. That fact could also complicate their maintenance in laboratories (Lusher et al. 2017, Gosling 2003) and therefore causing bias against their selection for experimental studies.

Environmental relevance of MPs used in exposure studies

To evaluate the environmental relevance of experimental studies, we conducted a meta-review of recent reviews assessing the characteristics and concentrations of MPs in nature. Since 48% of the studies included in this review do not report the MP shape used in experimental trials, drawing conclusions is challenging. Among studies reporting shape, beads/spherules were the most common MP debris. One of the main reasons, for the preference of spherical MPs is their uniform size and shape which facilitates particle identification and quantification compared to irregular debris, such as fibres (Ward et al., 2019). Furthermore, microfibers are not readily available in the market and their generation, within a consistent size range, is strenuous and time-consuming (Christoforou et al., 2020; Cole, 2016). However, there are clear arguments beyond convenience for including different shapes of MPs in experiments, such as, abundance in coastal environments or noxious capacity. According to our meta-review of 13 review papers of environmental MP characteristics, fibres are the most common shape, as concluded in 5 of the reviews, constituting up to 80-90% of all global water samples (Barrows et al. 2018). A reason for their abundance could be the increase in their demand: the latest World Apparel Fibre Consumption Survey reveals that the use of synthetic fibre for textile industry has increased substantially from 2005 to 2008 (FAO/ICAC 2005). These fibres enter the aquatic environment through garment washing and improper filtration of wastewaters (De Falco et al., 2019). Fibres are not only abundant in aquatic environments but also inside bivalves collected from the wild (Sendra et al., 2021). In addition to their abundance, fibres have proven to be more damaging than other shapes due to their elongated shape and thus their capacity to be ingested by bivalves despite their length (Beecham, 2008). Studies reveal that fibres are more toxic compared to spherical and fragmented MPs (Gray and Weinstein, 2017; Lehtiniemi et al., 2018). Therefore, we emphasise the urgent need for more studies focusing on the effect of microfibers on bivalves.

Apart from the shape, the composition of MPs was another characteristic evaluated for environmental relevance. Our findings showed that 43% and 18% of exposure studies used polystyrene (PS) and polyethylene (PE) respectively. However, according to the environmental MP reviews, PE and polypropylene (PP) have been considered as major sources of MP pollution in the aquatic ecosystems investigated, and these materials constituted 36.4% of the European plastic demand in 2017 (Association of Plastic Manufacturers, 2017). Nevertheless, a recent meta-analysis of distribution of plastic types suggested that the relative abundance of polymer types is not uniform across ocean zones. The study points out that low density polymer types, such as PE, are more common in surface waters, whereas PP and polyester are more dominant in intertidal areas and polyamide and acrylic in subtidal areas (Erni-Cassola et al., 2019). With the exception of few deep-sea species, most marine bivalves used in the exposure studies reviewed were shallow estuarine and coastal species (Dame, 1993). Therefore, to enable more relevant inferences of bivalve exposure to the dominant polymer we recommend a shift of focus from PS and PE to PP in experimental studies.

Finally, we determined the environmental relevance of MP size and concentration used in bivalve exposure studies. Particles <10µm were used in 69.4% of the studies from which 32% were nanoplastics (<1µm). Importantly, there is currently no consensus on the most common size range of MP in aquatic habitats and this could be attributed to the limitation in collection and quantification methodologies of smaller MPs (Covernton et al., 2019). However, Cai et al. (2018) observed that MP smaller than 300µm contributed 92% of the total MP quantified in South China Sea and last estimates relating to the abundance of MP in the marine environment suggest that the amount of nanoplastics could be much higher than previously thought (Lindeque et al., 2020). In terms of bivalve retention efficiency a study on 13 species of bivalves showed that all particles larger than 4µm were ingested but the retention efficiency of any smaller particles was decreasing the smaller the particles were (Møhlenberg and Riisgård, 1978; Rosa et al., 2018). This is attributed to the selection properties of the bivalve gills as small particles can pass through the intrafilamentary gaps, and are thus not retained on the surface of the ctenidium from where particles are usually directed to the food grove

(Christoforou et al., 2020; Rosa et al., 2018). However, in this review it was evident that, in 16 studies, nanoplastics were still able to induce responses from the exposed bivalves. Thus, regarding the environmental and biological relevance of the MP sized used, we conclude that the focus of exposure studies on nanoplastics is relevant.

During the last years, one of the most controversial topics in MP research (Burns & Boxall 2018, Haegerbaeumer et al. 2019) has been the use of high MP dosages in laboratory exposure studies. Our meta-review regarding the environmental levels of MPs, revealed that the highest MP concentration recorded in aquatic environments was 102 particles/L, in Skagerrak, at the coastal waters of Norway and Denmark. Similar values to this level have been used as a reference to environmentally relevant values for MP concentration in other studies (Bour et al. 2018, Woods et al. 2018). Based on this threshold, 81.5% of the bivalve exposure studies (reported in particles/volume) reviewed here, would be above realistic limits for environmental concentrations. MP concentrations that are orders of magnitude higher than the maximum reported concentrations from the field could exacerbate the MP impacts and have a questionable biological meaning. On the other hand, using in bivalve exposure studies, the maximum concentration reported from the marine environment and perhaps up to one order of magnitude higher (100-1000 particles/volume) might be sensible given that MPs accumulate much faster than they biodegrade in the marine environment thus concentrations is coastal ecosystems are expected to rise.

Consensus regarding MP research

Another issue faced by researchers in the MP research field is the inconsistency in the units for reporting MP concentrations. In exposure studies, the MP concentrations are reported in particles/volume or weight/volume while environmental concentrations are typically reported in items/area or items/volume. Unfortunately, there is no direct conversion between these units which prevents us from assessing the environmental relevance of studies and prevents the comparison between findings and conclusions. Hence, we highlight the need for consensus in reporting units for future research. Specifically, we recommend using particles/volume as this is the most frequently reported unit and also enables – when the material and the size are provided - to calculate the weight/volume but not vice versa.

Furthermore, 23% of bivalve exposure studies did not report critical information on the MP characteristics like shape and type. Due to the now established impact of shape and type on the response of exposed bivalves but also for allowing for replicability of experimental procedures, it is essential that MP characteristics are provided in detail.

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Author Contributions

EB: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization

EC: Conceptualization, Methodology, Writing-Original Draft, Writing-Review & Editing, Visualization, Funding acquisition

JL: Conceptualization, Methodology, Writing-Review & Editing, Supervision

SS: Conceptualization, Methodology, Writing-Review & Editing, Supervision, Project administration

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