Interaction Mechanisms Between Marine Sponges (Porifera) and Microplastics: A Bioecological Overview

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Abstract. Microplastics, plastic particles measuring less than 5 mm, have become one of the main pollutants in marine ecosystems, with significant impacts on marine organisms, including sponges. The filter-feeding capacity of marine sponges allows not only the intake of nutrients but also the unintentional uptake of microplastic (MP) particles. This may lead to physiological disturbances, cellular stress, and altered ecological interactions with their environment. However, the extent to which sponges interact with microplastic contamination remains largely unobserved and poorly understood. This study aims to explore the bioecological response of marine sponges to microplastic contamination. This study is a reflection of the literature with the This study used Systematic Review method using the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines to examine the interaction between marine sponges (Porifera) and microplastics. Data sources were obtained from the Scopus database. The search was conducted using the keywords "sponge" and "microplastics". which includes inclusive and exclusive criteria. Inclusion criteria for articles: 1) availability of complete libraries; 2) discussion of sponge interactions with microplastics; 3) articles from 2014-2025. Exclusion criteria are: Exclusion criteria are: 1) theses, books, observation articles, final assignments, review papers. The synthesis results show that sponges have a significant capacity to capture and store microplastics, making them an important component in the study of micropollutant dynamics in the marine environment.

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1 Introduction

Plastic waste contributes approximately 80% of total marine pollution, with approximately 8 to 10 million tons entering the oceans annually. Plastic waste consists of macroplastics and microplastics. Plastic can entangle animals, restrict movement, and cause serious injury. Many organisms accidentally ingest plastic because it resembles their natural prey. This ingestion risks irritation and damage to the digestive tract, impaired food intake, and reduced reproductive function [1]. Microplastics (MPs) are plastic particles with a diameter of 1 µm and 5 mm that can be found in terrestrial and marine ecosystems. The persistence and abundance of MPs have received worldwide attention as an environmental threat, especially to aquatic environments.

Filter-feeding organisms have long been used as bioindicators of marine pollution. This is due to their sessile nature and ability to continuously filter large amounts of suspended particles, including phytoplankton, detritus, and microscopic contaminants from the air column [2]. This ability allows for the accumulation of various pollutants, including microplastics, within their body tissues, thus representatively reflecting the environmental conditions in which they live. The primary focus of most microplastic research to date has been limited to economically valuable marine organisms, particularly those consumed by humans, such as fish and bivalves [3]. This dominant economic perspective overlooks the importance of other groups of organisms that play significant ecological roles but have not been widely studied in the context of microplastic contamination [4]. One group of organisms with significant potential but which has received little attention in microplastic studies is the marine sponge (Porifera).

Sponges are geographically and spatially cosmopolitan and occur in shallow water reefs, deep-water habitats, hydrothermal vents, polar regions, and in many freshwater systems. Sponges have a body that is made up of a system of pores, channels, and spaces. Sponges are simple multicellular filter-feeders that generate water flow through an aquiferous system by means of water-pumping flagellated cells (choanocytes) [5]. Water will be easy to flow in and out continuously. Sponges suck and filter water through their entire body surface to obtain food. Their high sensitivity to environmental changes and their relative abundance in benthic ecosystems [1]. However, the use of marine sponges as bioindicators of MPs has hardly been investigated and there is limited information about marine sponges that enable us to understand if these organisms are capable of reflected the environmental quality of aquatic ecosystems and if they could be used as bioindicators for MPs.

Sponges, as active filter feeders in benthic ecosystems, are highly susceptible to the accumulation of microplastic particles, yet they are rarely the primary focus of contamination studies. This study seeks to fill this gap by evaluating: (i) whether the amount of microplastics found in sponges differs significantly from that in other filter feeder organisms; and (ii) whether the physical characteristics of microplastics, such as shape, size, color, and polymer type, show variation between species. This review aims to provide a critical synthesis of microplastic contamination in marine organisms, particularly those with strategic ecological roles such as sponges, while also comparing the profiles of microplastics accumulated in various types of filter feeders.

2 Materials and method

2.1 Literature selection

This study is a literature review to examine microplastic contamination in sponge (Porifera). The article data obtained include articles searched through Scopus (https://www.scopus.com/). We also expanded our literature search to include additional databases: Google Scholar (http://scholar.google.com) from 2014-2025 research has been conducted in Indonesia by adding the keyword 'Indonesia'.

2.2 Data Criteria

The data of this literature review refers to the Preferred Reporting Items for Systematic Review (PRISMA) guidelines which contain inclusive and exclusive criteria. Data search the literature was identified based on search keywords, namely 'sponge' and 'microplastics', which obtained a total of 101 references as of July, 2025. The list of data obtained was then manually filtered based on the research title, year of publication, full article/open access. To carry out this filter, inclusive and exclusive criteria were created. Inclusion criteria for libraries: 1) availability of a complete library; 2) discussion of sponge interactions with microplastics; 3) librarians from 2014-2025. Exclusion criteria are: 1) theses, books, observation articles, final assignments, review papers; 2) multiple publications. Then the library filter analysis was carried out with the alignment of topics, backgrounds, objectives, research methods to results and discussions. The following information was obtained from each article: species, sampling location, method, tools and materials, influence, microplastic shape, microplastic color, microplastic size, microplastic polymer, microplastic concentration.

2.3 Extraction Data

Each article identified from the Scopus database is then curated according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Then, it is manually re-examined to ensure its compliance with the specified topic and inclusion criteria. After the curation process is complete, the compiled bibliographic data is analyzed using a bibliometric approach. This analysis is performed through biblioshiny, a graphical interface of the bibliometrix package in RStudio, with the syntax *library(bibliometrix)* followed by *biblioshiny()* to run the platform. This approach allows for the visualization of publication trends, and journals systematically based on structured data.

3 Results and discussion

Our literature review identified the number of studies on microplastics in sponges. The trend in the number of studies is shown in Figure 1. Next, we examined the annual trend in publications related to microplastics based on keywords.

The number of articles published on this topic showed a consistent upward trend from 2019 to 2023. In 2019, the number of publications was small, indicating that this issue had not yet become a major focus among academics. Significant growth began in 2020, then accelerated in 2021, and peaked in 2023 with the highest number of articles in the past five years. In 2024, the number of articles decreased, although it remained higher than at the beginning of the period. This pattern reflects increasing scientific attention to this issue before experiencing a slight decline, likely due to a change in research focus or challenges in publication.

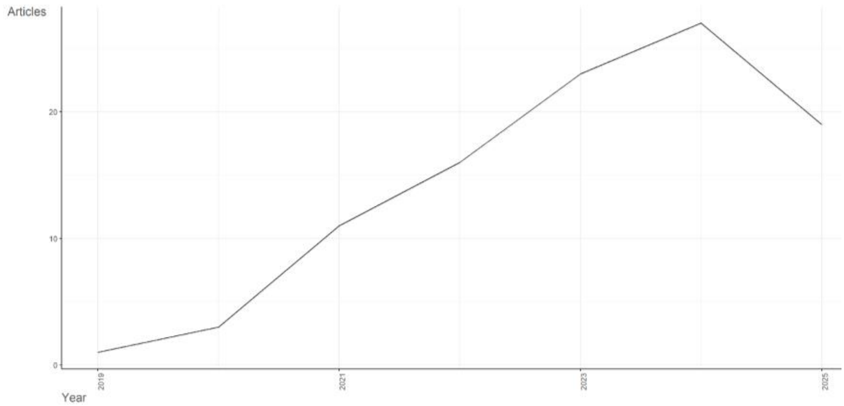

Fig 1. Annual publication trends using keywords

Scientific publications on microplastics show a tendency for topics to be concentrated in certain journals with high reputations in the field of marine environmental pollution. As shown in Figure 2, Marine Pollution Bulletin tops the list with 10 publications. This dominance reinforces the journal's position as a leading reference in marine pollution research, particularly microplastics. Science of the Total Environment follows closely behind, followed by Environmental Pollution. Several other engineering and environmental journals, such as Chemical Engineering Journal, Environmental Research, and Chemosphere, also contribute, albeit in smaller numbers. This distribution indicates that the issue of microplastics is not only a concern in the fields of oceanography and marine biology, but also in interdisciplinary studies encompassing environmental engineering and process engineering.

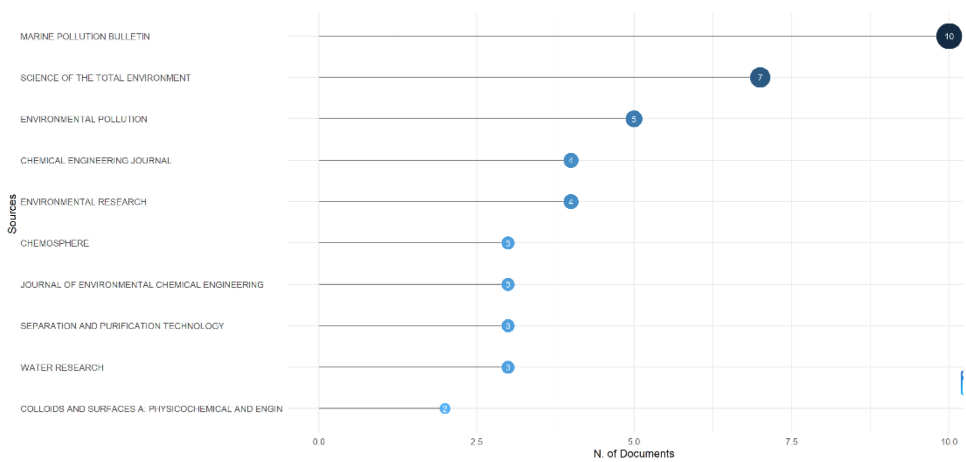

Fig 2. Most journal sources on microplastic contamination in sponges

This literature review discusses microplastics in sponges (Porifera). Eleven articles reviewed focused on the interaction between microplastics and sponges. The results of the review are presented in Table 1. The results of the 16 articles reviewed indicate that microplastics can be found in various sponge species from diverse environments, both tropical and extreme environments such as Antarctica. Microplastics were predominantly analyzed in the literature using FT-IR.

Table 1. Final compilation of 11 articles on the interaction of Sponges (Porifera) with microplastic contamination

No.	Title	Year	Jenis	Country	Articles Review Results	Ref.
1	Human Activity as a Growing Threat to Marine Ecosystems: Plastic and Temperature Effects on the Sponge *Sarcotragus spinosulus*	2025	*Sarcotragus spinosulus*	Spain	Microplastics were found in 45% of sponge samples. Sponges exposed to microplastics had an average of 0.9 ± 0.88 MP per sample, while healthy sponges had an average of 0.5 ± 1.08 MP per sample. Affected sponges contained microplastics in the form of fibers (77.8%) and fragments (23.2%), similar to healthy sponges which consisted of fibers (80%) and fragments (20%). In terms of color, most MPs in affected sponges were blue (55.6%) and transparent (22.2%), while in healthy sponges they were predominantly blue (80%).	doi: 10.3390/toxics13010066
2	Microplastics determination and quantification in two benthic filter feeders *Sabella spallanzanii, Polychaeta* and *Paraleucilla magna*, Porifera	2024	*Paraleucilla magna*	Italy	The average microplastic count in the sponges was 66 ± 31 p/g DW. Eighty-five percent of the particles were fibers, with the majority being transparent, followed by blue. The polymer types found included nylon, polyethylene (PE), polypropylene (PP), alkyd resin (AR), polyethylene terephthalate (PET), and polyurethane (PUR).	doi: 10.1016/j.heliyon.2024.e31796
3	Preliminary Report of Microplastic (MPs) Presence on East Java Freshwater Sponges at Brantas Porong River	2024	*Oncosclera asiatica and Eunapius carteri sponge*	Indonesia	*O. asiatica* sponge contained 1,150 microplastic particles per 20 grams of wet weight, dominated by red and black fibers, black fragments, and pellets. Meanwhile, *E. carteri* contained 2,850 particles per 20 grams of wet weight, with the dominant characteristics being white foam, crystal pellets, blue fibers, and black fragments.	doi: 10.1051/bioconf/20249404019
	Marine sponges as bioindicators of	2023	*Dendrilla antarctica Topsent, 1905;*	Antartica	The total microplastic content in sponges reached 5 mg/kg, but PET and aliphatic	doi: 10.1016/j.scitotenv.2023.166043

	pollution by synthetic microfibers in Antarctica		*Haliclona (Rhizoniera) scotti (Kirkpatrick, 1907); Microxina sarai Calcinai & Pansini, 2000 and Mycale (Oxymycale) acerata Kirkpatrick, 1907*		polyamides (such as nylon) were generally not detected, except for 27 µg/kg nylon 6,6 in H. scotti.	
5	Fate of microplastic captured in the marine demosponge *Halichondria panicea*	2023	*Halichondria panicea*	Denmark	The study was conducted on *Halichondria panicea*, comparing the fate of inedible plastic particles (2 and 10 µm in size) with that of edible bacterial and algal cells. *Cyanobium bacillare* cells (small) were captured and digested by *choanocytes*, while *Rhodomonas salina* cells (larger) were captured at the inlet and digested in the mesohyl. 2 µm plastic beads were captured by *choanocytes* and excreted through the outlet in an average time of 58 ± 34 minutes. 10 µm beads were captured at the inlet, transported to the mesohyl by amoeboid cells, and then excreted after 95 ± 36 minutes.	doi: 10.1016/j.marpolbul.2023.115403
6	Particle uptake by filter-feeding macrofoulers from the Mar Grande of Taranto (Mediterranean Sea, Italy): potential as microplastic pollution bioremediators	2023	*Paraleucilla magna*	Italy	Three microplastic concentrations (C1: 14 particles/L; C2: 140 particles/L; C3: 1,400 particles/L) were tested to assess the potential of *Paraleucilla magna* as a microplastic filter. The digestion protocol successfully removed 98% of the tissue, facilitating MP quantification. The filtration rate of *P. magna* decreased with increasing microplastic concentration.	doi: 10.1016/j.marpolbul.2023.114613
7	*Seagrass sponge (Agelas conifera: Demospongia*)	2023	*Agelas conifera*	Indonesia	The research results show that *Agelas conifera* sponge tissue can accumulate 166.66–300 microplastic particles per gram.	doi: 10.1088/1755-1315/1251/1/012064

	potential of microplastic accumulation from Pramuka Island, Seribu Islands				The dominant color of microplastics found was blue.	
8	Investigation of Global Trends of Pollutants in Marine Ecosystems around Barrang Caddi Island, Spermonde Archipelago Cluster: An Ecological Approach	2022	*Cribrochalina olemda, Clathria Reinwardtii & Clathria sp.*	Indonesia	The average microplastic content detected in sponges was 8.32 units/m3. The polymer types found included PA (polyamide), PE (polyethylene), PP (polypropylene), PS (polystyrene), ABS, PC (polycarbonate), and PVC (polyvinyl chloride).	doi: 10.3390/toxics10060301
9	Microplastic distribution in urban vs pristine mangroves: Using marine sponges as bioindicators of environmental pollution	2021	*Halichondria melanadocia, Amorphinopsis atlantica, & Haliclona implexiformis*	Mexico	Only microplastic fibers were found in all study compartments and locations, with an average size of 2.3–6.2 mm and colors of blue, red, black, and white. The average abundance of microplastics in marine sponges was 3,456 particles/kg dry weight at location A (range 2,000–5,000/kg) and 1,861 particles/kg at location B (range 556–4,444/kg).	doi: 10.1016/j.envpol.2021.117391
10	Plastics in Porifera: The occurrence of potential microplastics in marine sponges and seawater from Bocas del Toro, Panamá	2021	*Aplysina cauliformis Carter (1882), Amphimedon compressa Duchassaing de Fonbressin & Michelotti (1864), Callyspongia vaginalis Lamarck (1814), Ircinia campana Lamarck (1814), Mycale laevis Carter (1882)* and *Niphates erecta Duchassaing de*	United States	The number of potential microplastic particles (PMPs) in sponge tissue ranged from 6 ± 4 to 169 ± 71 particles per gram of dry weight. Most particles were very small (10–20 µm), but fibers larger than 5,000 µm (5 mm) were also found.	doi: 10.7717/peerj.11638

			Fonbressin & Michelotti (1864)			
11	Sponges as bioindicators for microparticulate pollutants?	2021	15 coral reef sponges (class Demospongiae)	Germany	Polystyrene was found in sponge tissue at a concentration of 91–612 particles/gram dry weight.	doi: 10.1016/j.envpol.2020.115851

3. 1 Accumulation of microplastics

Microplastic (MP) abundance levels in sponge tissue show significant variation across species and geographic locations. In a study by [1], sponges exposed to MPs contained an average of 0.9 ± 0.88 particles per sample, higher than healthy sponges with only 0.5 ± 1.08 particles. In freshwater habitats, *Oncosclera asiatica* and *Eunapius carteri* showed very high abundances, at 2,850 and 1,150 particles per 20 grams of wet weight, respectively [6]. In other locations such as Pramuka Island, sponges such as *Agelas conifera* recorded MP accumulation of 166.66–300 particles/g of tissue [7]. In tropical areas such as Spermonde, abundance values average 8.32 particles/m³ [8], while in mangrove and Antarctic regions, abundances reach 3,456 particles/kg [9] and up to 5 mg/kg of sponge tissue [10] Furthermore, sponges in Caribbean waters have been recorded to contain 6 ± 4 to 169 ± 71 particles/g dry weight [11], confirming the capacity of sponges as passive accumulators of MP. These data indicate that accumulation is not uniform, depending on the sponge species, particle density in the habitat, and the intensity of anthropogenic pressure.

3. 2 Microplastic Characteristic

The physical and chemical characteristics of microplastics found in sponge tissue vary widely. Most particles are in the form of fibers, with a proportion reaching 77.8% in affected sponges and 80% in healthy sponges (*Sarcotragus spinosulus*) [1]. Fibers also predominate in *Paraleucilla magna*, accounting for up to 85% of the total particles [12]. Several studies have also reported the presence of fragments, pellets, and foams [6][7]. Particle sizes range from 2–10 µm microbeads [5] to fibers >5 mm [11]. The most common colors found include blue, transparent, red, black, and white. Sponges on Pramuka Island, for example, are predominantly blue [7], while in Antarctica and other urban locations, blue and transparent particles are most common [13][9].

In terms of polymer composition, some of the most commonly identified types are polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyamide (nylon) [12][8]. In addition, alkyd resin (AR), polyethylene terephthalate (PET), polyurethane (PUR), polycarbonate (PC), and polyvinyl chloride (PVC) were also found. The diversity of shapes, colors, and types of these polymers reflects the spectrum of plastic pollution sources, ranging from textiles and industrial equipment to household waste.

3.1 Research on microplastic contamination in other filter feeder organisms

Several studies have been conducted to explore microplastic contamination in filter-feeding organisms other than sponges, such as mussels, polychaetes, and barnacles. These organisms are known to continuously filter particles from water, placing them at high risk of microplastic accumulation from degraded plastic waste in water bodies. While the primary focus of many studies remains on consumable organisms, studies of other filter-feeders are emerging. Table 2 presents an overview of studies microplastics in various non-sponge, filter-feeding organisms.

Table 2. Overview of microplastic accumulation in other filter-feeding

No.	Location	Species	Microplastics accumulation/ uptake	Reference(s)
1.	Italy	*Sabella spallanzanii*	117 ± 46 p/g DW	doi: 10.1016/j.heliyon.2024.e31796

2.	USA	Gooseneck barnacles (*Lepas spp.*)	1-30 particles/individual	doi: 10.7717/peerj.184
3.	Italy	*Mytilus galloprovincialis, Sabella spallanzanii, Phallusia mammillata, Paraleucilla magna*	250 p/L	doi: 10.3390/jmse12061000
4.	Indonesia	*Diadema africanum*	41 particles/individual	doi: 10.14710/ik.ijms.28.4.289-300
5.	Indonesia	*Anadara granosa*	618.8 ± 121.4 particles/individuals	doi: 10.1088/1742-6596/1725/1/012053
6.	Spain	*Diadema africanum*	9.7 ± 3.9 items/individual	10.1016/j.marpolbul.2021.113174
7.	New Zealand	*Perna canaliculus*	0 to 0.48 particles/g (wet wt)	Doi: 10.1016/j.marpolbul.2019.110641
8.	Eastern North Pacific	*B. musculus;* *B. physalus;* *M. novaeangliae*	$5.30 \times 106 - 1.74 \times 10^7$ $2.99–9.96 \times 10^6$ $1.03–3.12 \times 10^5$ (fish-feeding); $2.12–6.37 \times 10^6$ (krill-feeding)	doi: 10.1038/s41467-022-33334-5
9.	Mexico	*Ccopepods*	268 particles/individuals	doi: 10.3390/microplastics3030025
10.	Netherlands	*Megaptera novaeangliae*	0.1 microplastics/m^3	doi: 10.1016/j.marpolbul.2015.04.007

Research on microplastic contamination has expanded to a variety of filter-feeding organisms beyond sponges, encompassing invertebrates such as clams and barnacles, as well as large vertebrates like baleen whales. Variations in body shape, filtering mechanisms, and habitat lead to different accumulation rates among taxa.

Sessile organisms such as clams (*Anadara granosa*), marine worms (*Sabella spallanzanii*), and ascidians (*Phallusia mammillata*) have been shown to filter microplastics from seawater at relatively high accumulation rates, reflecting their ecological role as indicators of water quality [14]. The consistent presence of transparent or blue microplastic fibers in these organisms supports the hypothesis that domestic waste and textiles are the primary sources of contamination. to large mammals such as baleen whales (*B. musculus, M. novaeangliae*) show a high capacity for accumulating microplastics, both through passive and active filtration of contaminated seawater [15].

Mussels and marine worms living near the substrate surface showed high microplastic abundance values, indicating that benthic organisms are the primary targets of microplastic pollution in coastal zones. Baleen whales, which filter millions of liters of seawater per day, are estimated to ingest millions of microplastic particles. This reinforces the point that contamination impacts not only small and sessile biota but also marine megafauna, which should reside at more protected trophic levels. These taxonomic and physiological differences suggest that vulnerability to microplastics is not just a local ecological issue, but a global, cross-species phenomenon.

4 Conclusions and future perspectives

In marine ecosystems, marine sponges (Porifera) are important ecological players as filter feeders, filtering suspended particles from the water column.They also serve as a home for microbes and aid in nutrient recycling. An analysis of 11 empirical studies found that microplastics accumulate in sponge tissues, with significant differences in quantity, polymer type, particle shape (fibers, pieces, or pellets), and dominant color. These results support the notion that sponges are sensitive bioindicators of marine microplastic pollution. Microplastics in sponge tissue have the potential to disrupt physiological processes, such as inhibiting the production of bioactive compounds in sponges, which are important in the pharmaceutical industry. Further research is needed to examine the biological reactions of sponges to specific polymers to determine changes in tissue structure, secondary metabolite capacity, and their impact on the ecological function of sponges within the benthic community. This approach is crucial as a scientific basis for developing pollution mitigation strategies while maintaining the ecological significance of sponges in the marine environment.

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