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Editorial

Plastic pollution in marine and freshwater biota

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ABSTRACT

Plastic pollution is now recognised as a growing concern for both the environment and associated biota. Consequently, a plethora of scientific reports are being produced regarding the occurrence, distribution, and transfer pathways of litter particles. However, there are scientific gaps that need to be filled regarding micro- and nanoplastic impacts on marine and freshwater organisms. This Special Issue (SI) aimed to provide an update on plastic pollution and its consequences on aquatic ecosystems, with a particular focus on biological domains, by adopting a multidisciplinary perspective. Several research articles and reviews were collected, focusing on the origin, fate, and effects of plastics in marine and freshwater environments, along with their interactions with biotic components. We believe this SI will contribute to the development of new studies on plastic pollution and the elaboration of science-based policies at different levels of our modern society.

1. Introduction

Plastic pollution is one of the most urgent threats of the modern Anthropocene era, being recognised as a growing concern for both humans and the environment (e.g., GESAMP, 2015; Azevedo-Santos et al., 2019, 2021; Bajt, 2021; Huang et al., 2021; Porta, 2021; Zhang et al., 2022; Rangel-Buitrago and Neal, 2023). Over the past decade, several reports have documented the rising volume of plastic debris of various sizes (from macro- to micro- and nanoplastics) and polymer composition in extremely diversified environmental compartments (hydrosphere, lithosphere, atmosphere, biosphere) (Bank and Hansson, 2022). Plastic debris, of various shapes, sizes, colors, and of both of primary and secondary origin, are pervasive contaminants widespread in all environmental domains (Mao et al., 2022) including remote areas such as polar regions (Corsi et al., 2021; Caruso et al., 2023) and those with high biodiversity (Giarrizzo et al., 2019).

Several scientific reports are being produced regarding the occurrence, distribution, and transfer pathways of plastic particles among environmental matrices. Regarding impact on human and environmental health, a deeper knowledge of sources, transport pathways, accumulation and toxicity is required including their role as a vehicle of other existing and/or associated chemical pollutants (i.e., plastic additives) (Caruso, 2019; Jacquin et al., 2019).

This Special Issue (hereafter SI) aims to provide an update on plastic pollution and its consequences on aquatic ecosystems, with a particular focus on biological domains by adopting a multidisciplinary perspective. Several research articles and reviews focused on the origin, fate, and effects of plastics in marine and freshwater environments, and their interactions with biotic components are summarized:

Gabriella Caruso, Elisa Bergami, Neelu Singh, Ilaria Corsi. Plastic occurrence, sources, and impacts in Antarctic environment and biota. 2022, 1(2): 100034. DOI 10.1016/j.watbs.2022.100034 (Cited as: Caruso et al., 2022)

Chenxi Wu, Xiong Xiong, Amir Hossein Hamidian, Yulan Zhang, Xiangrong Xu. A review on source, occurrence, and impacts of microplastics in freshwater aquaculture systems in China. 2022, 1(3): 100040. DOI 10.1016/j.watbs.2022.100040 (Cited as: Wu et al., 2022)

Valter M. Azevedo-Santos, Tommaso Giarrizzo, Marlene S. Arcifa. Plastic use by a Brazilian freshwater bird species in its nesting activities. 2022, 1(4): 100065. DOI 10.1016/j.watbs.2022.100065 (Cited as: Azevedo-Santos et al., 2022)

France Collard, Simon Leconte, Jóhannis Danielsen, Claudia Halsband, Dorte Herzke, Mikael Harju, Felix Tulatz, Geir W. Gabrielsen, Arnaud Tarroux. Plastic ingestion and associated additives in Faroe Islands chicks of the Northern Fulmar *Fulmarus glacialis*. 2022, 1(4): 100079. DOI 10.1016/j.watbs.2022.100079 (Cited as: Collard et al., 2022)

Charles V. Neves, Christine C. Gaylarde, José Antônio Baptista Neto, Khauê S. Vieira, Bruno Pierri, Carolina C.C. Waite, Daniela C. Scott, Estefan M. da Fonseca. The transfer and resulting negative effects of nano- and micro-plastics through the aquatic trophic web—A discreet threat to human health. 2022, 1(4): 100080. DOI 10.1016/j.watbs.2022.100080 (Cited as: Neves et al., 2022)

Mariana Beatriz Paz Otegui, Gabriela Carvalho Zamprogno, Enrique Ronald Yapuchura Ocaris, Mercia Barcellos da Costa. Initial discovery of microplastic pollution in *Mnemiopsis leidyi* (Ctenophora: Lobata). 2023, 2(2): 100140. DOI 10.1016/j.watbs.2023.100140 (Cited as: Paz Otegui et al., 2023)

Badiozaman Sulaiman, Jamie C. Woodward, Holly A. Shiels. Riverine microplastics and their interaction with freshwater fish. 2023, 2(4): 100192. DOI 10.1016/j.watbs.2023.100192 (Cited as: Sulaiman et al., 2023)

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Fabiula Danielli Bastos de Sousa. Plastic effects on marine and freshwater environments. 2024, 3(1): 100228. DOI 10.1016/j.watbs.2023.100228. (Cited as: Danielli Bastos de Sousa, 2024)

Zhenlu Wang, Xianghong Dong, Muzi Zhang, Lei Gan, Jian Shao, Weiling Sun. Effects of environmentally relevant concentrations of micro(nano)plastics on aquatic microorganisms: Changes in potential function but not in overall composition. 2024, 3(1): 100233. DOI 10.1016/j.watbs.2023.100233 (Cited as: Wang et al., 2024)

2. Overview on the interaction of plastic items with marine and freshwater biota

Exposure to plastic debris may damage both terrestrial and aquatic organisms, with consequences ranging from sub-lethal, severe impairment to death. In the long term, a loss of biodiversity is expected from plastic pollution (e.g., Fig. 1).

In freshwater aquaculture systems in China, Wu et al. (2022) highlighted that microplastics (MPs, i.e., synthetic particles with size ranging from 1 μm to 5 mm, according to the definition by Frias and Nash, 2018) can be potentially dangerous to aquatic organisms and ecosystem function, although to date a clear risk assessment of plastic pollution in natural conditions is not possible. Future research addressing the role of MPs as vectors of pathogens and pollutants, as well as new analytical methods to assess these effects on human health in aquaculture is recommended.

In riverine environments, there has been an extensive recognition of the sources and factors driving the spatio-temporal distribution of MPs (Sulaiman et al., 2023), providing information on particle internalisation by fish tissues/organs. New insights on the potential ecotoxicological risks related to the interaction of MPs with freshwater fish have suggested a jointly modulated toxic effect that includes retention time, level of accumulation, penetration into tissues/organs, as well as the physical and chemical nature of the MPs and their role as a carrier of chemical pollutants and/or pathogens.

Notably, interactions of plastic particles with biota occur through entanglement, ingestion and/or inhalation (Nelms et al., 2019; Corami et al., 2020; Iannilli et al., 2020; Savoca et al., 2021). Plastic particles may cause physical injuries such as internal abrasion and mechanical damage (Wright et al., 2013) or toxic effects, including endocrine disruption and carcinogenicity. Effects on organisms are strictly dependent on the size and shape of the plastic particle as well as on the chemical nature of the polymer, as observed in *Daphnia magna* Straus, 1820; Schwarzer et al. (2022); MPs derived from polystyrene (PS), polypropylene (PP), and polyvinylchloride (PVC) show greater toxicity toward aquatic organisms, damaging the endocrine, reproductive, immune, and nervous systems. Plastics absorb contaminants which may accumulate and/or undergo biomagnification along the food chain. Compared to micro-, nanoplastics are even more dangerous to species due to their greater bioavailability, and their high surface/volume ratio also favours the absorption of existing chemical pollutants (Caruso, 2019; Corsi et al., 2021). Elucidating the cumulative toxic effects of MPs in different polluted environments is therefore suggested as a critical step (Vo and Pham, 2021).

Through transfer across the trophic web, plastic pollution may reach the upper trophic levels (up to humans), but the effects of plastic pollution are still not fully known, consequently, toxic chemicals should be measured in human tissues to assess exposure levels and establish public health protection measures (Neves et al., 2022).

The wide occurrence of plastic fragments in the Paraná River Basin (southeastern Brazil) was discernible when it was documented that Garibaldi (*Chrysomus ruficapillus* (Vieillot, 1819), freshwater birds belonging to Passeriformes) were found to use these materials to build their nests in this region for the first time (Azevedo-Santos et al., 2022). The authors have suggested potential risks to the birds caused by entanglement or asphyxia, stressing the need to conduct similar observations in other environments. In a marine bird species, fulmar (*Fulmarus glacialis* (Linnaeus 1761)) chicks collected from the Faroe Islands (Collard et al., 2022) were found to have plastic and related additives. A high proportion of chicks (95%, 2 and 6 weeks old) ingested plastic (white and yellow polyethylene and polypropylene, on average 12.4 ± 17.5 pieces/bird), with unknown consequences on their health.

Ingestion of MPs was first reported in over 220 marine organisms including species of commercial interest like fish (anchovies, herrings, Atlantic cod, common carp) and shellfish (mussels, shrimps, oysters, lobsters) (Lusher et al., 2017; Corami et al., 2022). More recently, Provencher et al. (2022) have reviewed the occurrence of plastic ingestion and trophic transfer across several organisms, underlining the

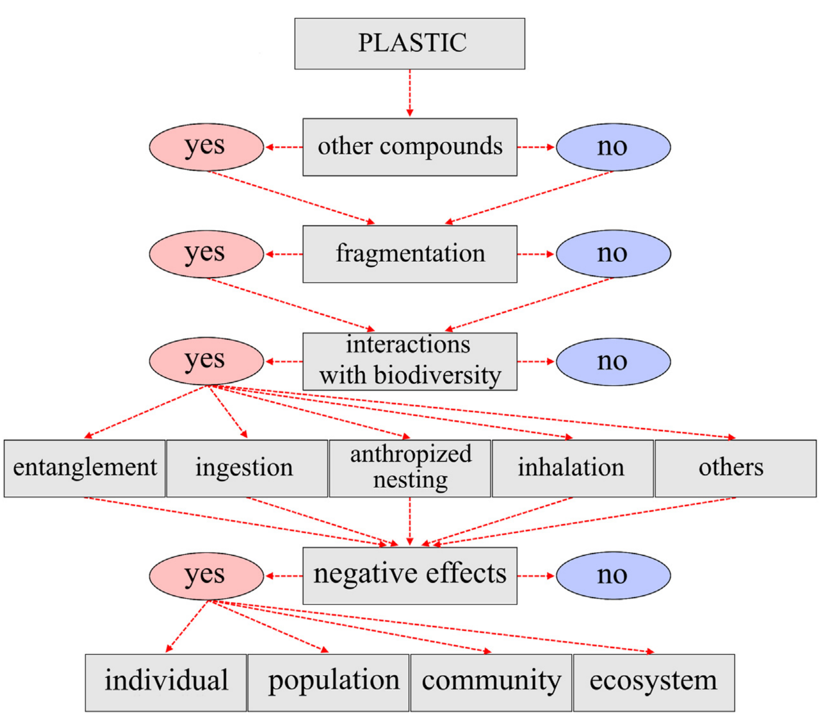

Fig. 1. Possible pathways through which plastic negatively affects aquatic biota. Plastic entering the aquatic environment may be contaminated or not by other agents (i.e., chemicals, pathogens). It may interact with aquatic biota after fragmentation or in its original size (i.e., commercial beads). The main expected interactions include: entanglement (the junction in or capture of organisms by anthropogenic material); ingestion (consumption of anthropogenic material through food); anthropized nesting (the use of material in nests or burrows); inhalation (entry into the respiratory system), among others (e.g., dispersal of organisms on anthropogenic debris to non-native regions). Red arrows indicate the steps of plastic towards the different levels of organization.

importance of understanding predator-prey relationships and how trophic transfer may increase the detrimental effects of plastic pollution.

Along the southeast coast of Brazil, MPs have been found in specimens of the ctenophore *Mnemiopsis leidyi* Agassiz 1865 (Paz Otegui et al., 2023), where a total of 328 MPs items were retrieved and identified as polyurethane, unplasticized polyvinylchloride, and polyethylene polylauryl lactam with prevalence of blue, black, red, and green fibres and blue colors. This study suggests the potential use of this organism as a bioindicator species in MPs monitoring.

In remote Antarctic regions, Caruso et al. (2022) have reviewed the sources, occurrence, and distribution of plastics both in environmental matrices such as ice, snow, sediments, and seawaters as well as in Antarctic organisms from plankton to higher trophic levels (fish, seabirds and mammals). Although the occurrence of plastics has been well documented, including inside the body of terrestrial and aquatic species, the current knowledge of potential effects is limited to a few studies addressing potential exposure scenarios and ecotoxicological outcomes. Therefore, more studies should be performed to understand the threat posed by plastic pollution in Antarctica and other polar areas which are already facing other global threats including climate change.

New insights on the effects of micro- and nanoplastics (MNPs) on the composition and function of the microbial community within microbial flocs (a model for functional microorganisms in aquaculture) have recently been reported (Wang et al., 2024). Exposure of microbial flocs to NPs (80 nm) and MPs (8 μm) for a period of 35 days resulted in significant differences in the concentrations of total ammonia, nitrogen, or nitrite between those exposed to MNPs and the control group. MNPs exposure was found to significantly increase microbial community richness and affect nitrogen cycle dynamics. The relative abundance of bacteria forming biofilms, potentially pathogenic bacteria, and those involved in plastics degradation changed significantly after MNPs exposure. Conversely, no significant effects were recorded in the microbial diversity of mature microbial flocs.

3. Advances provided by this SI and future challenges

Although considerable literature exists on plastic pollution when compared with other fields, this SI highlights clear shortfalls in knowledge that were minimized by the studies presented. All marine and freshwater environments are being impaired by plastic pollution, which is mostly the result of improper post-use plastic disposal, but to date there are no clear connections between the effects of plastics on human health, animal health, and the environment, as evidenced by a bibliometric analysis (Danielli Bastos de Souza, 2024). Moreover, a new challenge in this research field might be the identification of organisms as potential bioindicators of plastic pollution (Caruso et al., 2023).

Altogether, papers included in this SI provide important data that can be used to address plastic pollution at local, regional, and global scales. For example, data provided by Caruso et al. (2022) is extremely important for implementing national policies aimed at reducing plastic in polar and remote areas. Therefore, we recommend the need for the findings of these articles to be communicated in mass media in various languages. This is because, in many nations, decision makers have no familiarity with the English language, scientific methods, or both. As such, the implementation of policy based on scientific evidence pertaining to plastic pollution may be difficult. From a global perspective, many nations on the planet concerned with pollution are conducting negotiations for an unprecedented treaty on plastic pollution (Bergmann et al., 2022; Stokstad, 2022; Vitorino et al., 2022; Tessnow-von Wysocki et al., 2023). Therefore, this SI could be used to provide more scientific support in the negotiation process for the elaboration of a broad international Plastic Treaty as evoked by the United Nations.

4. Conclusions

Plastic pollution is a global issue. These synthetic polymers are introduced in aquatic ecosystems in quantities/modalities not comparable with previous records during the history of humanity. Therefore, there is a clear need for more research to assess potential impacts on living beings. Based on this perspective, this SI provides 9 contributions regarding the impact of plastics on marine and freshwater ecosystems and biota from different countries. This SI will certainly contribute to new studies on plastic pollution and to the development of science-based policies at different levels of our modern society.

CRediT authorship contribution statement

Gabriella Caruso: Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Ilaria Corsi:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Chenxi Wu:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Elisa Bergami:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Fabiana Corami:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Valter M. Azevedo-Santos:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization.

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