



## Microplastics vs. ichthyoplankton: effects of this interaction in controlled and estuarine environments

## Microplásticos vs. ichthyoplankton: efeitos desta interação em ambientes controlados e estuarinos

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### ABSTRACT

This literature review exploring the relationship between microplastics and ichthyoplankton was conducted in the main databases available online, considering the period from 2007 to 2021. Sixty articles were found reporting the presence of microplastics in estuarine environments (71.7%), and ingestion by ichthyoplankton in estuarine environments (16.6%) and under experimental conditions (11.7%). The most abundant microplastic found in natural environments was fiber (55%). Environments with densities between 17.5 and 4100 particles/m<sup>3</sup> exhibited greater possibilities of ingestion of these particles by ichthyoplankton, the smaller the microplastic particle (63 µm-0.5 mm) the greater the probability (95%) of being ingested by ichthyoplankton (>2.56 mm). *Danio rerio* (zebrafish) was the species commonly used to assess the effects caused by the interaction between microplastics and ichthyoplankton under experimental conditions. The effects



frequently reported were: increased heart rates (25%); growth inhibition (25%); interference in larvae's swimming speed (53.4%); and inflammation in various organs (e.g., liver, intestine) (50%).

**Keywords:** estuary, fibers, plastic fragments, ingestion, microplastics, ichthyoplankton.

## RESUMO

Uma revisão na literatura sobre a relação do microplástico com ictioplâncton foi realizada nos principais bancos de dados disponíveis on-line considerando o período de 2007-2021. Foram identificados 60 artigos que relatam: presença de microplástico em ambiente estuarino (71,7%); ingestão pelo ictioplâncton em ambientes naturais (16,6%) e em condições experimentais (11,7%). O microplástico mais abundante em ambiente natural é a fibra (55%). Ambientes com densidades entre 17,5 – 4100 part/m<sup>3</sup> apresentam maior possibilidade de ingestão dessas partículas pelo ictioplâncton. Quanto menor o microplástico (63 µm- 0,5mm) maior a probabilidade (95%) de ser ingerido pelo ictioplâncton (>2,56 mm). *Danio rerio* é a espécie comumente utilizada para avaliar os efeitos causados pela interação do microplástico com o ictioplâncton em condições experimentais. Os efeitos frequentemente relatados são: aumento na frequência cardíaca (25%), inibição do crescimento (25%), interferência na velocidade de natação das larvas (53,4%) e inflamações em diversos órgãos (e.g. fígado, intestino) (50%).

**Palavras-chaves:** estuário, fibras, fragmento plástico, ingestão, microplásticos, ictioplâncton.

## 1 INTRODUCTION

Microplastics (MP) are plastic fragments smaller than five millimeters (Gigault et al., 2018), which can be ingested by different organisms (plankton, fish, birds, and even mammals), together with water when feeding (Phillips & Bonner, 2015; Batel et al., 2016; Garcia et al., 2019). The ingestion of those particles by these organisms can induce decreased feeding, reduce hormonal and reproductive rates, and cause internal injuries that can lead to death (Moore, 2008; Lusher et al., 2013).

Given that MP particles fall within the same size range as planktonic organisms, their densities in aquatic environments contribute to their ingestion by plankton predators, which can ingest these particles by confusing them with food (Cole et al., 2011; Desforges et al., 2015). Currently, MPs pose a threat to ichthyoplankton, and can be easily transferred to higher trophic levels through the food chain (Lima et al., 2014).



Systematization of information has shown that studies conducted in controlled environments have described in detail the effects of MPs on ichthyoplankton at different ontogenetic stages. On the other hand, studies conducted in natural environments have reported the ecological consequences of MP ingestion (Lima et al., 2014, 2015; Payton et al., 2020). Frequently, estuaries classified as highly contaminated by MP have exhibited densities ranging between 17.5 and 4100 particles/m<sup>3</sup> (Zhao et al., 2015; Pazos et al., 2018; Hitchcock & Mitrovic, 2019; Rodrigues et al., 2019).

The interaction between larvae and MPs in controlled environments occurs from the ingestion of these particles, which coincides with the beginning of exogenous feeding of these organisms (Mazurais et al., 2015). Once this pollutant particles enter the body, they are incorporated and tend to accumulate in gastrointestinal, respiratory, and muscular tissues, as well as in most organs, reducing feeding capacity and inhibiting larvae's growth and swimming capacity (Lu et al., 2016; Chen et al., 2017; LeMoine et al., 2018; Hoang & Felix-Kim, 2020; Yang et al., 2020).

The increasing abundance of MP in aquatic environments has awakened concerns about its insertion in the trophic chain. Information about the interaction between MP and ichthyoplankton as well as the toxic effects involved is still scarce. It is essential to systematically confront the findings obtained by studies that have assessed the interaction between MP and ichthyoplankton in controlled environments with the findings of studies conducted in natural environments. This confrontation would be intended to parameterize the controlled conditions, bringing them closer to those found in estuarine environments. Therefore, the goal of the present study was to systematize information obtained from studies that have addressed the interaction between MP and ichthyoplankton in controlled and estuarine environments, correlating the possible effects caused by the ingestion of these particles on fish larvae.

## 2 METHODS

The present study is a systematic literature review performed in databases of journals such as Google Scholar, Scopus, Web of Science, and CAPES, aimed at assessing studies that have addressed the correlation between MP and



ichthyoplankton in controlled (laboratory) and estuarine environments. Only journals with environmental topics were taken into consideration, and peer-reviewed journals were selected. The period from 2007 to 2021 was selected for the analysis, because it is when the first studies related to the topic to be addressed were found. The search was performed using the following keywords, alone or in combination: 'microplastic', 'plankton', 'estuary', 'fish larvae', and 'estuarine environment'.

The selection of journals was performed in two stages: (1) screening of the studies considering the inclusion and exclusion criteria set for the bibliography; and (2) analysis of the studies. The inclusion criteria used in the first stage were research on MP found in estuaries, and the interaction between MP and ichthyoplankton in controlled or estuarine environments. The exclusion criteria considered studies that addressed MP but not in estuarine environments, studies repeated in different platforms, and studies conducted with MP and larvae of organisms other than ichthyoplankton. The second stage corresponded to the analysis performed by the reading of the studies and systematization and tabulation of data.

The choice of studies that addressed the issue of MP in estuaries was chosen due to the importance of this ecosystem for the ichthyoplankton, being the estuary a nursery for marine and freshwater nectonic species. Therefore, understanding how this pollutant affects the ichthyoplankton is essential to support future studies on the impacts of MP on marine and continental fish stocks.

The studies were classified into two categories, i.e., controlled environment (laboratory) and natural environment (estuary). Those classified as controlled environments were studies conducted with estuarine ichthyoplankton in laboratory environments, under controlled experimental conditions with respect to doses, size and type of MP offered under known temperature and salinity. With respect to natural environments, the studies selected were those that used ichthyoplankton from estuarine environments impacted by MPs, and reported correlation after capture, even though it had not been the main objective of the studies, and the environmental variables were possibly unknown.



### 3 MICROPLASTICS VS. ICHTHYOPLANKTON: SPATIAL DISTRIBUTION OF SPECIALIZED BIBLIOGRAPHY

The bibliographic search resulted in 1,849 articles. However only 60 articles met the inclusion criteria required by the present study, given that they addressed the presence of MPs in estuarine environments (71.7%) and the correlation between the presence and/or ingestion of these particles by ichthyoplankton in natural environments (16.6%) or under experimental conditions (11.7%).

Twenty-two journals addressed the interaction between MP and ichthyoplankton in natural and controlled environments. The journal with the highest publication rate was *Environmental Pollution* (25%), followed by *Marine Pollution Bulletin* (23%). The period with more publications on the topic assessed was from 2015 to 2020. For studies on MP vs. ichthyoplankton in controlled environments, *Environmental Pollution Bulletin* had the highest percentage of publications (42%).

The works selected for the present study were geographically distributed as shown in Figure 1. China was the country with the largest number of studies addressing the relationship between MP and ichthyoplankton in natural environments (15%). About 30% of the plastic produced worldwide came from this country and, consequently, resulted in a concern with MPs generated by this production, given that they would end up reaching aquatic environments (Yang et al., 2020). There was no predominance of studies among countries addressing the relationship between MP and ichthyoplankton in controlled environments.

Studies that have assessed the effects and toxicity of MP under controlled conditions chose to work with fish in the larval stage (Mazurais et al., 2015; Karami et al., 2017; LeMoine et al., 2018; Boyle et al., 2020; Hoang & Felix-Kim, 2020; Yang et al., 2020). This preference is associated with high swimming ability, high mobility rates, and greater interaction with the contact surface.

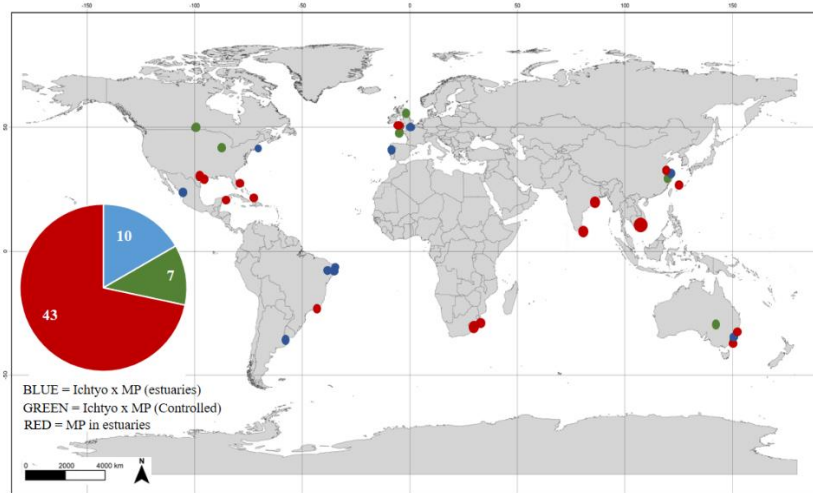
Reports of MP toxicity in larval development are still scarce (LeMoine et al., 2018), and results diverge in the experimental designs, i.e., species, types, and size of MP under assessment. It was observed that these experiments commonly exposed organisms to a single type of MP for a short period (3 to 42 days), which did not allow the correlation with significant effects on larval growth (Mazurais et al., 2015; LeMoine et al., 2018) (Table 1). The characteristics of MP (shape and



roughness) ingested by fish larvae will determine the residence time in their digestive tract (Mazurais et al., 2015).

*Danio rerio* (zebrafish) was the species commonly used for determining the impacts caused by MP on ichthyoplankton in controlled environments (Karamin et al., 2017; LeMoine et al., 2018; Boyle et al., 2020). This species has a transparent embryo throughout its development (allowing to monitor the effects caused by MP in real time) (Santos et al., 2020).

Figure 1. Geographic distribution of the sixty studies selected for the present review. Blue = microplastics (MP) and ichthyoplankton (Ichthyo) in estuaries; Green = microplastics and ichthyoplankton in controlled environments; Red = abundance of microplastics in estuaries.



Initial studies have indicated that MPs accumulated in organisms through tissues directly in contact with water, such as gastrointestinal and respiratory tissues, interfere with their functions (Batel et al., 2016; Grigorakis et al., 2017). However, some ecotoxicological studies have mapped the paths and impacts of MP on ichthyoplankton assessing different species, types, and size scales of MP (Mazurais et al., 2015; Karamin et al., 2017; LeMoine et al., 2018; Hoang & Felix-Kim, 2019; Boyle et al., 2020; Yang et al., 2020). Larvae begin to accumulate MP during the period that coincides with the start of exogenous feeding, approximately five days after hatching (Lu et al., 2016; LeMoine et al., 2018), which can affect various tissues (e.g., muscle, gills) and organs (e.g., intestine, liver).

Among the reported studies, half of them indicated that MPs reduced swimming speed of larvae, and were retained in the digestive tract or transported from the intestine to body tissues through the epithelial lining, causing mechanical



obstruction of the gastrointestinal system and inflammatory responses (Phillips & Bonner, 2015; Silva-Cavalcanti et al., 2017; Hoang & Felix-Kim, 2020; Yang et al., 2020). MP could also cross the chorion (10%), influence behavior (25%), increase heart rates (25%), and inhibit larval growth (25%) (Lu et al., 2016; Chen et al., 2017; Galloway et al., 2017; LeMoine et al., 2018).

In controlled environments, MP ingestion by ichthyoplankton occurred through manipulation with different dosages (Table 2). At a dosage of 10 µg/L (smallest manipulated dosage), the larvae ingested and excreted MPs, with no further damage being observed (Hoang & Felix-Kim, 2020). The studies found negative impacts on larval development at high MP concentrations (>500 mg/L) (Karamin et al., 2017; Boyle et al., 2020) with sizes <63 µm (Yang et al., 2020) (Table 1). Larvae exposed to overdose of MPs (1000 µg/L to 1.050 g/L) had multiple adverse effects, e.g., destruction of nerve fibers, inhibition of acetylcholine, enlargement of the intestinal cavity (Yang et al., 2020), infiltration, inflammation, and liver necrosis (Lu et al., 2016) (Table 1).

The present review did not allow inferring the mortality rate of fish larvae caused by MPs, since only one of the studies had observed a small increase in mortality rate (Mazrais et al., 2015). MPs measuring around 45 µm were found in the digestive tract of *Dicentrarchus labrax* (European bass) during the exposure period (14, 20, and 34 days after hatching), and there had been an increase (21.9%) in the mortality rate according to the amount of MP per larva, 14 and 20 days after hatching in a controlled environment (Mazrais et al., 2015). This change in mortality rate has been shown to be potentially induced by obstruction of the gastrointestinal tract due to the formation of MP knots or clumps.

Another important observation is related to the body shape of the larvae and the excretion time of MPs. A study conducted by Hoang and Felix Kim (2020) with *Pimephales promelas* (fathead minnow) (Rafinesque, 1820) found that larvae with curved bodies excreted the MPs more slowly (MPs remained in the intestine for up to 24 hours). In straight-body larvae, the excretion of particles occurred after 12 hours, with no re-consumption allowed. This morphological characteristic favored higher concentrations of MPs in curved-body larvae when compared to straight-body larvae, considering the excretion time >1 hour (Hoang & Felix-Kim, 2020).



Table 1. Studies carried out under experimental conditions offering microplastics to different species of ichthyoplankton.

Authors, year	Country	Species used	MP used	Dose administered and temperature	Exposure time	Harm observed
LeMoine et al., 2018	Canada	<i>Danio rerio</i>	Polyethylene with red fluorescence	20 mg/L Temp=27.0°C	19 days	Transient changes in gene expression. Insignificant effects.
Yang et al., 2020	China	<i>Carassius auratus</i>	Green fluorescent polystyrene with diameter of 70 nm and 5 µm	10, 100, 1.000 µg/L Temp = 25°C	1, 3, and 7 days	Increase in heart rate. Inflammation of organs (liver, intestine, and gills).
Mazurais et al., 2015	France	<i>Dicentrarchus labrax</i>	Fluorescent polyethylene	Mixtures of 10 and 45mm= 1,050 g/L Temp = 20°C	43 days	Increased mortality rate.
Hoang & Felix-Kim, 2019	USA	<i>Pimephales promelas</i>	Green fluorescent polyethylenes	25 and 50 mg/L Size: 63 to 75 µm and 125 to 150 µm Temp = 25°C	2 days	Consumption and excretion of MP.
Karamin et al., 2017	Australia	<i>Danio rerio</i>	Polyethylene	5, 50, 500 mg/L Temp=28.42°C	20 days	Accumulation of MP in the intestine.
Boyle et al., 2020	UK	<i>Danio rerio</i>	Polyvinyl chloride (PVC) and Polyethylene terephthalate (PET)	200 µm 125, 250, and 500 mg/L Temp= 27°C	3 days	Change in gene expression.

With respect to the limitations of studies conducted in controlled environments, it is worth mentioning that, under environmental conditions, larvae are generally exposed to greater MP diversity (e.g., fibers, hard plastic, soft plastic, fragments, pellets) (Lima et al., 2015; Vendel et al., 2017; Rodrigues et al., 2019) than those offered in controlled environments. Generally, primary MPs (e.g., pellets) have been the most frequently offered in this type of experiments (Mazurais et al., 2015; Karamin et al., 2017; LeMoine et al., 2018; Hoang & Felix-Kim, 2019; Boyle et al., 2020; Yang et al., 2020).

There were also studies that evaluated MP associated with other pollutants in controlled environments. Even though there is not vast literature on the subject, it is already known that MP can act as a reservoir for trace metals and as carriers of persistent organic pollutants, with phthalates, bisphenols, and organochlorine





pesticides being the most common types in estuaries (Boyle et al, 2020; Hanvey et al., 2017). The main adverse effects reported for ichthyofauna have been accumulation of persistent organic pollutants in liver, increase in plasma osmolarity and cortisol, and inhibition of branchial carbonic anhydrase (Barletta et al., 2019).

Literature reports addressing the time of MP excretion by different planktonic organisms are still scarce, which makes the assessment of MP ingestion and re-consumption relevant in a future perspective. This type of study would help understand the biotransfer processes of these contaminants to organisms at different trophic levels, since a multiplicity of organic contaminants are absorbed by MPs (Ferreira et al., 2018). This way, experimental studies should be conducted under more realistic conditions, approaching natural conditions as much as possible, in order to obtain better results regarding MP toxicity, thus constituting an important tool in subsidizing hypotheses to be tested in natural environments.

#### **4 INTERACTION BETWEEN MP AND ICHTHYOPLANKTON IN NATURAL ESTUARINE ENVIRONMENTS**

The number of studies addressing the presence and abundance of MPs in estuarine environments close to urbanized sites has intensified (Table 2). This fact justifies the assessment of the ecophysiological impacts caused by these particles, as well as their ecotoxicity in these environments (Jabeen; et al., 2017; Silva-Cavalcanti et al., 2017; Vendel et al., 2017; Lahens et al., 2018; Yang et al., 2020; Polanco et al., 2020).

The ichthyofauna of estuaries undergo spatiotemporal changes according to the breeding season of species, environmental fluctuations, and possible anthropogenic stressors (Barletta et al., 2020). In their early stages of life, fish species are highly vulnerable, especially to environmental conditions (salinity, temperature, and turbidity). This way, variations in these conditions influence the distribution patterns, density, and diversity of these species in estuaries (Rodrigues et al., 2019).

As fundamental environments for ichthyofauna, estuaries serve as nurseries used by many species to complete their life cycle (Lima et al., 2015). Fish reproduce at times of the year in these places, because they are favorable to



the development of their larvae. Any disturbance in these environments can directly affect the reproduction and development of several fish species (Barletta et al., 2020).

Table 2. Correlation between the interaction of microplastics and ichthyoplankton reported in studies conducted in natural estuarine environments.

Author/ year	Study area	Species studied	Microplastic type	Season	Impacts
Ferreira et al., 2018	Goiana Estuary State of Pernambuco Brazil	Cynoscion acoupa	Filaments and fibers	Early and late dry seasons, late and rainy seasons	Microplastic intake and biotransfer
Pazos et al., 2018	Rio de La Plata Estuary (South America)	Zooplankton	Fiber		Microplastic intake
Rodrigues et al., 2019	Douro Estuary Portugal	Pomatoschistus micros, Sardina pilchardus, Pomatoschistus minutus, Solea senegalensis	Hard plastic and fibers	Dry and rainy seasons	Microplastic intake
Lima et al., 2015	Goiana Estuary State of Pernambuco Brazil	Rhinosardinia bahiensis, Harengula clupeola	Soft and hard plastics	Dry and rainy seasons	Microplastic intake
Lima et al., 2014	Goiana Estuary State of Pernambuco Brazil	Anchovia clupeioides, Cynoscion acoupa	Soft and hard plastics	Dry and rainy seasons	Microplastic intake
Payton et al., 2020	Port of Charleston USA	Zooplankton	Fibers and fragments	Rainy seasons	Microplastic intake
Steer et al., 2017	English Channel UK	Common dragonet, European eel, Poor code	Fibers and fragments	Rainy seasons	Microplastic intake
Barletta, 2019	Goiana Estuary State of Pernambuco Brazil	Cathorops spixii, Eusinostomos Melanopterus	Fibers	Early and late dry seasons, late and rainy seasons	Microplastic intake
Barletta et al., 2020	Goiana Estuary State of Pernambuco Brazil	Haemulidae Species	Paint chips, wires, soft and hard fragments	Early and late dry seasons, late and rainy seasons	Microplastic bioaccumulation increases towards the top of the food web
Jabeen et al., 2016	Yangtze Estuary China	Marine and freshwater fish species	Transparent fibers	Dry and rainy seasons	Microplastic intake



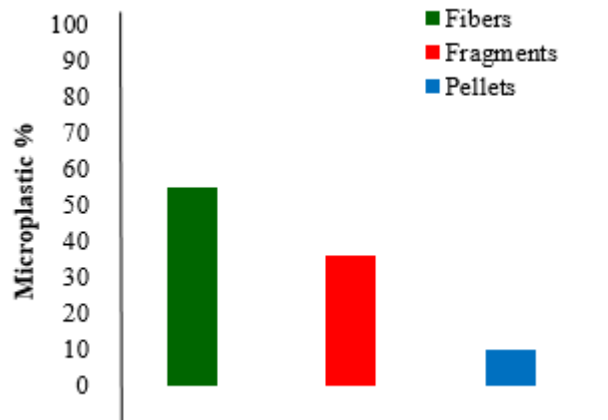
MPs tend to be found in higher concentrations in places with intense anthropogenic activities, which result from excessive waste production in these areas (Rodrigues et al., 2019; Nunes et al., 2021). According to the studies assessed in the present review, estuarine pollution caused by MP had ranged from 17.5 to 4100 particles/m<sup>3</sup> (Zhao et al., 2015; Pazos et al., 2018; Hitchcock & Mitrovic, 2019). MPs most frequently found in urban estuaries correspond to: (a) fibers with sizes between 1.4 and 3.5 mm (55%) (Zhao et al., 2015; Pazos et al., 2018; Rodrigues et al., 2019); (b) fragments (36%) (Lima et al., 2014; Naidoo et al., 2015; Pan et al., 2021); and (c) pellets (9%) (Zhao et al., 2015; Ferreira et al., 2018; Hitchcock & Mitrovic, 2019; Campanale et al., 2020) (Figure 2). MPs can be found in high concentrations, overlapping the availability of larvae during heavier rainfall periods, in the upper region of the estuaries (Rodrigues et al., 2019) and in the middle and lower regions of the estuaries (Lima et al., 2015). Fibers and fragments (soft/hard) were the most frequent types of MP found (Naidoo et al., 2015; Phillips & Bonner, 2015; Zhao et al., 2015; Pazos et al., 2018).

Fibers represent one of the most common types of MP found in studies that had assessed their ingestion, and can pose a risk to aquatic organisms of being entangled. When ingested, these fibers can generate clumps, causing injuries such as internal abrasion, thus interfering with food intake (Avio et al., 2015; Botterell et al., 2019).

Wind direction, rainfall, and freshwater inflow are environmental parameters that influence the distribution and abundance of MP within estuaries (Eerkes-Medrano et al., 2015), as well as tidal movement and environmental stratification processes (Lima et al., 2014). It is possible that MP leaving the estuary at ebb tide return to this environment during high tide and vice versa (Sadri & Thompson, 2014; Figueiredo & Vianna, 2018; Hitchcock & Mitrovic, 2019; Rodrigues et al., 2019). This dynamic increases the possibility of creating a hotspot, such as the Capibaribe Estuary, northeastern Brazil, which receives the contribution of plastic waste from its tributaries through the discharge of domestic wastewater (Zanardi-Lamardo et al., 2016).



Figure 2. Percentage of microplastic frequently found in anthropized estuaries, according to the articles used in the present review.



Vendel et al. (2017) found that the fish analyzed in Mamanguape and Paraíba estuaries, northeastern Brazil, exhibited MP intake of 1 to 4 particles per individual (196 fish ingested MP), including fibers (90%), soft fragments (6%), and hard fragments (4%). The authors pointed out that MPs could be found in the environment regardless of different anthropogenic activities, since Mamanguape Estuary is located in an environmental protection area, presenting lower environmental impacts when compared to other estuarine environments, subject to greater anthropogenic activities.

Studies addressing MP concentrations in different estuaries should be cautious due to the different types of sampling, quantification, and digestion methods (Rodrigues et al., 2019; Justino et al., 2021), since the different sampling techniques reported in the literature—water pumps (Zhao et al., 2014), plankton nets (Lima et al., 2014), and blanket nets (Sadri & Thompson, 2014)—point to the need for a standardized methodology to quantify MP in the environment.

The presence of MP was observed in several commercially important fish species for human consumption, such as *Hoplosternum littorale*, *Cynoscion acoupa*, and *Dicentrarchus labrax* (Mazurais et al., 2015; Lusher et al., 2016; Silva-Cavalcanti et al., 2017; Ferreira et al., 2018; Justino et al., 2021). Therefore, the intake of MP by species used for human consumption is a means through which humans are exposed to these particles and their chemical components (Bouwmeester et al., 2015; GESAMP, 2016; Jin et al., 2021; Nunes et al., 2021).

In Brazil, high rates of MP have been observed in the digestive tract of economically important freshwater fish species. About 63 filament-type MP



particles were found in a single individual, which indicates that food safety issues should be taken into consideration for the human population (Silva-Cavalcanti et al., 2017; Ferreira et al., 2018, 2019). MPs have already been observed in the human intestine. According to the Food and Agriculture Organization of the United Nations (FAO), the intake of these particles varies from 74 thousand to 121 thousand particles per year, according to age and sex (FAO, 2019). However, the effects of MP toxicity in humans through ingestion of contaminated food are still incipient.

Estuaries located in urbanized areas have greater MP abundance (e.g., fibers and fragments) originated from human activities in these locations (Pazos et al., 2018; Rodrigues et al., 2019). The great availability of MPs in these environments may favor the ingestion of their particles by ichthyoplankton, since these organisms are not selective feeders and ingest whatever is available.

## 5 FINAL CONSIDERATIONS

The present literature review highlights the occurrence of MPs and their effects on ichthyoplankton in natural and controlled environments. The information provided indicates that this pollutant was ingested by different species of ichthyoplankton in estuaries with high MP concentrations (17.5 to 4100 particles/m<sup>3</sup>) and the smaller the MP particle (<63 µm) the greater the probability of being ingested by ichthyoplankton (6.14±7.09/MP±ichthyoplankton). It was possible to observe that MP caused adverse effects in controlled environments, interfering with the swimming ability of larvae, inducing oxidative stress, increasing heart rates, inhibiting growth, and promoting inflammation of various organs (e.g. intestine, liver, and pancreas). The dosage and type of MP used under controlled conditions differed from the type and densities found in natural environments. Thus, it is expected further studies will be conducted in controlled environments, ensuring that the doses and types of MP offered are similar to those found in natural environments, in order to more accurately characterize the impacts caused to ichthyoplankton. According to the literature, fibers represented 55% of the types of MP ingested by different species of ichthyoplankton (e.g., *C. acoupa*, *P. micros*, *S. pilchardus*, *P. minutus*) in natural environments, which exhibit the ability to bioaccumulate and transfer those MP fibers to higher trophic levels. Perspective



on future research in this field, that experimental studies should be conducted under more realistic conditions, approaching natural conditions as much as possible, in order to obtain better results regarding MP toxicity, thus constituting an important tool in subsidizing hypotheses to be tested in natural environments.

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