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# The Presence of Microplastics in Shellfish: A Review

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**Abstract**
This study aims to find the presence of microplastics in Shellfish through the literature review method of several studies conducted. The increase in plastic pollution in water systems since the 1950s has become a significant problem worldwide due to the slow decomposition rate. Microplastics, mainly primary and secondary, can accumulate in marine organisms such as Shellfish and enter the food chain, which is a concern for humans. Shellfish, especially M. galloprovincialis, can be used as bioindicators and bioremediation tools to tackle microplastic pollution. Microplastics are a severe problem in the world's oceans, especially in marginal and densely populated coastal areas. Marine organisms like Shellfish contain microplastics, which can cause physical damage and disrupt the immune system. Mytilus edulis clams and Crassostrea gigas oysters are the most consumed species with significant microplastic content. Research has also shown the presence of microplastics in Mytilus chilensis in the Gulf of Ushuaia, South America, with fibers and fragments being the most common types. Microplastics are also found in wild mussels in Tunisia, with the estimated annual dietary intake of microplastics by Tunisians through wild mussel consumption amounting to 4.2 particles per capita per year. Mussels of the genus Mytilus were proposed as guardian organisms to monitor microplastic pollution.

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## INTRODUCTION

Plastic pollution has increased significantly in water systems since the 1950s and is increasingly becoming a major problem worldwide due to the slow decomposition rate of these materials (Besley et al., 2017, Lots et al., 2017) . Due to its environmental impact, humans have entered a new era called the Anthropocene, where plastic pollution is considered to exert one of the most significant effects (Brander et al., 2020).

Plastic is a synthetic organic polymer often used because it is lightweight, cheap, and versatile in food packaging, medical devices, pharmaceuticals, and construction equipment (Bergmann *et al*., 2015). The resulting plastic waste is a problem that attracts public attention because of its slow decomposition rate. In Indonesia, plastic waste is estimated to reach 187.2 million tons per year (Nugraha et al., 2018).

Plastic is composed of long-chain molecules called macromolecules. Plastic cannot decompose quickly due to its long constituent chains. Plastic particles consist of various sizes, including microplastics. Microplastics (MP) are particles less than 5 mm in size. These microplastics can form from large plastic tears due to biota bites and sun degradation (Crawford *and* Quinn, 2017b).

Microplastics can be divided into two based on their origin: primary and secondary. Primary microplastics refer to microplastics that are produced intentionally in microscopic size, whereas secondary microplastics are microplastics that are formed through the fragmentation of large-size plastics. Microplastics can spread into aquatic environments, including rivers, lakes, and oceans, and can even be found in the air and soil. They become an environmental problem because of their ability to absorb chemical pollutants and because they can enter the food chain, ranging from small organisms to humans. (Lin et al., 2018; Shim et al., 2017)

Microplastics float and accumulate in sediments, allowing these particles to be ingested accidentally by marine organisms. As filter-feeder organisms, Shellfish have a way of feeding by filtering plankton so that microplastic particles that float and settle in sediments will accumulate on the clam's body through filtering activities of these particles when eating (Wagner *and* Lambert, 2017).

Mussels are one of the mollusks that are sessile (sedentary), filter feeder (food filter), and more tolerant of changes in environmental conditions (Bendell et al., 2020b; Ding et al., 2020). This filter-feeder organism can be used as a bio-monitoring agent for the aquatic environment because it settles on the bottom of the water and is exposed directly to contaminants. These properties support environmental monitoring, so Shellfish are widely used as indicators of microplastic pollution (Perez et al., 2020).

Based on this theory, which states that the presence of Shellfish can be used as biomonitoring for the presence of microplastics, it is necessary to prove whether it is true that Shellfish contain microplastics and what Shellfish can be used as environmental biomonitoring. To find the presence of microplastics in Shellfish, this study conducted a literature review of several relevant articles examining the abundance of microplastics in Shellfish.

## METHOD

This research method is based on the Systematic Literature Review (SLR) method. Systematic literature review (SLR) is a systematic technique for collecting, critically examining, integrating, and contrasting different research results regarding the research question or topic you wish to research. The search begins by finding articles related to the research topic that are then searched. Systematic review examines a particular problem by identifying, evaluating, and selecting specific problems and asking questions that are answered based on predetermined criteria. This is a continuation of previous research that is of good quality and relevant to the research question. Literature analysis provides a comprehensive overview of learning analytics methods, benefits, and challenges in the context of higher education. Examination of these aspects indicates positive contributions. However, the literature review also reveals negative considerations regarding using learning analytics (Suhartono, 2017).

Overall, the Single Lens Reflex (SLR) analysis can be facilitated by breaking it down into four main stages. The first stage is defining the SLR objective, where individuals or teams identify what they aim to achieve using SLR technology. The second stage involves the initiation and literature selection process, where relevant resources and literature are gathered and evaluated to support the subsequent process. The third stage is analysis and coding, where data and information from literature and direct observations are processed and incorporated into the appropriate context. Finally, the fourth stage is planning to present the results, where the analysis results are organized and presented clearly and effectively to relevant stakeholders. By understanding and following these four stages, the SLR process can be more structured and efficient (Suhartono, 2017).

A literature review summarizes and critically evaluates existing literature on a particular topic (Hart, 2018). SLR includes a list of peer-reviewed research and grey literature and rigorous criteria for identifying, evaluating, and synthesizing literature. The systematic literature review is often required to determine research agendas as part of dissertations or theses and as a complementary component of research grant proposals (Triandini et al., 2019).

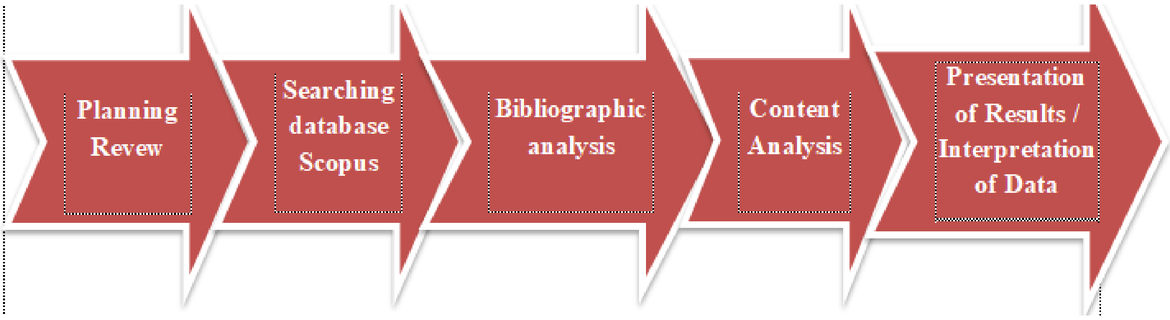


Figure 1 Flow chart related to the stages of research Systematics Literature Review

Based on keyword searches in the Scopus database, after collecting different articles, researchers selected 7 articles related to the research topic by studying these articles in detail and agreeing on the contents regarding the presence of microplastics in Shellfish.

## RESULTS AND DISCUSSION

### Microplastics

#### *Understanding Microplastics*

According to the National Oceanic and Atmospheric Administration (NOAA), plastic is classified into four categories based on size: macroplastics (>2.5-100cm), mesoplastics (>5mm - 2.5cm), microplastics (<5mm - 1μm), and nanoplastics (<1μm). (Djaguna et al., 2019). Mikroplastik (MP) adalah Partikel kecil sampah plastik dengan ukuran < 5 mm. In plastic manufacturing, additives are added to increase durability and resistance to degradation. Prolonged exposure to sunlight can lead to photoplastic degradation. Ultraviolet (UV) radiation in sunlight causes oxidation of the polymer matrix, leading to breaking bonds (Emriadi, 2021).

#### *Sources of Microplastics in The Environment*

Based on the source, microplastics are divided into two major groups: primary and secondary. (1) Primary microplastics refer to plastics produced intentionally in small sizes. Purposefully produced plastic is like the microbeads used in cosmetics and toothpaste. Examples include microbeads used in personal care products and products used in air-blasting technology. (2) Secondary microplastics exist in the environment through fragmentation of any plastic items already used or plastic waste. Once microplastics enter the environment, they are difficult to remove because they are difficult to degrade. Secondary microplastics come from the fragmentation of large plastic waste due to sunlight degradation, mechanical weathering (wind, waves, sand, etc.), and environmental chemical and biological processes (Lin et al., 2018; Shim et al., 2017).

Many sources of pollutants have developed in the environment (Di *and* Wang, 2018), such as (1) industrial waste, where microplastics are used both in cosmetics and as air blasting agents. Microplastics enter waterways through domestic or industrial drainage systems, while wastewater treatment plants trap macroplastics and small portions of plastic debris inside oxidation ponds or sewage sludge. Most microplastics will pass through those filtration systems (Cole et al., 2016a). (2) household waste, where waste generated from careless disposal of waste items will enter the river system, directly or indirectly, and then be transferred to the sea and ocean (Lin et al., 2018). (3) Activities around the coast, where coastal tourism, fisheries, recreational areas, ships, and marine industries (e.g., aquaculture, oil mines) are sources of plastics that directly enter the marine environment and pose a risk to biota both as macroplastics and as secondary microplastics (Cole *et al*., 2016).

### *Forms and Types of Microplastics*

Form is a parameter used for microplastic classification because it impacts the interaction between microplastics and other contaminants or microorganisms in wastewater (Sun et al., 2018). Microplastics can be divided into several types, namely fibers, fragments, pellets, foam, fading fibers, and films. Fiber is a microplastic that has a long and thin appearance. Fragments are small pieces or parts of large plastic items that are irregular in shape. Pellets are ovoid disc-shaped or cylindrical shapes. The film is a piece of plastic waste with a very thin layer. Foam is foam-shaped particles. Fading fiber is the fiber that has faded. While a microplastic cannot be defined as a fiber, pellet, foam, fading fiber, or film, it is defined as a fragment (Di *and* Wang, 2018).

Microplastics are fragments of irregular shape due to greater weathering and degradation of plastics. Microplastic ball beads have mostly been used for laboratory and industrial purposes. A study found that the fragment was easily digested by juvenile Calanus finmarchicus and adults and that the irregular form of polyethylene was easily digested by the larvae of the small sheephead fish (Cyprinodon variegatus). Compared to ball-shaped microplastics, irregularly shaped microplastics negatively impact larval swimming behavior, lowering the total distance traveled and maximum speed (Botterell et al., 2020).

The types of microplastics that are often found in shellfish are PP&A (polyesters, (PEST), polyamide, (PA), and acrylics) and then polypropylene (Bendell et al., 2020a), PE, Polypropylene (PP), polystyrene (PS), Polyethylene Terephthalate (PET), semi-synthetic cellulose and High Density Polyethylene (HDPE) (Q. Li et al., 2021).

### **Distribution of Microplastics to Shellfish**

The cycle of microplastic distribution in the aquatic environment begins with plastic waste in the ocean. Plastic pollution in water areas raises concerns for aquatic ecosystems. Plastic waste that enters the waters degrades into microplastics. Because of this, microplastic particles can enter the food chain until they reach higher trophic levels. Microplastics have been detected in various organisms often consumed by the public (Deswati *et al*., 2021).

Microplastics come from the fragmentation of plastic waste over a long period. Microplastics that enter the environment are not easy to remove because they are difficult to degrade. Plastic debris floats and degrades over a long period and accumulates into sediments. This is a concern for organisms that are in the waters. Its small size allows it to be accidentally ingested by marine organisms as it is mistaken for prey (Barboza et al., 2018).

The most common type of microplastic was foam (78.32%), followed by flakes (17.38%). High foam levels have also been reported on sandy beaches in South Korea (Eo et al., 2018) and Russia (Esiukova, 2017). However, most studies conducted around the world mainly report fragments and fibers. The emergence of certain types of microplastics depends on terrestrial activity and social behavior in a particular region (Hengstmann et al., 2018).

As filter feeder organisms, Shellfish have a way of feeding by filtering plankton so that microplastic particles that float and settle in sediments will accumulate on the clam's body through filtering activities of these particles when eating (Wagner *and* Lambert, 2017). This causes microplastics to enter the food chain and become a concern for humans because Shellfish are a food that humans often consume (Bergmann *et al*., 2015).

Current studies show that microplastics tend to accumulate more in lagoon environments, and microplastic consumption by filter feeder shellfish increases as microplastic concentrations in surrounding waters increase. Shellfish, including M. galloprovincialis, can be used as a good bioindicator for plastic pollution in aquatic environments and as a bioremediation tool to decontaminate MP-contaminated waters. The intake of microplastics by Tunisians was found to be very low, although Shellfish, which are thought to be an annual diet, contain high concentrations of microplastics. This is due to regional factors and culinary traditions. Since Laguna Bizerte contains plants necessary for shellfish and oyster cultivation, moving these local plants out of the lagoon and into the open ocean environment may make more sense. More research is needed to better understand the potential impact of microplastics on aquatic life and human livelihoods, depending on Bizerte Lagoon's resources (Wakkaf et al., 2020).

**Abundance of Microplastics in Shellfish**

The seriousness of the microplastic problem can be seen from the presence of 4.85 trillion microplastic particles floating in the world's oceans, with a size of 0.33 to 4.75 mm and an estimated mass of 35,540 tons. Microplastic densities are higher in marginal oceans and densely populated coastal areas (Uddin et al., 2020). Marine organisms such as fish, Shellfish, crabs, and others that humans will eat also contain microplastic in the ocean, especially Shellfish, whose way of eating is to filter plankton. Two types of Shellfish and the most consumed in the world, two widely cultivated and commercially important species were identified: Mytilus edulis mussels and Crassostrea gigas oysters, with global production of 2.1 105 tonnes and 6.6 105 tonnes, respectively, in 2010 (Cauwenberghe & Janssen, 2014).

Microplastics were observed to absorb organic contaminants or inorganic from the environment. When consumed, such microplastics cause physical harm, such as blocking or harming the intestines. In addition, some ingested lawmakers reduced digestive ability, reduced growth rate (Besseling et al., 2014), fecundity (Sussarellu et al., 2016), and disrupt the immune system (Avio et al., 2015) in many species. On the other hand, some of the ingested microplastics did not affect the growth or survival of Gammarus pulex (Weber et al., 2018) or the physiology of Perna clams (Santana et al., 2018).

Here are some research results on the presence of microplastics in Shellfish in some research results in journal articles.

Table 1. Review of research journals on the presence of microplastics in Shellfish

| No | Author Name | Year | Journal Information | Research Results |
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| 1. | Perez, Analia F.<br>Ojeda, Mariel<br>Rimondino, Guido N.<br>Chiesa, Ignacio L.<br>Mouro Di, Rosana<br>Boy, Claudia C<br>Calcagno, Javier A | 2020 | *Marine Pollution Bulletin*, Vol. 161<br>doi: https://doi.org10.1016/j.marpolbul.2020.111753 | For the first time, microplastic pollution was reported at Mytilus Chilensis in Ushuaia Bay, one of South America's most remote areas. The results showed the presence of microplastics throughout the samples, with samples containing an average of 8.6 ± 3.53 items per individual. Fiber and flakes are the most common types, with percentages of 77.91 percent and 17.44 percent, respectively). The average fiber length was 742.3 ± 702.1 µm, and the average fragment cross-sectional area was 1944.80 ± 960.94 µm2. The polymers identified are polyamide, semisynthetic cellulose material, and PVC copolymer. The amount of microplastics per individual is higher than that reported in densely populated areas. M. chilensis can play a role in a comprehensive |

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| | | | | assessment of microplastics in the Gulf of Ushuaia and provide information on the interaction of microplastics with biota (Perez et al., 2020). |
| 2. | Cauwenberghe, Lisbeth van Janssen, Colin R. | 2014 | *Environmental Pollution* Vol. 193 (65-70) doi: [http://dx.doi/org/10.1016/j.envpol.2014.06.010](http://dx.doi/org/10.1016/j.envpol.2014.06.010) | From the results of the research, (Cauwenberghe & Janssen, 2014) obtained the abundance of microplastics for Mytilus edulis, the average microplastic content in organisms without cleaning is 0.36 ± 0.07 particles per gram of soft tissue (wet weight (ww)). After a 3-day purification period, only 0.24 ± 0.07 g1 of WW particles were obtained. The same trend also occurs in Crassostrea gigas. In animals without irrigation, an average of 0.47 ± 0.16 particles of g1 ww were detected, while after irrigation, the concentration of microplastics decreased to an average of 0.35 ± 0.05 particles (ww) per gram of soft tissue. Only red or blue particles produce a different Raman spectrum. The transparent color of the particles is likely due to the presence of pigments that interfere with determining the type of plastic. Therefore, the spectrum obtained relates to the pigment contained in the particle, not the type of plastic. Three pigments were measured: hematite (red pigment), two copper blue pigments, and phthalocyanine. For both species, a 3-day cleanup period eliminated either entirely (in the case of M. edulis) or most (in the case of C. Edulis gigas) the largest microplastics (i.e., particles > 25 mm in length). In M. edulis, microplastic particles measuring 5–10 mm (50.0%) most often appear after defecation, while in C. gigas, the particles that most often appear are 11–15 mm (29.6%) and 16-20 mm (33.3%). |
| 3. | Wakkaf, Takwa El Zrelli, Radhouan Kedzierski, Mikaël Balti, Rafik Shaiek, Moez Mansour, Lamjed Tlig-Zouari, Sabiha Bruzaud, Stéphane | 2020 | Marine Pollution Bulletin Vol. 158 doi: [https://doi.org/10.1016/j.marpolbul.2020.111355](https://doi.org/10.1016/j.marpolbul.2020.111355) | Research results (Wakkaf et al., 2020) provide estimates of microplastic concentrations per soft tissue of wet-weight (ww) Mytilus galloprovincialis shells, with the highest records found at Lagoon Bizerte zone 2 stations (3.5 ± 0.3 item $g^{-1}$ ww) and LB1 (2.9 ± 0.5 item $g^{-1}$ ww), and lowest at station LB6 (0.7 ± 0.5 item $g^{-1}$ ww). Clear-coloured microplastics were found to be the most ingested particles by wild mussels (61.64%), followed by black and blue particles (10.34%, respectively; Figure 2). This latter color distribution follows roughly the same distribution found with |

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| | Rabaoui, Lotfi | | | seawater samples. The estimated annual dietary intake of microplastics by Tunisians through wild mussel consumption was 4.2 items capita$^{-1}$ year$^{-1}$, equivalent to 0.04 µg capita$^{-1}$ year$^{-1}$. |
| 4. | Ding, Jinfeng<br>Li, Jingxi<br>Suna, Chengjun<br>Jiang, Fenghua<br>Dia, Changfei<br>Zhang, Min<br>Ju, Peng<br>Ding, Neal Xiangyu | 2020 | Science of the Total Environment<br>Vol. 739<br>doi: [https://doi.org/10.1016/j.scitotenv.2020.139887](https://doi.org/10.1016/j.scitotenv.2020.139887) | Microplastics were detected in 70–100% of shellfish samples from Qingdao and 70–90% of mussel samples from Xiamen, with abundances ranging from 1.2 to 4.1 items/individual (or 0.8–4.4 items/g, wet weight of the digestive system) for mussels from Qingdao, 1.3–6.0 grains/individual (or 2.1–4.0 grains/g) for mussels from Xiamen. Microplastics have a viscose composition and tend to be fibrous, white, black, or transparent. Microplastics 500 µm is the main size range, and the size range of 100-200 µm is the most common size. The characteristics of microplastics in water-dwelling Shellfish are different from the characteristics of microplastics in sedimentary Shellfish, and the characteristics of microplastics in Shellfish depend on the sampling area shell length and are related to the wet weight of the Shellfish, the wet weight of the digestive system (Ding et al., 2021). |
| 5. | Ding, Jinfeng<br>Sun, Chengjun<br>He, Changfei<br>Li, Jingxi<br>Ju, Peng<br>Li, Fengmin | 2021 | Science of the Total Environment<br>Vol.782<br>doi: [https://doi.org/10.1016/j.scitotenv.2021.146830](https://doi.org/10.1016/j.scitotenv.2021.146830) | In the study, microplastics in the digestive systems of four locally cultivated shellfish species (Chlamys farreri scallops, Mytilus galloprovincialis clams, Crassostrea gigas oysters, and Ruditapes philippinarum clams) in Qingdao, China, were analyzed and detected in 233 of 290 shellfish samples (80%) over four seasons. Microplastic abundances in the four bivalve species ranged between 0.5 and 3.3 items/individual or 0.3 and 20.1 items/g wet weight of the digestive system, with significant species- and region-specific differences but no season-specific differences. Microfiber is the most dominant form of all microplastics found. Eighteen types of polymers between 7 and 5000 µm in diameter were identified by µ-FT-IR (505 of the 587 suspected items identified as microplastics) with polyvinyl chloride (PVC) and rayon being the most abundant. Bivalves collected in the summer contained larger microplastics. R. philippinarum collected smaller microplastics and showed differences in |

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| | | | | microplastic features compared to the other three bivalve species. By comparing and analyzing the types of microplastic polymers between each species of Shellfish and the surrounding environment, microplastics in mussels can reflect the variability of microplastic polymer types in sediments in different regions. Mussels can reflect the variability of microplastic polymer types in water to some extent (Ding et al., 2021). |
| 6. | Li, Jiana<br>Green, Christopher<br>Reynolds, Alan<br>Shi, Huahong | 2018 | Environmental Pollution Vol.44 (1-44) | The results showed that in wild mussels sampled from eight sites around the UK's coastal environment, the total residual load ranged from 0.7 to 2.9 individuals/g of tissue and 1.1 to 6.4 individuals/individual. For supermarket-bought Shellfish, the amount of microplastics in pre-cooked Shellfish (1.4 particles/g) was much higher than in direct-supplied Shellfish (0.9 particles/g). Micro-FT-IR spectroscopy was performed on 136 randomly selected samples, with 94 elements characterized. Spectra found that 50% of the debris was microplastics, and another 37% consisted of rayon and cotton fibers. The levels of microplastics detected in Shellfish bought in supermarkets indicate potential exposure to humans and suggest that microplastic counting should be included in food safety management measures and environmental monitoring (J. Li et al., 2018). |
| 7. | Li, Jiana<br>Qu, Xiaoyun<br>Su, Lei<br>Zhang, Weiwei<br>Yang, Dongqi<br>Kolandhasamy, Prabhu<br>Li, Daoji<br>Shi, Huahong | 2016 | Environmental Pollution Vol.214<br>doi: http://dx.org/10.1016/j.envpol.2016.04.012 | Bivalves are particularly concerned about possible microplastic exposure because their extensive filtering activity exposes them directly to microplastics in the water column. This study found that the total amount of microplastics ranged from 0.9 to 4.6 elements/g and from 1.5 to 7.6 items/individual. M. edulis contained more microplastics (2.7 elements/g) in the wild group than (1.6 elements/g) in the aquaculture group. Microplastic abundance was 3.3 elements/g in Shellfish from regions with intense human activity and was much higher than regions with less human activity (1.6 items/g). The most common microplastics are fibers, followed by debris. The proportion of microplastics smaller than 250 mm ranges from 17% to 79% of total microplastics. Diatoms were distinguished from shellfish microplastics for the first time using scanning electron microscopy. The scans |

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| | showed that the amount of microplastics stored in a relatively narrow range in Shellfish was closely related to environmental pollution (J. Li et al., 2016). |

Some authors have proposed Shellfish of the genus Mytilus as the guardian organisms of choice for monitoring microplastic pollution, as they can filter large amounts of water and concentrate microplastics up to several thousand times (Li et al., 2015; Bråte et al., 2018) per unit weight or volume, compared to surrounding water and sediment (Karlsson et al., 2017). Although a positive correlation was found between microplastic levels in water and microplastic levels in shellfish samples (Qu et al., 2018), Other authors argue that Shellfish can only ingest microplastics in very small sizes (Ward et al., 2019).

Mytilus chilensis species are distributed along the Pacific coast of Chile, reaching the Strait of Magellan and Beagle Strait at the southern tip of South America (Larraín et al., 2018), inhabit rocky areas in areas of intertidal communities (Curelovich et al., 2016). Although M. chilensis is the most economically important mollusk for aquaculture in Chile, it is also exploited on a small scale in the beagle sector of the Argentine Strait (Fabro, 2019). Due to its wide distribution in latitudes, it is exposed across a wide range of environmental conditions, making it a suitable model for a wide range of research, including Population genetics, biological monitoring, ecology, physiology, and metagenomics, among others (Astorga et al., 2017); (Conti et al., 2019). In the Beagle Channel, particularly in Ushuaia Bay, M. chilensis has been used for biomonitoring experiments involving heavy metals and hydrocarbons (Conti et al., 2019).

## CONCLUSION

Microplastics were found in Mytilus Chilensis in Ushuaia Bay, with an average of 8.6 ± 3.53 items per individual. The most common types of microplastics are fibers and flakes, with polymers identified, including polyamides, semisynthetic cellulosic materials, and PVC copolymers. Another study showed that Shellfish from different regions were also contaminated with microplastics, with variations in the abundance and types of microplastics found. The research highlights the importance of monitoring and managing microplastics in Shellfish to protect the environment and human health.

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