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First evaluation of microplastics in juveniles of the invasive blue crab *Callinectes sapidus* from a Mediterranean coastal lagoon

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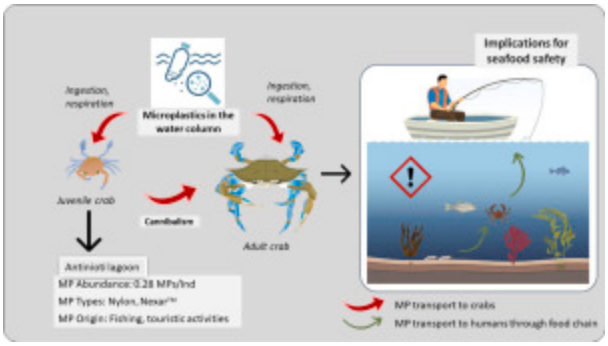
Highlights

- The first study to confirm the presence of MPs in blue crab juveniles.
- The abundance of crab-ingested MPs was determined 0.28 MPs/Ind.
- The investigated MPs were identified as Nylon and Nexar particles.
- The crab-ingested MPs originated from fishing and touristic activities
- The ingestion of MPs is influenced by their abundance in the water column.

Abstract

Microplastic pollution has affected every region of the marine environment and every level of the food chain. The potential health risks associated with the consumption of seafood products affect the worldwide seafood industry. Crustaceans are the fastest-growing fisheries industry. However, due to their predatory feeding behavior and benthic habitats, crabs are at higher risk of consuming MPs than other marine organisms. This is especially true for blue crabs (*Callinectes sapidus*) who spent most of their lives in coastal environments (such as lagoons and estuaries), which are among the most burdened environments by microplastic pollution. This study evaluated the occurrence of MPs within juvenile blue crabs from Antinioti lagoon, Greece. The findings showed an average abundance of 0.28 MPs/Ind with MPs being identified as nylon and polyethylene (PE), by Raman microscopy. Hence, blue crabs are affected by microplastic pollution from the early stages of their lives.

Graphical abstract



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Introduction

Microplastic pollution in the marine environment is continuously increasing and causes marine life from the smallest (zooplankton) to the highest (marine mammals) levels to be affected by the ingestion of significant numbers of microplastic particles (MPs). In recent years, there has been an increased interest in evaluating the occurrence of MPs in the gastrointestinal tracts of commercially exploited marine organisms (such as fish, molluscs, and shrimps) (Calderon et al., 2019, Digka et al., 2018, Ben Ismail et al.). This occurs due to the need to monitor the density of MPs within marine species that constitute most of the seafood production, as MPs tend to accumulate to higher-level organisms via the food chain. Hence, the most important species of fish, shrimp, and molluscs are being sampled and

analyzed to determine the MP abundance of their digestive tracts (Lusher et al., 2013, Claessens et al., 2011).

Several studies combined field measurements and lab analysis and showed that MPs exist in seafood products, can cause toxic effects on marine life, and have the potential to accumulate in species higher in the food chain (Miliou et al., 2016, Farrell and Nelson, 2013, Tosetto et al., 2017). MPs have been found to transfer from plankton to fish, crabs, molluscs, and eventually humans (Setälä et al., 2014, Farrell and Nelson, 2013, Santana et al., 2017). The ongoing research on the biomagnification of microplastic pollution through the consumption of seafood products provides information and warning signs regarding product safety and potential implications for human health (Kershaw and Rochman, 2015). This is essential for the coastal population whose diet is regularly based on the consumption of seafood. In the study of Hantoro et al. (2019), the authors estimated the global intake of MPs from the consumption of seafood products by humans. Their findings indicate that more than 80,000 MPs per capita are being ingested annually from fish, crustaceans, and molluscs, around the globe. Nevertheless, the majority of MPs found in commercially exploited marine species are usually located in parts of the animal that are removed before cooking (such as digestive tracts, gills, stomachs, etc.), although in some cases the entire organism is being consumed (such as anchovies, sardines, etc.) (Akhbarizadeh et al., 2018, Karami et al., 2017, Mercogliano et al., 2020, Simantiris et al., 2023). Considering human health, MPs have been found in many human samples such as placenta, stool, colon, lung, sputum, liver, breast milk, and even blood samples (Barceló et al., 2023). Despite the findings regarding the deleterious effects of MPs on marine organisms, the current knowledge of the health risks for humans is still limited. However, researchers have shown that high amounts of MPs ingested by humans can lead to immune and stress responses, and induce reproductive and developmental toxicity, cancers, respiratory disorders, and inflammatory bowel disease (Blackburn and Green, 2022, Winiarska et al., 2024). Moreover, in vitro, studies have shown that MPs can induce apoptosis and cytotoxic effects, with cell damage influenced by the MPs characteristics, such as the type, size, and charge (Winiarska et al., 2024).

Considering seafood production, crustaceans are the fastest-growing fisheries among all other types of seafood and have doubled their landings in recent years (Boenish et al., 2022). However, MPs find crustaceans before humans do. Studies have shown that crustaceans ingest MPs as a result of their feeding behaviors and burrowing activities (Egbeocha et al., 2018). The ingested MPs can accumulate in the hepatopancreas and gills of crabs posing a potential health risk to these vital organs (Brennecke et al., 2015). Although MPs usually remain in the gills and gut, they can also be translocated to other organs as well (such as

hepatopancreas, hemolymph, ovaries, etc.) (Farrell and Nelson, 2013). Some potential negative effects of the presence of MPs in the crabs' vital organs concern functions of the immune system and animal physiology (Burgos-Aceves et al., 2021, Prokić et al., 2019, Watts et al., 2016). Also, due to the predatory feeding behavior of crabs, MPs can be ingested by consuming prey that is already contaminated by MPs (trophic transfer mostly from bivalves (Watts et al., 2014)), and hence the risk of consuming MPs is higher for organisms that prey on crabs (Farrell and Nelson, 2013).

Moreover, studies have shown that the rate of intake of MPs in crabs is much higher than in other crustaceans (D'Costa, 2022). Besides feeding, crabs can accumulate MPs from their respiratory system (Villegas et al., 2022), directly from the water (in their gills), and from the sediments (D'Costa, 2022). The uptake of MPs in their gills is most likely the effect of a branchial pumping mechanism from the scaphognathite of the respiratory system of blue crabs, which allows MPs to get stuck on the gills (Watts et al., 2014). Marine sediments are the most affected underwater areas by microplastic pollution (Simantiris et al., 2023), but also the habitat of crustaceans. Thus, crustaceans are at higher risk than other marine organisms, and the uptake of MPs from sediments (via direct ingestion of respiration) has been reported in several studies (Devriese et al., 2015, Farrell and Nelson, 2013, Brennecke et al., 2015, Murray and Cowie, 2011, Wójcik-Fudalewska et al., 2016, Waite et al., 2018). The accumulation of MPs in crabs depends on several factors (such as the environmental abundance of MPs, ingestion rates, body size, mobility, etc.) (Capparelli et al., 2022, Watts et al., 2014, Remy et al., 2015, Truchet et al., 2022, Scherer et al., 2017). Nevertheless, detailed information of the processes that influence the accumulation of MPs in crabs are still very limited in the current literature.

The blue crab (*Callinectes sapidus*) is an invasive species originating from the western Atlantic coasts. (Millikin, 1984, Nehring, 2011, Williams, 1971). The species thrives in coastal environments (such as coastal lagoons, river deltas, estuaries, etc.) due to the abundant food resources, the protection from predators, and the environmental parameters that facilitate the development of blue crab juveniles (Hines et al., 2007, Perkins-Visser et al., 1996). Blue crabs are considered a significant seafood product and are usually a part of the coastal communities' diet in both the western Atlantic coasts and the coasts of the Mediterranean Sea (Mancinelli et al., 2017).

Blue crab juveniles are consumed by fish and larger invertebrates and feed on plants, zooplankton, animals, and carcasses (Hovel and Lipcius, 2001, Laughlin, 1982). Due to their benthic habitats, feeding behaviors, and proximity to the coastal human populations, blue crabs are frequently exposed to MPs, especially particles that tend to accumulate in

sediments (such as PVC, PE, PP, among others) (Waddell et al., 2020, Wright et al., 2013). Due to biofouling, MPs may often be merged with food or other substrates, leading crabs to target and consume them (Murray and Cowie, 2011, Graham and Thompson, 2009).

This study aimed to determine for the first time whether ingestion of MPs occurs in juvenile blue crabs. Antinioti lagoon is an economically significant fishery that has recently added this invasive species as a seafood product. This study investigated the occurrence of MPs in blue crab juveniles and determined the polymers associated with ingested MPs using Raman spectroscopy, an emerging tool for MP analysis in aquatic environments (Simantiris et al., 2023) which is able to provide molecular information of the sample in a non-invasive and chemically specific manner (Rangan et al., 2023). Last, the authors assessed the abundance of MPs inside the juvenile crab individuals in relation to the abundance of MPs in the water column.

Section snippets

Study site

Antinioti is a shallow Mediterranean coastal lagoon located on the northeast coast of Corfu, Greece (Fig. 1). The lagoon's water properties are determined by the antagonistic effect between fresh and seawater inputs that are mainly controlled by atmospheric forcing (rainfall) (Simantiris et al., 2021). The Antinioti lagoon's bathymetry varies between 1 and 3 m. The lagoon presents high economic and ecologic importance due to its unique biodiversity that includes marine mammals, reptiles, fish,…

Results & discussion

It was found that *Chaetomorpha linum* is an ideal substrate for the concentration of juvenile crabs as well as many other invertebrate species of the lagoon (Chironomidae larvae, shrimps, isopods, amphipods, gastropods e.g. *Akera bullata*). A total of 77 juvenile blue crabs were collected and preserved in formaldehyde to be transported and analyzed in the lab.

The carapace width of the crabs varied between 0.4 and 2.9 with an average of 1.1 cm. During the analysis of their guts, stomachs, and…

Conclusions

Crustaceans are the fastest-growing production related to the seafood industry. However, as reported in all kinds of seafood products, crustaceans are susceptible to microplastic pollution. Although several studies have reported the presence of MPs in several crab individuals, the invasive blue crab has received little attention, and studies on the occurrence of MPs within juvenile blue crabs were not encountered in the current literature. In this study, the authors sampled juvenile blue crabs…

CRediT authorship contribution statement

Nikolaos Simantiris: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Visualization, Writing – original draft. **Yannis Cladas:** Investigation, Methodology, Writing – review & editing. **Christos L. Chochos:** Resources, Writing – review & editing. **Vasilis G. Gregoriou:** Resources, Writing – review & editing. **Constantin Koutsikopoulos:** Supervision, Writing – review & editing. **Hrissi K. Karapanagioti:** Resources, Writing – review & editing. **Markos Avlonitis:**…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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