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ARTICLE

Unravelling the stomach contents of fish and crab species from Cananéia, São Paulo: Are they eating plastic?

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Abstract. Plastic pollution represents a threat to marine ecosystems and has therefore been gaining space in the realm of public interest. In this study, we investigated the ingestion of food and non-food items (*i.e.,* plastic particles) by fish and crabs. These animals are commonly collected by trawling with a double-ring net along the coast of Cananéia, state of São Paulo, Brazil; some of them are consumed as food by the local population. Fish and crab stomachs were removed and dissected, and their contents were examined under a stereoscopic microscope with an image-capturing system. The presence or absence of plastic was also registered. We examined 139 specimens of 16 fish species and 143 specimens of four crab species. The most frequent food items found in fish were unidentified food, followed by crustaceans, molluscs, polychaetes, and other fish; in crabs, the items were unidentified food, followed by crustaceans, molluscs and fish. Plastic particles were found in all fish species, representing 47.5% of the individuals analysed. In crabs, the incidence of plastic was lower, occurring in only two species (5% in *Callinectes danae* and 3% in *C. ornatus*). Only four fish species analysed had previous records of plastic ingestion in the scientific literature. The high incidence of microplastics in our study is worrying because they negatively affect the animals' lives and can be transferred through the tropic web to top predators, including humans, through the ingestion of contaminated animals.

Keywords. Human exposure; Commercial fish; Plastic fibres; Anthropogenic influence.

INTRODUCTION

Globally, approximately 50% of the 300 million tonnes of plastic produced per year are intended for a single use before being discarded, resulting in a growing burden of waste that can contaminate rivers and the ocean (Galloway *et al.,* 2017a). Around 4.8-12.7 million tonnes of plastic waste enter the marine environment annually, and such a continuous increase generates five trillion pieces of plastic in the seawater (Jambeck *et al.,* 2015). This occurs because plastic polymers are not biodegradable and may persist in the environment for long periods, ranging from decades to hundreds of years. Plastics tend to fragment in the environment and result in large or small pieces depending on the different actions to which they are submitted (*i.e.,* physical, chemical, and mechanical); these actions are responsible for increasing the number of such particles in the water (Jambeck *et al.,* 2015; Galloway *et al.,* 2017a). The presence of plastic has been recorded in oceans of every geographical region (Klein *et al.,* 2018; Jambeck *et al.,* 2015; Law & Thompson, 2014). Nevertheless, plastic production is expected to reach over 33 billion tonnes by 2050 (Worm *et al.,* 2017).

There has also been a great deal of concern regarding microplastics, which are defined as plastic particles < 5 mm and are currently the most abundant type of plastic in the ocean (Borriello & Rose, 2022; Sheela *et al.,* 2022). Microplastics found in water are usually synthesised through the production of industrialised goods such as household products, cosmetics, toothpaste, facial cleansers (Corradini *et al.,* 2019), and medical products (Carr *et al.,* 2016) in the form of beads. Microplastic can also be generated from plastic waste through physical and chemical processes, like weathering, exposure to oxygen, temperature, and ultraviolet

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light (Li *et al.,* 2020). Microfibres are the most abundant particles in seawater (Suaria *et al.,* 2020). Most of these fibres come from textile products that break down during production and laundering (Cole *et al.,* 2011; Nelms *et al.,* 2017; Suaria *et al.,* 2020). A total of 68% of fibre production comes from 'artificial/semi-synthetic' (*e.g.,* viscose and rayon) and 'synthetic' (*e.g.,* polyester and polypropylene) sources. Still, microfibres can come from automotive tyre wear, degradation of cigarette filters, and fragmentation of maritime equipment such as ropes and fishing nets (Wagner *et al.,* 2018; De Falco *et al.,* 2018; Napper & Thompson, 2016).

The global concern for plastic's damaging impact on all life forms is increasing steadily (Barrowclough & Birkbeck, 2022; Gómez & Escobar, 2022). Microplastics have been shown to carry significant amounts of harmful substances added to their composition during their production; these additives are responsible for a few different proprieties that are conferred to them (Wang *et al.,* 2015). In addition, they attract other substances when on the water's surface due to their hydrophobic nature, including persistent organic pollutants (POPs), plant matter, bacteria, chemical contaminants, additives, monomers, oligomers, and metals that are adsorbed by the plastic's surface (Teuten *et al.,* 2009; Galloway & Lewis, 2017; Galloway *et al.,* 2017a; Cole *et al.,* 2019). This makes microplastics more harmful to organisms that inevitably absorb these substances by ingestion or breathing (Watts *et al.,* 2014; Galloway *et al.,* 2017b). Once inside the animal's organism, the substances in the plastic are released into the body's system, and plastic particles can enter the circulatory system and potentially be transferred to the animal's tissues, resulting in microplastic accumulation (Batel *et al.,* 2016; Cole *et al.,* 2019). Ingested plastics can attach adhesively to the gut of animals for more than two weeks, generating bioaccumulation and biomagnification of plastic and its contaminants (Nelms *et al.,* 2017) and consequently impacting the ecological functionality of keystone species and trophic levels (*e.g.,* bioturbation, nutrient cycling) (Boerger *et al.,* 2010; Gall & Thompson, 2015; Watts *et al.,* 2015; Galloway *et al.,* 2017b; Cau *et al.,* 2019). Microplastic ingestion by different aquatic animals can alter the feeding behaviour, lower lipid storage, and reduce growth and reproduction outputs, also reducing the offspring's quality and increasing oxidative stress (Browne *et al.,* 2013; Cole *et al.,* 2014; Watts *et al.,* 2015). This phenomenon has been increasingly documented in many groups, such as fish, crustaceans, mammals, and others (Gall & Thompson, 2015, Nicastro *et al.,* 2018; Cau *et al.,* 2019; Wilcox *et al.,* 2018). Still, nanoparticles of contaminated microplastic can go from the gut to the cell membranes, causing cell deregulation (Mattsson *et al.,* 2017). Recently studies have shown microplastic occurrence at the cellular level in human placenta (Ragusa *et al.,* 2021) and blood (Leslie *et al.,* 2022).

Some cases of plastic ingestion by marine organisms have already been published in Brazil. In fish species, for example, polymers were observed in the gastric content of the Atlantic bigeye *Priacanthus arenatus* Cuvier 1829, collected from a stretch of the Santa Catarina coast (Garopaba) in southern Brazil (Cardozo *et al.,* 2018). Miranda & Carvalho-Souza (2016) addressed the same phenomenon for two species, *Scomberomorus cavalla* (Cuvier 1829) and *Rhizoprionodon lalandii* (Valenciennes 1839), in north-eastern Brazil. Furthermore, Dantas *et al.* (2020) detected plastic ingestion by seven fish species in Ceará, and Macieira *et al.* (2021) reported the ingestion of such particles by seven coral reef fish species in Guarapari Islands, both of these areas in Brazil. In contrast, reports of polymers in the digestive content of decapod crustaceans in the country are still very scarce. Records are only available for the fiddler crab *Uca (Minuca) rapax* (Smith, 1870) (Brenneck *et al.,* 2015) and spider crab *Libinia ferreirae* Brito Capello, 1871, along the Cananéia coastline, in the state of São Paulo, Brazil (Gonçalves *et al.,* 2019); more detailed studies regarding the environment and species in different Brazilian regions are still scarce. No studies on the interaction of plastic with the regional biota had ever been carried out in the coastal region of São Paulo that is being assessed in the present study; this demonstrates a research gap regarding plastic ingestion by key species from both an ecological and economic perspective. In 2017, 12,380 tonnes of coastal fish were captured in the state of São Paulo (Ávila-da-Silva *et al.,* 2019); of these, 1,913 tonnes were captured in the Cananéia region.

Considering that Brazil is the fourth largest plastic-consuming country on the planet (Wit *et al.,* 2019) and that less than 40% of the Brazilian population benefits from garbage collection services and an adequate sewage treatment infrastructure (SNIS, 2014), a study investigating microplastics' real impacts on organisms' health is urgently needed along with efforts to prevent them from afflicting these same organisms. This problem is compounded when contaminated animals are ingested whole (Nelms *et al.,* 2019). Microplastic accumulation and biomagnification in top predators like humans have been discussed (Carbery *et al.,* 2018). However, studies on this topic are still recent, and therefore little is known about it. Microplastic ingestion could be responsible for generating many diseases, and it is estimated that plastic can cause cancer and endocrine disruptions in addition to reducing human fertility (Swan & Colino, 2021). Thus, regarding the problem posed by plastic, our study is the first to describe food items and the occurrence of plastic in marine fish and crab species of Cananéia in the state of São Paulo, Brazil.

MATERIAL AND METHODS

Study area

The region of Cananéia, off the coast of the state of São Paulo, Brazil (Fig. 1), and adjacent marine areas have a rich diversity of fauna and flora, which is of great importance for conservation efforts (Diegues, 1987). In 1993, the Atlantic Forest biome, prevalent in the region, was designated as a Biosphere Reserve (UNESCO, 2005). The mangrove area in Cananéia has also gained

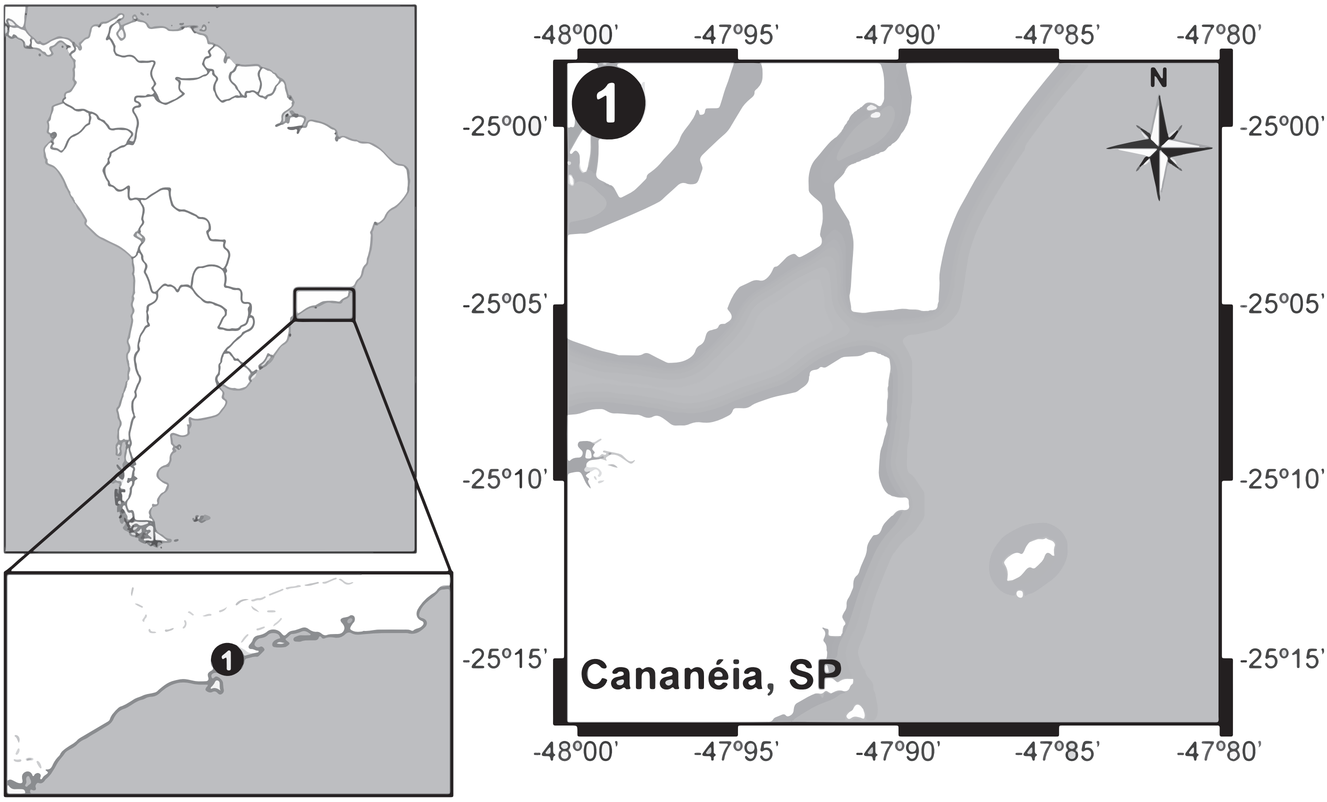

Figure 1. Sampling station in the Cananéia region, state of São Paulo, Brazil.

global recognition as the third-largest productive marine ecosystem in the South Atlantic due to its well-conserved environmental resources (Mendonça *et al.,* 2010). Cananéia was also named a World Natural Heritage Site in 1999 due to its importance in scientific research, conservation of human values and traditional culture based on the sustainability of the development standards employed (UNESCO, 1999). However, Cananéia has been undergoing an increase in population density and an intensification of fishing activities, which are the livelihood of many of the region's families (Mendonça & Katsuragawa, 2001).

Sampling

Specimens were collected in Cananéia's neighbouring oceanic areas (around 25°04′43″S, 47°50′34″W) in September 2019, seven kilometres from the coast, at depths between 11 and 15 metres. Collections were performed with a shrimp trawl (mesh size: 20 mm knot-to-knot at the body and 15 mm at the cod end) and a double rig net.

Immediately after trawling, we hand-picked the fish and crabs and transferred them to an isothermal box with ice; they were then kept in a freezer until they underwent analysis at a laboratory. This procedure followed the methods provided by Williams (1981) to ensure that the digestion of the stomach contents was impeded.

Fish specimens were identified to the lowest taxonomic level possible with a specialist's help, and crabs were identified in accordance with Melo (1996). The analysed species of crabs and fish were fixed in 10% formalin and formaldehyde solution and subsequently conserved in 70% ethanol. Vouchers of each fish specimen were deposited in the laboratory collection of the Centre for Research in Biology Ecology and Crustacean Farming [*Núcleo de Estudos em Biologia, Ecologia e Cultivo de Crustáceos* (NEBECC)] at the Zoology Department of the "Júlio de Mesquita Filho" University, Botucatu, São Paulo (NEBECC#00221 lot 1 to NEBECC#00236 lot 16).

Stomach content analyses

The stomach of fish and crabs were dissected, cut, and the contents were then washed in a Petri dish with distilled water and examined under a stereoscopic microscope (Zeiss® Stemi SV6) with an image capture system (Zeiss Stemi 2000-C). We used a modified version of the quantitative scoring method developed by Hyslop (1980), Williams (1981), and Mantelatto & Christofoletti (2001) to calculate the proportion of ingesta in each prey category. To minimise the food identification error, the items were classified in major taxa. Most of the food bits were macerated or were in an advanced digestion stage; therefore, it was not possible to identify them at the levels of genus or species. The presence or absence of plastic particles was visually examined as in Barros *et al.* (2020), through the criteria established by Norén (2007) for identifying plastic particles, that is, the absence of visible cellular or organic structures; the fibre needed to be equally thick throughout all its length, clear, and with a homogeneous colour. Only the particles that followed all the criteria were considered to be anthropogenic material, *i.e.,* plastic. The plastic particles found were counted, photographed, and measured. Some measurements were implemented to minimise sample contamination by microplastics via air-borne particles or on the surface of the equipment. Sterile containers were used for sample collection; all apparatuses used in the laboratory and all of the surfaces in it were wiped down with 70% ethanol prior to the commencement of any work. In addition, a Petri dish filled with distilled water was kept in the laboratory to monitor air contamination during sample analysis (Torre *et al.,* 2016).

RESULTS

We examined 16 fish species that were grouped according to their feeding behaviour: a) pelagic/benthic fish – *Peprilus crenulatus* Cuvier, 1829; b) pelagic fish – *Chloroscombrus chrysurus* (Linnaeus, 1766) and *Trichiurus lepturus* Linnaeus, 1758; c) benthic fish – which encompass all the other fish, along with four species of omnivorous benthic crabs. In total, 139 fish and 143 crab stomachs were sampled, and their contents were analysed. Figure 2 shows the occurrence of food items for each species.

The unidentifiable (UD) item was the predominant food item (52%), followed by crustaceans (29%), fish (4%), and sediment (4%). The other items were unrepresentative (Fig. 2). It is noteworthy that some species such as *Menticirrhus martinicensis* (Cuvier, 1830), *Stellifer brasiliensis* (Schultz, 1945), *Polydactylus virginicus* (Linnaeus, 1758), *Isopisthus parvipinnis* (Cuvier, 1830), *Oligoplites saurus* (Bloch & Schneider, 1801), and *T. lepturus* did not present UD as the most predominant food item; for them, crustaceans, fish, and molluscs were more predominant.

Crabs also had UD as their predominant food item (47%), followed by crustaceans (32%), molluscs (13%), and fish (7%). The other items were unrepresentative (Fig. 2). For *Hepatus pudibundus* (Herbst, 1785) and *Callinectes sapidus* Rathbun, 1896, the occurrence of crustaceans, fish and molluscs was higher than UD food items.

Microplastics were recorded for all fish species analysed (47.5% specimens). However, for crabs, the plastic was only found in *Callinectes ornatus* Ordway, 1863 and *Callinectes danae* Smith, 1869, two of the four crustacean species analysed (3% of individuals) (Fig. 2). One to three fragments of plastic were registered per fish with an average fragment size of 1.97 mm (ranging from 0.05 to 5.43 mm), for crabs the average fragment size was of 1.80 mm (ranging from 0.14 to 3.24 mm). Plastic microfibres were the most abundant item, representing 78% of the fragments found, in the colours blue (76%), black (19%), red (5%), and transparent (1.5%). Moreover, blue microplastic particles were found (22%) (Fig. 3). Table 1 shows the details for each species. During the analysis process, the controlled Petri dishes did not show contamination by participles in suspension in the air of the laboratory.

DISCUSSION

This study reports the food items ingested by different species of fish and crabs along the coastline of Cananéia, a region surrounded by an area designated for environmental protection and characterised by the presence of widespread subsistence fishing activity by the local population (Mendonça *et al.,* 2013; Mendonça, 2015).

Table 1. Abundance and length of microplastics ingested by 16 fish species and two crabs species from Cananéia, São Paulo.

Specie	With particles (number, %)	Min/Max no. particles/specie	Particles length (mm)	Particles colour	Particles type
Benthic fish					
Menticirrhus martinicensis	6 (34.7%)	1/3	1.66 ± 1.17	Blue > black > red	Fibre > fragment
Micropogonias furnieri	12 (50%)	1/2	1.57 ± 1.82	Blue	Fibre = fragment
Stellifer brasiliensis	1 (25%)	2	1.45 ± 0.13	Blue	Fibre
Eugerres brasilianus	2 (100%)	1	0.25 ± 0.06	Blue	Fibre
Polydactylus virginicus	2 (50%)	1	3.39	Blue	Fibre
Conodon nobilis	7 (87.5%)	1/3	2.64 ± 1.44	Blue > black	Fibre
Isopisthus parvipinnis	4 (75%)	12	0.96	Blue	Fibre = fragment
Paralonchurus brasiliensis	5 (71.4%)	1/3	1.18 ± 1.03	Blue	Fibre > fragment
Haemulopsis corvinaeformis	6 (66.6%)	1/2	2.48 ± 1.47	Blue > black = red = transparent	Fibres
Genidens barbus	2 (50%)	1	0.63	Blue	Fragment
Oligoplites saurus	2 (33.3%)	1	2.77 ± 2.81	Blue	Fibre
Aspistor luniscutis	5 (26.3%)	1/3	7.57 ± 5.87	Black	Fibre
Cathorops spixii	1 (12.5%)	1	2.56	Black	Fibre
Pelagic/benthic fish					
Trichiurus lepturus	5 (55.5%)	1/3	3.06 ± 1.69	Blue > red	Fibre
Pelagic fish					
Peprilus crenulatus	2 (66.6%)	1/3	1.92 ± 1.25	Blue > black	Fibre
Chloroscombrus chrysurus	4 (57.1%)	1	1.72 ± 1.19	Blue > black	Fibre
Crabs					
Callinectes ornatus	1 (3.3%)	2	3.16 ± 0.11	Blue	Fibre
Callinectes danae	4 (4.7%)	1	1.11 ± 0.81	Blue	Fibre > fragment

In addition, we detected the occurrence of plastic, *i.e.*, anthropogenic material, in the fish and crab stomachs. Of the 20 species analysed in this study, only the crabs *H. pudibundus* and *C. sapidus* had no plastic fragments in their stomachs. The occurrence of anthropogenic material suggests that other species from this region and of different trophic levels have most likely ingested plastic. Therefore, we emphasise the importance of studies geared toward estimating the number of plastic particles being ingested by species of the biota along the

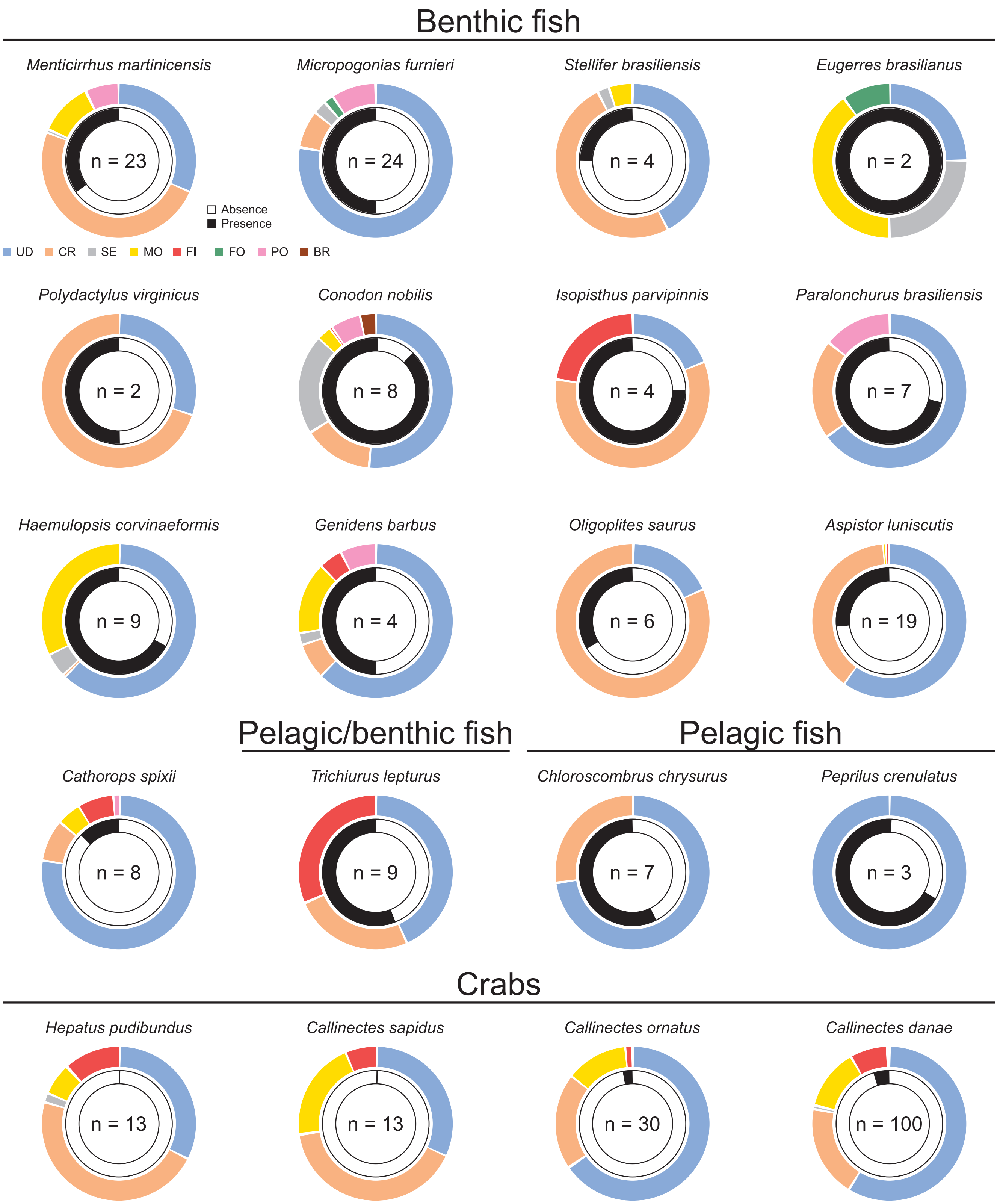

Figure 2. The coloured circle represents the food items, and the black and white circle represent the absence and presence of anthropogenic plastic material found in 16 marine fish (benthic fish, pelagic/benthic fish and pelagic fish) and four crab species in the region of Cananéia, São Paulo, Brazil (CR = crustaceans; SE = sediment; MO = mollusc; FI = fish; FO = foraminiferans; PO = polychaetes; BR = bryozoans. N = number of fish analysed. UD = Unidentified).

Brazilian coastline in order to show the different levels of impact on the environment and marine life in these sites. We also found that preserved conservation areas surrounding the Cananéia region have not prevented plastic entrance into the marine environment. In conservation areas, plastic pollution can be less concentrated but not absent since plastic particles can be transported to different regions via air, rain, wind, currents, rivers, and streams (Rochman, 2018; Lim, 2021).

All the fish analysed in our study ingested plastic particles, regardless of their feeding behaviour, and this was to be expected since plastic can be found anywhere in the ocean. Microplastics have been shown to move from the marine surface to the sediments (Gago *et al.,* 2018). Low-density plastics eventually reach the seafloor through density-modification due to biofouling or integration into zooplankton faecal matter (Cole *et al.,* 2016). Microplastic ingestion probably occurs during normal fish feeding activities, as evidenced by our results, which showed that pelagic, demersal, and benthic species had plastic in their stomach content. Plastic intake/contamination occurred independently of the trophic guild, which is in line with the findings of Dantas *et al.* (2020). We were not able to identify which species is most susceptible to microplastic ingestion based on their feeding habits. However, omnivores and predators can ingest more microplastics as a result of their wider range of diet sources, which can lead to a transfer of microplastics from prey to predator (Dantas *et al.,* 2020). The higher occurrence of microplastics in fish could be related to their behaviour of eating whole or large pieces of prey as opposed to crabs that lacerate their prey into small pieces; however, this hypothesis requires further tests. Studies on species with different eating habits in different food chains need to be performed carefully to understand the magnitude of the microplastic problem on marine life since organisms have contact with plastic particles independent of their food behaviour.

Our study showed a qualitative food habit for fish and crab species, being the first one to present these

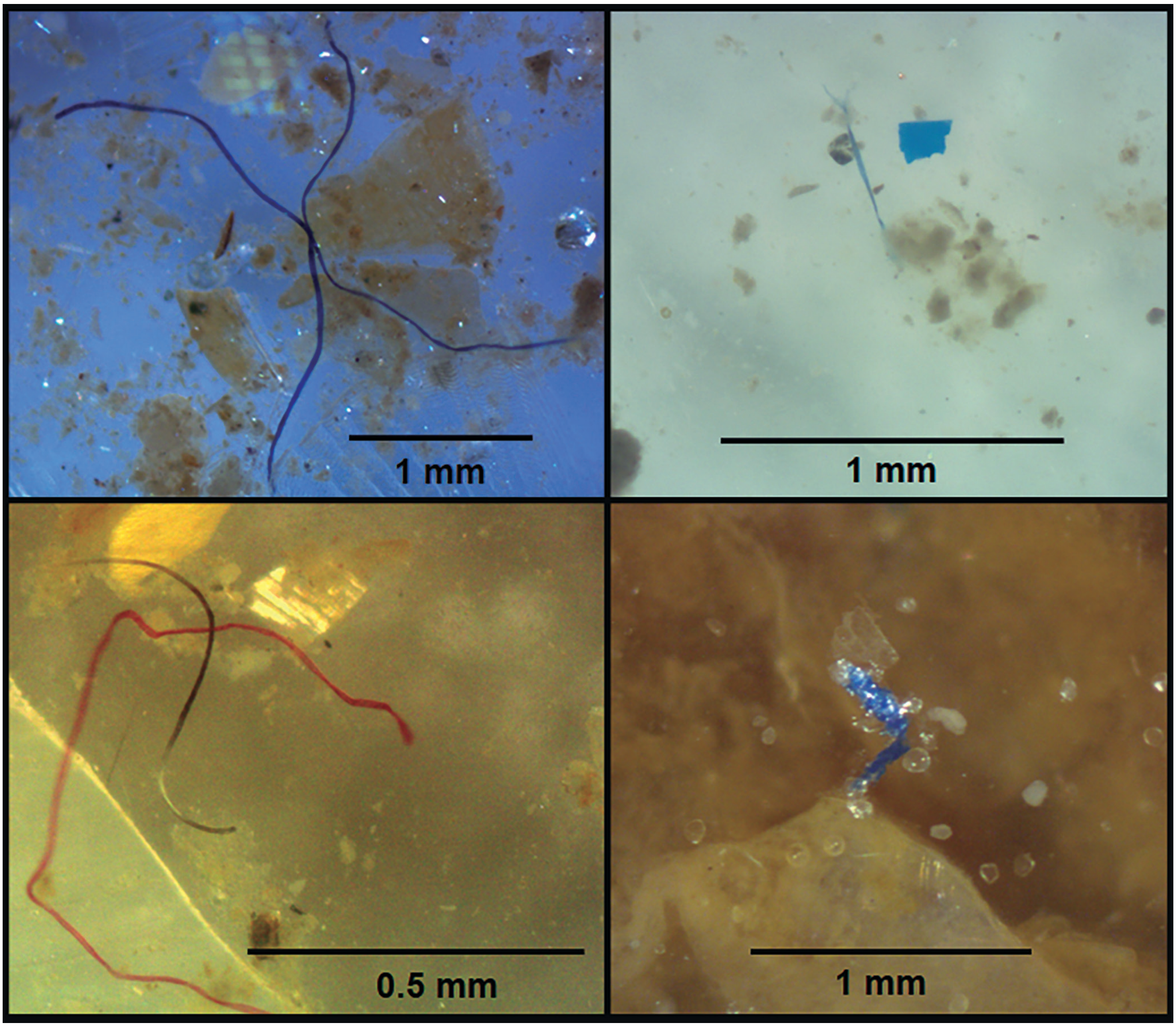

Figure 3. Representation of the plastic found in the specimens analysed. (A) largest plastic fibres found in *Polydactylus virginicus* stomach; (B) plastic particle and fibres found in the fish's stomach *Paralonchurus brasiliensis.*

results for the fish *Eugerres brasilianus* (Cuvier, 1830), *Haemulopsis corvinaeformis* (Steindachner, 1868), *P. virginicus, O. saurus,* and *P. crenulatus*. We detected differences between the diets of the following species: *E. brasilianus* and *H. corvinaeformis* displayed a preference for molluscs (such as bivalves) and sediment, while *P. virginicus* and *O. saurus* had a diet comprising predominantly crustaceans. These fish have demersal/benthic behaviour and are predators of benthos resources.

We were unable to identify food items ingested by *P. crenulatus* due to the species' accelerated digestion process. This species was reported to associate with jellyfish (Lawley & Faria-Jr., 2018), suggesting that the fish may feed off jellyfish tissue and/or even the jellyfish's food. Jellyfish tissue can be digested quickly; this has to do with the jellyfish's biochemical composition, with more than 90% of water, a high proportion of proteins, low C:N ratio, and an absence of hard structures, it is therefore easily degraded (Hsieh & Rudloe, 1994; Marques *et al.,* 2021). In addition, the food that is poached from the jellyfish has already undergone the initial stages of digestion, so its final digestion is faster.

Seven of the fish species analysed here had already been registered based on the occurrence of microplastic in their stomachs: *Conodon nobilis* (Linnaeus, 1758), *C. chrysurus, Cathorops spixii* (Agassiz, 1829), *H. corvinaeformis, O. saurus, S. brasiliensis,* and *Trichiurus lepturus* Linnaeus, 1758 (Dantas *et al.,* 2012; Silva *et al.,* 2018; Vendel *et al.,* 2017; Pegado *et al.,* 2018; Dantas *et al.,* 2020).

Crustaceans, like shrimps and crabs, use plant and organic matter accumulated in sediment as a food resource (Willems *et al.,* 2016). This can increase the crab's chance of indirectly ingesting plastics that are coated by biofilm (community of microorganisms) accumulated in the environment, which mistakenly understand this material to be food of high nutritional value. In terms of the crabs analysed in our study, there are reports of plastic occurrence only for *C. ornatus* (Santana *et al.,* 2017). However, it is noteworthy that the ingestion occurred under laboratory conditions (*see* Santana *et al.,* 2017 for more details). Thus, our study is the first to find evidence of plastic ingestion by *C. ornatus* under natural conditions. In light of our findings, we recommend that studies that seek to understand possible connections between food habits and plastic ingestion through trophic transfer be conducted.

The most frequent type of plastic we found was blue microfibre, as in many other studies conducted in marine environments (Duncan *et al.,* 2017; Compa *et al.,* 2018; Suaria *et al.,* 2020). These fibres are usually shed during the manufacturing and laundry processes and reach rivers and oceans mostly through sewage (Henry *et al.,* 2019). Some fish species eat microplastic particles because they confuse them with their natural food items. Ory *et al.* (2017) reached this understanding because they found blue plastic in the stomachs of *Decapterus muroadsi* (Temminck & Schlegel, 1844); the natural prey of *D. muroadsi* is a blue copepod that tends to live on the surface of the water, where the blue plastic particles are also found due to their lower density. These fish may confuse these particles with food. In our study, some fish representants of Carangidae, the same family studied by Ory *et al.* (2017), such as *C. chrysurus* and *O. saurus,* can have similar behaviours, thereby justifying the incidence of blue plastic ingestion. Blue nylon fibres (debris) are commonly found in the environment, facilitating accidental ingestion by animals. Dantas *et al.* (2020) found that blue polyester is the most common microfibre ingested by fish analysed in Brazil. The other blue microplastic particles found in our study could be a synthetic blue pigment used in the composition of paints and the coating of certain types of plastic, which are widely employed in the packaging industry (Lewis, 2004); Dantas *et al.* (2020) found these particles in Brazilian fish. All these plastic types, as well as their means of insertion, could be taking place in the region of Cananéia due to the improper disposal of garbage and sewage and fishing activity (loss or undue disposal of fishing gear). These activities need to be monitored since the population in this region increases by 10 times during the high season (summer) (Becegato, 2007), increasing the disposal of materials.

Many studies have shown that plastic ingestion causes significant damage to animals (*e.g.,* Watts *et al.,* 2015; Lönnstedt & Eklöv, 2016). Watts *et al.* (2015) showed that crustaceans contribute to breaking down microplastics when ingesting these particles, making smaller plastic particles available in the environment. It is noteworthy that the smaller the particles, the greater the risk they offer (Mattsson *et al.,* 2017) since they are more easily ingested (Pozo *et al.,* 2019; Foekema *et al.,* 2013). Microplastic accumulation in the animal body generates bioaccumulation of plastic and subsequent biomagnification (Rochman *et al.,* 2013; Perez-Venegas *et al.,* 2018; Nelms *et al.,* 2019); higher bioaccumulation is found in top predators, including humans (Carbery *et al.,* 2018; Au *et al.,* 2017). Different species that ingest plastic are sought after fishing resources; this increases the probability of plastic ingestion by humans (*e.g.,* Neves *et al.,* 2015; Digka *et al.,* 2018; Hara *et al.,* 2020). We included fish species with commercial importance in our study: *Micropogonias furnieri* (Desmarest, 1823), *E. brasilianus, P. crenulatus, O. saurus, Genidens barbus* (Lacepède, 1803), *M. martinicensis,* and *T. lepturus;* these last two species, in particular, are of significant commercial importance (Martins & Haimovici, 1997; Braun & Fontoura 2004). In addition, the blue crabs *C. sapidus* and *C. danae* have some commercial importance.

Regarding the species analysed in our study, none of them was recorded as threatened species in FishBase (https://fishbase.net.br, accessed on August 12th 2022). Nevertheless, such data is non-existent for some species, such as *P. crenulatus, G. barbus, C. spixii,* and *Aspistor luniscutis* (Valenciennes, 1840). Furthermore, quite a bit of the information found in the database has not been updated since 2009, and it therefore is obsolete; this is the case for *M. furnieri*. Our results reinforce the urgency of the need for further studies to shed light on the stability of populations of many species, given the pollution of the environment by different components, mainly plastic, fishing-induced pressures, and climate change.

CONCLUSION

This is the first study to document microplastic ingestion for nine fish and four crab species in their natural environments in Cananéia, São Paulo, Brazil. We found that unidentifiable food, crustaceans, molluscs, fish, and sediment are the most common items ingested by the species studied. Microplastics were found in different species that share the same environment. All of the fish species sampled in Cananéia were found to have ingested microplastics; this is independent of their habitat and feeding behaviours. Only two crab species did not present microplastics in the stomach. As previously reported, blue microplastic fibres were the most frequent microplastics in our study. The highest incidence of microplastic contamination was found in a region surrounded by preserved areas. Since a low number of individuals and species were analysed, this research in the Cananéia coast and mangrove areas should be extended to obtain more information and evidence of microplastic contamination and intake by the organisms in question. Research regarding plastic contamination is essential for guiding the Brazilian environmental authorities to create strategies for sustainable management of marine, coastal, and mangrove ecosystems in both the region and the country as a whole. Guidelines and laws should be created, and companies that use plastics should collect and reuse such material. Also, industry changes are necessary to start using natural and biodegradable products. We know this is a big challenge for Brazil; nevertheless, changes need to be implemented in this century if we want life on the planet to have a chance.

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