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UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
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CONTAMINAÇÃO POR MICROPLÁSTICOS EM CLUPEIFORMES NA ZONA DE ARREBENTAÇÃO DA PRAIA DE JAGUARIBE, ITAMARACÁ-PE

Paulo Gilson Felício do Nascimento Filho

Dissertação apresentada ao Programa de Pós-Graduação em Recursos Pesqueiros e Aquicultura da Universidade Federal Rural de Pernambuco como exigência para obtenção do título de Mestre.

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Resumo

A produção de materiais plásticos iniciou-se no final do século XIX, mas tais materiais só foram produzidos em larga escala a partir de meados do século XX. Com o avanço tecnológico do setor, esses materiais foram produzidos visando diferentes utilidades, desse modo, os mesmos foram substituindo outros materiais no mercado, como vidro, metais, entre outros.A grande problemática envolvendo esses materiais são os produtos descartáveis (de uso único), o que ocasionou um aumento exarcebado da sua produção e um consumo desenfreado dos mesmos, o que associado a ineficiência de um descarte adequado gerou um aumento significativo da presença desses materiais nos oceanos. Desse modo, realizamos um estudo com Clupeiformes na zona de arrebentação da Praia de Jaguaribe-PE, pois estes ambientes são considerados muito relevantes do ponto de vista ecológico e abrigam uma ampla diversidade de espécies de peixes, entre as quais se destacam aqueles pertencentes a essa ordem. Com isso, foram analisados 195 exemplares pertencentes a sete espécies da referida ordem, integrantes da Coleção de Peixes do Laboratório de Ictiologia/DEPAq, e indivíduos coletados no ambiente de estudo, visando a complementação do material. A pesquisa foi baseada nos tratos digestórios dos indivíduos, mediante o uso de hidróxido de sódio (NaOH) para extrair os microplásticos (MPs) presentes nos mesmos. Como resultados, foi verificada uma quantidade semelhante de MPs ingeridos entre as espécies, sendo *Anchoviella lepidentostole* a mais contaminada (60 MPs), sendo um carnívoro de 1ª ordem, que se alimenta, principalmente, de invertebrados bentônicos. Por fim, verificamos que três fatores contribuem para a ingestão dos microplásticos: hábito alimentar, características físicas de cada partícula e estação dos ano (chuvosa e seca). Podemos também concluir que há diversas fontes de ingresso dessas partículas no ambiente marinho, entre as quais a atividade pesqueira e a contribuição continental proveniente dos rios que deságuam nos oceanos.

PALAVRAS-CHAVE: resíduos plásticos; impactos antrópicos; poluição marinha; contaminação plástica

Abstract

The production of plastic materials began at the end of the 19th century, but such materials were only produced on a large scale from the middle of the 20th century. With the technological advances in the sector, these materials were produced with different uses in mind, thus replacing other materials on the market, such as glass, metals, among others. The biggest problem involving these materials are disposable products (single use), which caused an exaggerated increase in their production and an unrestrained consumption of them, which associated with the inefficiency of inadequate disposal generated a significant increase of their presence in the oceans. Therefore, we carried out a study with Clupeiformes in the surf zone of Praia de Jaguaribe-PE, as these environments are considered very relevant from an ecological point of view and are home to a wide diversity of fish species, among which those belonging to this order stand out. As a result, 195 specimens belonging to seven species of the aforementioned order were analyzed, deposited at the Fish Collection of the Ichthyology Laboratory/DEPAq, complemented by individuals collected in the study area. The research was based on the digestive tracts of individuals, using sodium hydroxide (NaOH) to extract the microplastics (MPs) present in them. As a result, a similar amount of MPs ingested was verified among the species, *Anchoviella lepidentostole* being the most contaminated one (60 MPs), as a 1st order carnivore, which feeds mainly on benthic invertebrates. Finally, we found that three factors contribute to the ingestion of microplastics: feeding habits, physical characteristics of each particle and season (rainy and dry). We can also conclude that there are several sources of entry of these particles into the marine environment, including fishing activity and the continental contribution from rivers that flow into the oceans.

Keywords: plastic waste; anthropogenic impacts; marine pollution; plastic contamination

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Sumário

1 INTRODUÇÃO

A produção de polímeros plásticos teve origem no final do século XIX, no entanto, só passaram a ser amplamente produzidos no século XX, com uso de forma limitada até meados desse século (BERGMANN et al., 2015). Tal material ocupou pouco espaço no mercado até os anos 1950, mas com o desenvolvimento tecnológico do setor e o surgimento de novos materiais ganharam relevância, substituindo materiais como vidro e metais, transformando a sociedade que conhecemos hoje (TELES et al., 2020).

Os polímeros são materiais sintéticos ou naturais constituídos por unidades de estruturas repetidas, unidas por ligações covalentes originando macromoléculas. São elaborados a partir de reações de polimerização que combinam monômeros, derivados principalmente de petróleo e gás natural, que são os principais ingredientes do plástico. Em sua composição, os plásticos também contém aditivos, que modificam algumas de suas propriedades, como plastificantes, antioxidantes, entre outros. Tais aditivos proporcionam a esse material diferentes utilizações, tornando a estrutura plástica formada mais rígida ou mais maleável, dessa forma diversificando seu uso em embalagens, sacolas plásticas, tubulações, tecidos, entre outros, ocasionando o uso desse material em larga escala (COLE et al., 2011).

A partir da invenção do plástico, um material resistente, durável, barato e com uma infinidade de utilizações, ocorreu uma revolução no modo como a sociedade moderna se desenvolveu. Com os avanços tecnológicos e a consequente verificação dos benefícios desse material, o plástico passou a ser produzido e consumido em larga escala ao nível global, passando a constituir um dos principais resíduos gerados pela humanidade. Um fato agravante desse processo foi a introdução do consumo de uso único, contribuindo para o aumento de sua produção e descarte, de modo que a poluição por resíduos plásticos se tornou um dos principais desafios ambientais da atualidade, principalmente em ambientes marinhos, onde há presença desses resíduos ao redor do mundo (NAPPER & THOMPSON, 2020).

Tais resíduos ingressam nos ambientes marinhos e costeiros por meio do descarte inadequado e da ausência de gestão e manejo do lixo produzido (JAMBECK et al., 2015), o qual é frequentemente descartado em aterros sanitários. Devido às ações do vento, retorna à superfície ele se torna "detrito", sendo o restante dos resíduos descartados irregularmente no meio ambiente (BARNES et al., 2009). Estima-se que cerca de 5-10% da produção global de plástico ingressam nos oceanos, o que correspondeu a 420 milhões de toneladas em 2017 (PLASTIC EUROPE, 2018).

Por serem resistentes e duráveis, os resíduos plásticos que ingressam no ecossistema marinho ainda permanecem nesse ambiente, seja no seu tamanho original ou em fragmentos, o que proporciona a sua interação com a fauna marinha (THOMPSON et al., 2005). Dessa forma, partículas plásticas têm sido encontradas em oceano profundo (CAUWENBERGHE et al., 2013) e até em ambientes dentro da Corrente Circumpolar Antártica (IVAR DO SUL et al., 2011). A grande preocupação acerca desses resíduos plásticos decorre de sua difícil remoção do ambiente aquático e interação com a biota marinha, onde pode ocorrer sua ingestão e consequente inserção na cadeia trófica (BARNES et al., 2009).

Tais resíduos plásticos são classificadas segundo o tamanho de suas partículas, em macroplásticos (> 25 mm), mesoplásticos (entre 5 e 25 mm), microplásticos (< 5 mm) e nanoplásticos (< 1μm). Em relação aos tipos de polímeros plásticos produzidos, oito deles se destacam economicamente, pois são utilizados desde a construção civil até em produtos pessoais: poliestireno (PS); polietileno de alta densidade (HDPE); polietileno de baixa densidade (LDPE); polipropileno (PP); poliuretano (PUR); tereftalato de polietileno (PET); cloreto de polivinila (PVC) e poliamida (PA) (GESAMP, 2015; KERSHAW et al., 2019).

Em relação aos microplásticos (MPs), além de sua classificação por tamanho, também são classificados em primários ou secundários, sendo os primários estruturas encontradas no mesmo tamanho em que foram produzidas e os secundários produzidos através do fracionamento de itens plásticos maiores, como a fragmentação de apetrechos de pesca, a ruptura de roupas sintéticas, entre outros. Tais fragmentações são ocasionadas pelo intemperismo e processos mecânicos, como a ação das ondas, ou pela ação da radiação solar (fotodegradação) (GESAMP, 2015; CASTRO et al., 2018).

Em contrapartida, os MPs primários são produzidos visando a indústria cosmética, onde são utilizados como microesferas ou micro-esfoliantes que entram na composição de diversos produtos dessa indústria. A grande preocupação em relação a esses MPs é que os mesmos podem absorver contaminantes tóxicos após serem lançados no sistema de esgoto, e dessa forma esses efluentes podem atingir os corpos d´água, como rios, estuários e por fim, os oceanos (TEUTEN et al., 2009). Dentre os principais tipos de MPs primários, os pellets se destacam como o tipo mais encontrado no ecossistema marinho e estuarino, sendo o poliestireno o polímero plástico mais predominantemente produzido (COSTA & BARLLETA, 2015).

A presença e permanência desses resíduos plásticos no ecossistema marinho possibilita sua interação com a fauna marinha, especialmente peixes, podendo ocorrer a ingestão dessas partículas, conforme já foi documentado em alguns estudos (CASTRO et al., 2018; SMITH et al., 2018; JUSTINO et al., 2021; 2023). Essa ingestão pode ocorrer de forma intencional ou acidental, causando vários efeitos físicos nos indivíduos que a ingeriu, tais como falsa sensação de saciedade, bloqueio do trato digestório, desnutrição, mudanças comportamentais e/ou fisiológicas. Além disso, também há o risco dessas partículas estarem contaminadas por compostos químicos tóxicos, tais como poluentes orgânicos persistentes (POPs), agrotóxicos, pesticidas ou produtos químicos utilizados para a produção do material plástico, que podem ser adsorvidos por essas partículas (MIRANDA & CARVALHO, 2016; WANG et al., 2020).

A ingestão de partículas plásticas contaminadas por compostos químicos podem levar à sua acumulação nos tecidos dos indivíduos que as ingerirem, podendo ser transferidos e amplificados por biomagnificação para níveis tróficos superiores, incluindo os seres humanos, como consumidores do topo da cadeia alimentar. Tal fato representa uma problemática muito relevante, pois, desse modo, os contaminantes químicos atingem uma ampla diversidade de organismos marinhos (TEUTEN et al., 2009).

O primeiro estudo que evidenciou a ingestão de resíduos plásticos por peixes foi realizado por Carpenter et al. (1975) e, desde então, vários artigos têm evidenciado sua presença em, aproximadamente, 400 espécies de peixes marinhos em diversos ambientes (CANNON et al., 2016; COLLARD et al., 2017; KARAMI et al., 2018; JUSTINO et al., 2021; 2023). Tal ingestão é influenciada pelo hábito alimentar e o habitat que a espécie ocupa, ocorrendo quando o peixe confunde a partícula plástica com algum dos itens que compõem a sua dieta natural, dessa forma, ingerindo a partícula de forma acidental (CARSON, 2014). No entanto, o termo “microplástico” só foi utilizado pela primeira vez em 2009 (COLABUONO et al., 2009), a partir do aumento significativo do número de publicações acerca desse tema, embora ainda exista uma carência de estudos voltados para determinados grupos taxonômicos, tais como os Clupeiformes, e em alguns ambientes, com destaque para as zonas de arrebentação (CASTRO et al., 2018).

As zonas de arrebentação são ambientes marinhos extremamente relevantes do ponto de vista ecológico, haja vista, que proporcionam condições ideais para o recrutamento de peixes (CLARK, 1997), servindo também como áreas que funcionam como berçário para uma ampla diversidade de espécies de peixes marinhos (ROBERTSON & LENANTON, 1984). Esses ambientes também são conhecidos por apresentar águas com temperaturas elevadas, disponibilidade de uma ampla gama de recursos alimentares e condições ambientais que favorecem um baixo risco de predação e proteção contra condições adversas (BLABER & BLABER, 1980). Desse modo, constituem ambientes fundamentais para o sucesso reprodutivo de um elevado número de espécies de peixes, contribuindo para o equilíbrio do ecossistema marinho (GIBSON, 1994).

Em relação à zona de arrebentação da Praia de Jaguaribe, situada no litoral norte do estado de

Pernambuco, local do presente estudo, a mesma é considerada rica do ponto de vista ictiofaunístico, por abranger uma grande diversidade de espécies, representadas principalmente por indivíduos em fases iniciais de desenvolvimento (SANTANA & SEVERI, 2009). Tais espécies também ocorrem em áreas adjacentes, como estuários, recifes e prados de fanerógamas, habitando a zona de arrebentação de forma sazonal ou anual (SANTANA et al., 2013). Algumas das espécies de peixes que ocorrem nesse ambiente são consideradas raras para esse tipo de ecossistema, o que reforça a sua relevância para a manutenção do equilíbrio do ecossistema costeiro (SANTANA & SEVERI, 2009; SANTANA et al., 2013).

Entre os peixes mais abundantes na zona de arrebentação da Praia de Jaguaribe, destacam-se aqueles pertencentes à ordem Clupeiformes, que abrangem as famílias Engraulidae, Pristigasteridae e Dorosomatidae (SANTANA & SEVERI, 2009; CALIFORNIA ACADEMY OF SCIENCES, 2024). Espécies dessas famílias são bem representadas nesse ambiente, ressaltando sua importância ecológica e econômica, dado seu valor pesqueiro (FRANÇA & SEVERI, 2022). Além disso, esses indivíduos são fontes de alimento para peixes maiores que possuem importância econômica, desse modo, contribuindo para o equilíbrio do ecossistema marinho (FRANÇA & SEVERI, 2022).

No entanto, há uma carência de estudos sobre a interação dessas espécies com os microplásticos em praias tropicais, e os possíveis efeitos que essa contaminação possa acarretar ainda não são totalmente compreendidos (SMITH et al., 2018). Portanto, é necessário realizar uma pesquisa para analisar a interação entre os microplásticos e os peixes que possuem diferentes hábitos alimentares, haja vista que tais espécies se alimentam de diferentes itens e que a ingestão desses fragmentos pode ocorrer de maneira diferente entre elas (AMORIM et al., 2020). Para tanto, elaboramos duas hipóteses que foram testadas: (I) a ingestão de microplásticos pode ocorrer via cadeia trófica, através do consumo de peixes de pequeno tamanho por peixes carnívoros e (II) há diferenças na quantidade e no tipo de microplástico predominantemente ingerido entre as espécies analisadas. Desse modo, analisamos essa interação em um ambiente que ainda não havia sido explorado, de modo que o nosso trabalho é inédito no tipo de ambiente estudado, bem como na avaliação em zonas de arrebentação de praias arenosas do litoral nordestino, para algumas das espécies analisadas nesse trabalho.

OBJETIVOS

Objetivo Geral

Avaliar a contaminação de peixes marinhos da ordem Clupeiformes, a partir da ingestão de microplásticos e a sua relação com o hábito alimentar e o nível trófico das espécies na zona de arrebentação da Praia de Jaguaribe, Itamaracá-PE.

Objetivos Específicos

- Verificar a ocorrência e a abundância de microplásticos (MPs) em algumas espécies de Clupeiformes de diferentes hábitos alimentares;
- Analisar qual nível trófico dos peixes é mais suscetível à ingestão de microplásticos;
- Analisar qual tipo de microplástico é predominantemente encontrado em espécies de cada nível trófico;

CAPÍTULO 1

CONTAMINATION BY MICROPLASTICS IN CLUPEIFORMES IN THE SURF ZONE ON A SANDY BEACH OF THE TROPICAL WESTERN ATLANTIC OCEAN

Este artigo foi submetido para publicação no jornal Marine Pollution Bulletin

CONTAMINATION BY MICROPLASTICS IN CLUPEIFORMES IN THE SURF ZONE ON A SANDY BEACH OF THE TROPICAL WESTERN ATLANTIC OCEAN

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Abstract

Microplastics (MPs) are plastic particles smaller than 5 mm in length found in freshwater and marine ecosystems, interacting with a broad variety of organisms, including fishes. The aim of the present study was to analyze the occurrence and abundance of microplastics in Clupeiformes in the surf zone of Western Atlantic sandy beach, located in the state of Pernambuco, northeastern Brazil. A total of 195 individuals belonging to seven species of Clupeiformes with different feeding habits were analyzed to determine differences in the total quantity and type of MPs predominantly ingested among the species analyzed. Samples from the digestive tract were submitted to alkaline digestion with sodium hydroxide (NaOH) for the extraction of MPs present in the gastro-intestinal contents. The different species ingested a similar quantity of MPs. *Anchoviella lepidentostole*, which is a first-order carnivore, was the species with the largest quantity recorded in this study (60 MPs). Fibers were the predominant type of MPs found in the majority of the species analyzed, with predominance of the transparent, blue and black type. The results enable the inference that three factors contributed to the ingestion of MPs: feeding habit, MPs type and seasonality (rainy and dry seasons). In conclusion, the study area is highly contaminated by plastic residues that are ingested by marine fauna, constituting a serious environmental and social problem, given the importance of these species in local food webs and the food security of local populations.

KEYWORDS: plastic residues; anthropogenic impacts; marine pollution; plastic contamination

1. INTRODUCTION

The production of plastic materials has increased dramatically since the 1960s, reaching an annual growth rate of 8.7% and contributing to industrial revenues of US$ 600 billion on the global scale (JAMBECK et al., 2015). Approximately eight million tons of plastics are discarded in oceans annually and, according to estimates, there are five trillion plastic particles in the surface waters of oceans (ERIKSEN et al., 2014). These residues enter the marine environment through industrial discharge or trash dumped along continental water courses (Mai et al., 2020), and are also transported by winds and wastewaters (SMITH et al., 2018).

Although pollution by plastic materials in marine and freshwater environments has been a scientific and social issue for decades (Cole et al., 2011; Li et al., 2016; Auta et al., 2017), concerns have increased recently due to the large quantity of small plastic fragments found in these environments. Such fragments are denominated microplastics (MPs), which are particles smaller than 5 mm in length and are categorized as primary and secondary (CASTRO et al., 2018). Primary MPs are small particles of plastic discarded into the environment, whereas secondary MPs originate from the fragmentation of larger plastic residues that break down after being exposed to the marine environment. Primary MPs may be released during the production of larger plastic materials and are also part of the composition of some personal hygiene products, such as body moisturizer, exfoliating soap, etc. (BOUCHER & FRIOT, 2017).

MPs are found in all types of aquatic environments and are accessible to a large variety of organisms – from microscopic organisms to fishes and aquatic mammals (WANG et al., 2020). Due to the small size and similarity to items that compose the natural diet, MPs may be ingested accidentally or intentionally by fishes, which can have physical effects, such blockage of the digestive tract, difficulty for absorbing nutrients, reproductive complications, etc. (WRIGHT & KELLY, 2017). Moreover, MPs may serve as substrate for the adsorption of toxic chemical substances and pathogenic microorganisms, therefore introduced into the aquatic food chain (WANG et al., 2020), in freshwater (Li et al., 2018; Li et al., 2020), coastal and oceanic environments (Ferreira & Hadju, 2023).

Surf zones are important coastal marine environments for the recruitment of fishes (CLARK, 1997). Several studies on the ichthyofauna of tropical beaches reveal that this environment also serves as a nursery, considering the presence of a large variety of fish species, especially in the initial phases of development (ROBERTSON & LENANTON, 1984). These environments also constitute feeding grounds and protection from both predators and adverse conditions (BLABER & BLABER, 1980). Indeed, surf zones have physical characteristics that lower the risk of predation, high water temperatures and a broad variety of food sources (GIBSON, 1994).

The surf zone of Jaguaribe Beach on the northern coast of the state of Pernambuco in northeastern Brazil has ecological importance, as it shelters a broad variety of fishes, including species considered rare for this type of ecosystem, as well as both annual or seasonal residents (SANTANA & SEVERI, 2009). Thus, the ichthyofauna of the surf zone of Jaguaribe Beach may be considered rich and abundant. Most fishes are small, including individuals in the juvenile phase and others that occur in adjacent areas, such as estuaries, reefs and seagrass meadows (SANTANA et al., 2013). Fishes belonging to the order Clupeiformes, which encompasses the families Engraulidae, Pristigasteridae and Dorosomatidae, are among the most abundant in the surf zone of this beach (SANTANA & SEVERI, 2009). Species of these families are well represented in this environment, which demonstrates its ecological importance, and are also commonly exploited by the human population, being of high value as fishery resources (FRANÇA & SEVERI, 2022).

Despite the importance to the food security of coastal populations, there is a lack of knowledge on the interaction between fish contamination by microplastics and human consumption. Moreover, the possible effects of this type of contamination on human health are not yet fully understood (SMITH et al., 2018). Thus, there is a need to investigate the interaction between MPs and fishes with diverse feeding habits, as such species feed on different items and the ingestion of plastic particles may occur in different manners among them (AMORIM et al., 2020). Therefore, the aim of the present study was to determine the occurrence and abundance of MPs in species of Clupeiformes with different feeding habits in the surf zone of Jaguaribe Beach, identifying the most common types of MPs, the feeding habit most susceptible to ingesting MPs and possible sources of plastic particles in the environment studied.

2. MATERIAL AND METHODS

2.1 Study area

The municipality of Itamaracá (07°43’08” and 07°45’32”S; 034°50’14” and 034°51’05”W) is part of Itamaracá Island, located on the northern coast of the state of Pernambuco in northeastern Brazil, at approximately 50 km from the state capital, Recife. The coastal region, which includes Jaguaribe Beach (Figure 1), is comprised of a flat zone (altitude; 30 to 60 m), with an abrupt break near littoral areas (KEMPF, 1970). The substrate comprises dead or relatively inactive corals and calcareous algae on a sandstone foundation (MEDEIROS & KJERFVE, 1993).

Jaguaribe Beach is subjected to waves moving mainly in the southeast direction and a dominant northerly current. Its substrate is sandy soil with a high content of calcium carbonate produced by the decomposition of rocky outcrops due to coastal erosion and sediments composed of quartz sand, foraminifera, mollusk shells and fragments of calcareous algae (*Halimeda* and *Lithothamnion*) (LOPES, 1999; GUERRA et al., 2005; SANTANA & SEVERI, 2009).

2.2 Material and analytical procedure

This study involved the use of specimens of the order Clupeiformes with different feeding habits deposited in the Fish Collection of the Ichthyology Laboratory of *Universidade Federal Rural de Pernambuco* (UFRPE), as well as additional collections from the study area performed to complement the material available at the lab. The species analyzed were *Anchovia clupeoides*

(Swainson, 1839), *Anchoviella lepidentostole* (Fowler, 1911), *Lycengraulis grossidens* (Spix & Agassiz, 1829), *Chirocentrodon bleekerianus* (Poey, 1867), *Opisthonema oglinum* (Lesueur, 1818), *Lile piquitinga* (Schreiner & Miranda Ribeiro, 1903) and *Anchoa tricolor* (Spix & Agassiz, 1829) (Figure 2).

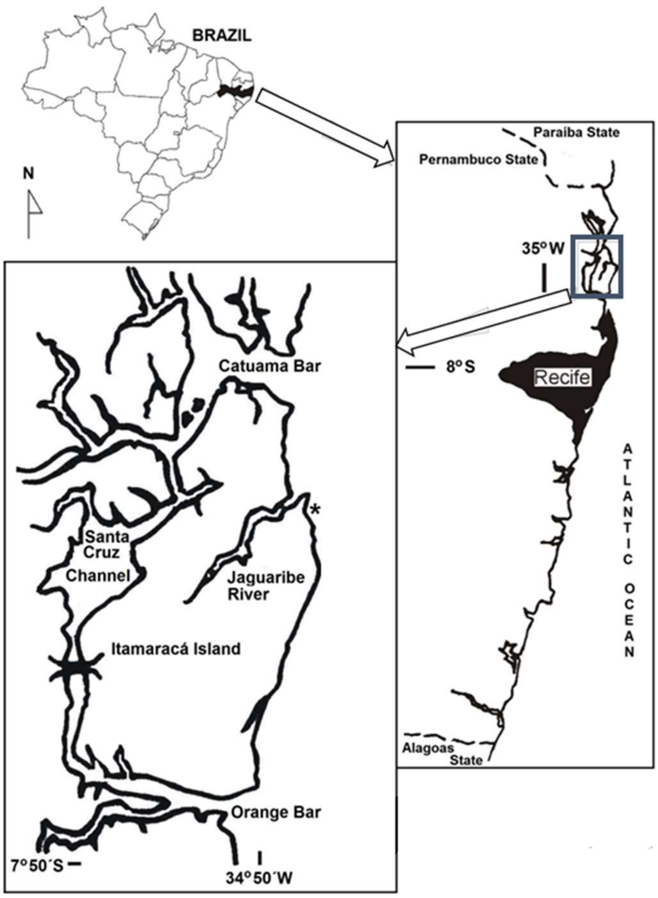

Figure 1- Location of Jaguaribe Beach (*) on the northern portion of the Itamaracá Island, Pernambuco State, Northeastren (modified from Santana & Severi, 2009).

Collections for complementary material were authorized through License SISBIO 22500-6 and were performed using a type of beach seine 10 m in length, 1.5 m in height and mesh size of 1 cm. The individulas were anesthetized with eugenol (200 mg/L), and transferred to a solution of 4% formalin for euthanasia, according to Bittencourt et al. (2012) and Rotili et al. (2012), and later preserved in 70% ethanol until analyses. All fish were measured (calipers) and identified taxonomically based on Figueiredo & Menezes (1978), Munroe (2002) and Nizinski & Munroe (2002a,b). Collection and analysis procedures were approved by the Ethical Committee for Animal Use in Experiments of the Federal Rural University of Pernambuco (CEUA Number 3334280922).

The classification of species feeding habits was based on Paiva et al. (2008) and Favero et al.

(2019), as planktivores (P) – species that feed on phytoplankton and zooplankton; 1st order carnivores (C-I) – species that feed mainly on benthic invertebrates; 2nd order carnivores (C-II) – species that mainly feed on invertebrates and fishes. For the analysis of MPs contamination, individuals with a full or partially full digestive tract were prioritized (GOMES & VERANI, 2003).

2.3 Extraction of microplastics

An alkaline digestion protocol was adopted using sodium hydroxide (NaOH) for the extraction of microplastics from the digestive tract of the specimens (JUSTINO et al., 2021). Samples of the digestive tract were first washed with filtered distilled water prior to immersion in a NaOH 1M solution at a proportion of 1 g of digestive tract per 100 ml of solution. The material was then placed in a laboratory oven for drying at 60°C for a 24-hour period. The samples were than vacuum filtered through a 0.7-µm fiberglass filter (Whatman). The filters were placed in lidded Petri dishes and dried again at 60°C for another 24 hours. The following step was the visual analysis of the filters using a stereomicroscope with magnification between 10 and 50 X and a limit of detection of 0.02 mm. Fragments considered microplastics were photographed, counted and measured with the aid of a micrometer reticle. MPs were then categorized based on shape (Justino et al., 2021) as fiber (filamentous shape), fragment (irregular shape), film (flat shape), foam (soft format and irregular shape) and pellet (spherical shape).

2.4 Contamination control

To avoid possible aerial contamination and cross-contamination, a quality control protocol for analytical procedures was adopted based on Justino et al. (2021). A set of procedures was executed to avoid contamination, such as the use of 100% cotton lab coats and disposable gloves and handling in a clean, secure environment with restricted access. Moreover, all solutions were vacuum filtered through a 0.7-µm fiberglass filter (Whatman) and all equipment was duly sanitized with 70% ethanol prior to each chemical digestion. A blank was used for each set of 10 samples analyzed, which was composed of 10 ml of filtered NaOH 1M solution submitted to the same treatment as the samples. Microplastic fragments found in the blank were disregarded in the analysis of the samples.

2.5 Data analysis

Significant differences ($p<0.05$) in MPs number found between species and feeding habits were examined using analysis of variance, considering the total quantity and shape of the MPs. The Shapiro-Wilk test was used to determine the distribution (parametric or nonparametric) of the data. As the data were nonparametric, the Kruskal-Wallis test was used with Dunn's post-hoc text for significant differences between the species analyzed. All statistical analyses were performed in the R environment (R-core Team, 2024).

3. RESULTS

A total of 195 individuals were analyzed, belonging to seven species of Clupeiformes (Table 1): *A. lepidentostole*, *L. grossidens*, *A. tricolor*, *C. bleekerianus*, *L. piquitinga*, *A. clupeoides* and *O. oglinum*. The first species is a 1st order carnivore, the following two are 2nd order carnivores; and the remaining four ones are planktivores, according to Paiva et al. (2008) and Favero et al. (2019). Among the total, 136 individuals (69.7%) had microplastics in the digestive tract.

The frequency of occurrence of MPs among the individuals of each species was high, varying from 74.1% in *A. clupeoides* to 63.3% in *A. lepidentostole* (Table 2). MPs number in individual gastrointestinal tracts ranged from one to seven particles. The median number of MPs found differed significantly among the species (p=0.003), ranging from 2.00 in *A. lepidentostole* to 1.27 in *O. oglinum* (Table 2).

Table 1- Number, minimum (min.) and maximum (max.) standard length (SL) and sampling season of of Clupeiformes species individuals (number in parenthesis) analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil.

Species	Number	SL (mm)		Sampling season
		min.	max.	
A. lepidentostole	30	46.8	59.3	rainy (20), dry (10)
L. grossidens	30	52.1	100.9	dry (30)
A. tricolor	30	43.7	74.9	dry (30)
L. piquitinga	30	57.0	77.1	dry (30)
A. clupeoides	27	63.5	112.4	rainy (3), dry (24)
O. oglinum	18	52.0	103.0	dry (18)
C. bleekerianus	30	47.9	84.3	rainy (15), dry (15)

Table 2 – Feeding habit, total and mean MPs number found in the Clupeiformes species analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil. *Feeding habit: C-I – 1st order carnivore, C-II – 2nd order carnivores, P – planktivores.

Species	Feeding habit*	Total MPs number	Mean MPs number	MPs occurence (%)
A. lepidentostole	C-I	60	2.00	66.3
L. grossidens	C-II	50	1.66	73.3
A. tricolor	C-II	47	1.56	73.3
L. piquitinga	P	48	1.60	70.0
C. bleekerianus	P	45	1.50	66.6
A. clupeoides	P	35	1.29	74.1
O. oglinum	P	23	1.27	66.7

Three hundred eight MPs particles composed of five types were identified: fiber, fragment, pellet, film and foam. Fiber and fragment were the dominant types among species (37 and 27% of the total) (Figure 2A). Transparent (32%), blue (24%), black (21%) and brown (18%) were the dominant colors of fibers (Figure 2B), with less participation of red and green ones (<5%). Total size range of MPs types varied form 0.04 to 4.0 mm but the dominant (65%) size class was 0.1 to 1.0 mm (Table 3, Figure 2C). Fiber was the MPs type with the largest range and maximum size found (0.05 to 4.00 mm), whereas the other types' size range varied from 0.02 to 0.4 mm. All MPs types presented higer percentages at the 0.1-1.0 mm size class (from 42 to 91%), except for film with most particles sizes (76%) below 0.1 mm (Figure 2C).

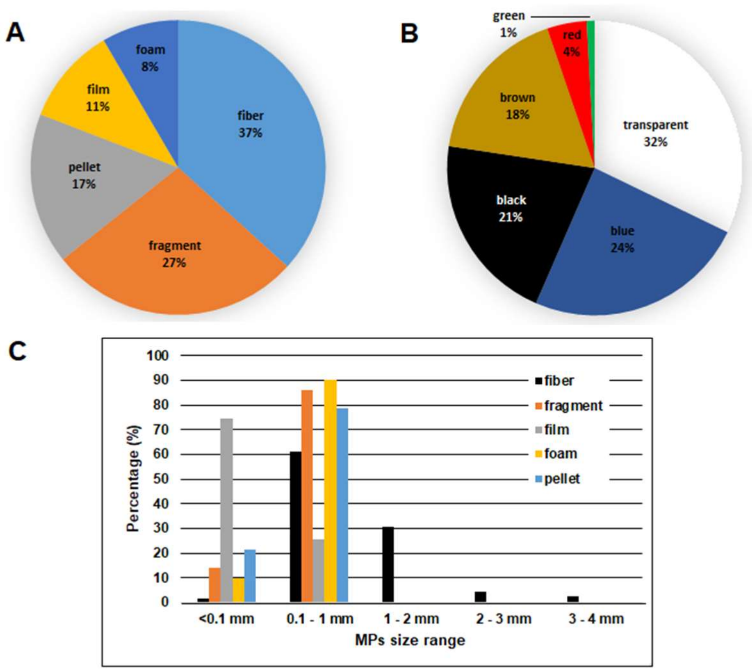

Figure 2 – Percentages of each MPs type (A), different fiber colors (B), and occurrence of each type at different classes of MPs size range found in all Clupeiformes species analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil.

Table 3 – Size range of each MPs type found among the Clupeiformes species analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil.

MP type	Size range (mm)	
	min.	max.
Fiber	0.05	4.00
Fragmente	0.04	0.32
Film	0.02	0.40
Foam	0.05	0.38
pellet	0.04	0.30

The different types of MPs were found in all species analyzed, with the exception of foam, which was not found in *L. grossidens* or *A. tricolor* (Figure 3). Fiber was the most common type in the contaminated specimens of most species, ranging from 40.7% to 100% of the individuals, followed by fragments, with greater occurrence in *O. oglinum* (94.4%) and *L. grossidens* (93.3%). The highest occurrence of film-type MPS was found in *L. piquitinga* (53.3%), foam-type in *C. bleekerianus* and *A. lepidentostole* (40%), and pellet-type in *A. tricolor* (46.7%) (Figura 3).

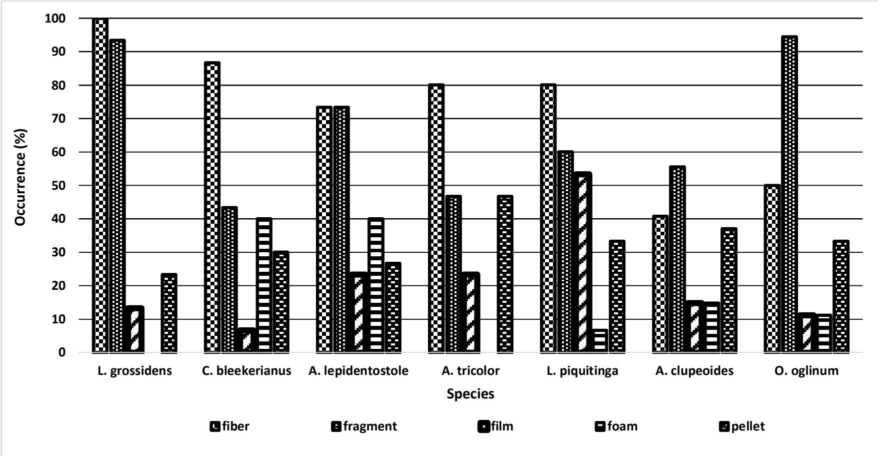

Figure 3 – Occurrence percentage of all MPs types in contaminated specimens of the Clupeiformes species analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil.

The total number of MPs found in the digestive tracts differed among Clupeiformes species of with different feeding habits (p = 0.02), and was higher in the 1st order carnivore (*A. lepidentostole*) compared to 2nd order carnivores and planktivores (Table 2).

With regards to the relative proportion of the type of MPs found in the total composition of items ingested by the species, fiber was found predominately in *L. grossidens* (100%), *A. tricolor* (70%), *A. lepidentostole* (67%), *L. piquitinga* (60%) and *C. bleekerianus* (57%), with a predominant occurrence of transparent, blue and black colors (Figura 2A). Fragment was found predominantly in *O. oglinum* (61%) and *A. clupeoides* (44%), film in *L. piquitinga* (47%), pellet in *A. tricolor* (37%), and foam in *C. bleekerianus* (40%) (Figure 4).

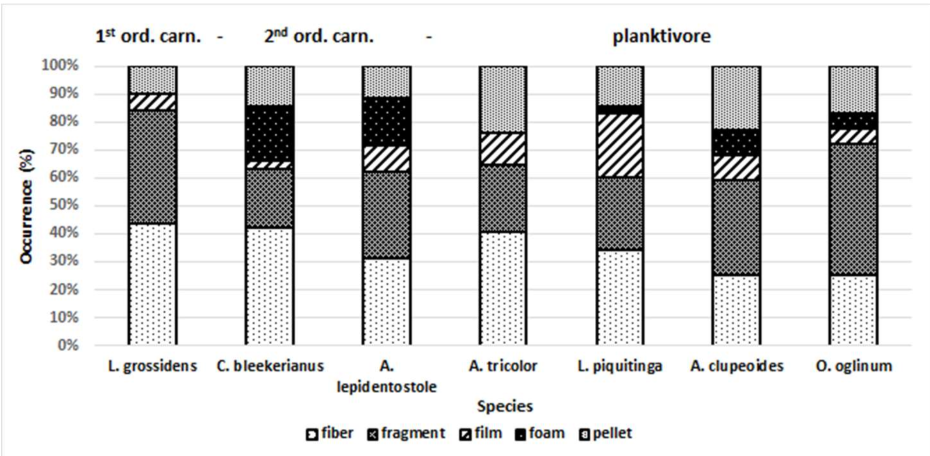

Figure 4 – Occurrence percentage of ingested MPs types by each Clupeiformes species analyzed from the surf zone of Jaguaribe Beach, Itamaracá Island, State of Pernambuco, Brazil.

Specimens available in the Ichthyology Collection and complementary material from the study area were used in the present study. For the seasonal analysis, species with individuals collected in both seasons were prioritized. However, due to the seasonality of some species, this was only possible for *C. bleekerianus* and *A. lepidentostole* (Table 1). These species had a significant ingestion of foam-type MPs (Figure 3), whereas those only caught in the dry season had less ingestion or no ingestion of this type of MP, as occurred with *L. grossidens* and *A. tricolor* (Figure 3).

4. DISCUSSION

The rates of contamination by microplastics were high (69.7%) for the seven marine species analyzed, as the majority of individuals had at least one plastic particle in the digestive tract. Pelagic, demersal-pelagic and demersal fishes have high rates of contamination by microplastics (NETO, 2019; JUSTINO et al., 2021), which may explain the significant quantity of MPs found in the gastrointestinal tracts of the individuals analyzed. The greater presence of plastic items in marine compared to freshwater environments contributes to the greater contamination by MPs in marine fishes (Jabeen et al., 2017).

Fiber was the type of MP found most in the species studied, which is in agreement with data described in previous studies (SILVA, 2018, BESSA et al., 2018; NETO, 2019; JUSTINO et al., 2021), in which the presence of fibers was reported, especially blue, black and transparent ones, which can facilitate ingestion, as fishes are visually oriented animals. These fiber colors give indications of the different sources of origin of the particles (HASTUTI et al., 2019; RAZAVIARANI et al., 2024). Moreover, many particles had evidence of wear, which demonstrates that the MPs hab already been in the environment for some time, as also reported in studies conducted by Castro et al. (2018) and Smith et al. (2018).

In the present investigation, we found one to seven plastic particles per specimen, which is similar to results described by Silva (2018) and Dantas et al. (2020), who respectively recorded the presence of one to 10 MPs and one to 14 MPs in the specimens analyzed.

Although various types of MPs were found in the species analyzed, fibers were the most ingested one, although the proportion differed among species, as also occurred with the second most ingested type of MP in the individuals analyzed. The results demonstrated that species with carnivorous feeding habits mainly ingested fiber-type MPs. *Lycengraulis grossidens* and *Anchoa tricolor*, which are 2nd order carnivores, had significantly greater ingestion of this type of MP over the other types. In contrast, the proportion was lower in *Anchoviella lepidentostole*, which is a 1st order carnivore. Thus, one may infer that feeding habit is one of the factors that influence the ingestion of MPs. Ferreira et al. (2018) also recorded greater ingestion of fiber-type MPs in carnivorous fishes. In agreement with the present findings, Mizraji et al. (2017) also reported greater ingestion of fiber-type MPs compared to other types in carnivorous fishes collected on the central coast of Chile. Conversely, Justino et al. (2021) found a greater occurrence of pellets in carnivorous fishes in the Estuarine Complex of the Santa Cruz Channel, Itamaracá, Pernambuco. A greater ingestion of fragment-type MPs in carnivorous fishes of Biawak Island, an environmental conservation area in Indonesia, was reported by Ismail et al. (2018). Such differences in MPs type ingestion among species of similar feeding habits may be attributed to plastic sources to the environment, environmental conservation status and fragmentation processes.

Anchoviella lepidentostole was the species that ingested the largest quantity of MPs (n = 60) in this study. This is a 1st order carnivore that feeds mainly on benthic invertebrates, which inhabit the bottom of lakes, estuaries and oceans and may live attached, buried or associated with rocks, aquatic plants and trunks during part or all of the lifecycle (ROSENBERG & RESH, 1993). Thus, this species has a greater proportion of its pectoral fin compared to the other clupeiform species analyzed in this study, which gives it the ability to explore environments in which the energy to seek food is more limited, such as the substrate. Moreover, the larger pectoral fin gives the fish greater maneuverability and superior fluctuation control, which enables it to make fast, precise movements or move slowly in the water, contributing to the significant capture of benthic invertebrates (FRANÇA & SEVERI, 2024).

The distribution of plastics in the marine environment is influenced by environmental factors, such as currents and winds, as well as the characteristics of each type of plastic particle, such as its physical and chemical properties and sources of origin (AUTA et al., 2017). Particles with low density tend to float and accumulate in surface waters and may be transported to either coastal zones or more distant regions (FAZEY & RYAN, 2016). Over time, these particles can become encrusted, which changes their density, causing them to sink. This leads to the accumulation of these particles in deep waters and on the substrate, favoring ingestion by demersal species (SILVA et al., 2023).

Thus, the physical characteristics of each plastic particle can contribute to the ingestion of MPs by fishes, as particles tend to sink over time and species that feed on organisms associated with the substrate tend to ingest a greater quantity of MPs by feeding on contaminated prey items or by ingesting MPs unintentionally, confusing the particles with possible prey items (SILVA, 2018). The foraging activity of fishes that feed on these organisms may also contribute to the ingestion of MPs, as such activity leads to the suspension of plastic residues retained in the substrate, making them available in the environment. Moreover, it is likely that demersal fishes can also ingest plastic particles directly from sediments (WARDLAW et al., 2022; SFRISO et al., 2024). Thus, fishes the feed on organisms associated with the substrate are more frequently contaminated by MPs (SILVA, 2018; WARDLAW et al., 2022), ingesting mainly fibers and fragments, as found in the present investigation.

With regards to planktivorous species, *L. piquitinga* was the most contaminated (48 MPs), mainly ingesting fibers and – in a smaller proportion – foams. The individuals analyzed of this species were only collected in January, which is a month of low precipitation on the coast of the state of Pernambuco. In contrast, *Chirocentrodon bleekerianus*, which ingested 45 MPs, was collected in June and September, which are months of higher precipitation, especially June. *C. bleekerianus* also ingested a greater proportion of fibers, but foam-type MPs were also well represented in this species. The presence of foam-type MPs is associated with the increase in precipitation and the main sources are the fragmentation of buoys and packaging, the fragments of which are transported by the winds and surface current, reaching beaches due to their low density (SILVA et al., 2023).

Thus, season of the year is another factor that contributes to the distribution of plastic particles in the marine environment, especially in the rainy season. The higher precipitation and water level of rivers leads to a greater flow of freshwater into the marine environment, transporting various solid waste products, including plastic materials, thus facilitating the interaction of fishes with MPs (CASTRO et al., 2018; SMITH et al., 2018). *Chirocentrodon bleekerianus* was the species that most ingested foam-type MPs, as this species was mainly collected in June, which is the month of highest precipitation in the study area (MEDEIROS & KJERFVE, 1993).

Despite the smaller numbers compared to other species in this study, *Anchovia clupeoides* and *Opisthonema oglinum* exhibited significant contamination by MPs, mainly fragments, differing from the other species analyzed. Individuals of these species were collected in October (*Opisthonema oglinum*), March and December (*Anchovia clupeoides*), months of lower precipitation of the dry season in the study area (MEDEIROS & KJERFVE, 1993), which may have influenced the low ingestion of foam-type MPs (SILVA et al., 2023).

Irrespective of feeding habit, all species analyzed in the surf zone of Jaguaribe Beach exhibited significant contamination by MPs. Dantas et al. (2020) also found significant contamination by MPs is fishes of different trophic guilds from a tropical beach in northeastern Brazil (Ceará State).

5. CONCLUSION

The environment analyzed in this study is contaminated by plastic residues, which are available to a broad variety of organisms, including fishes. These organisms ingested plastic particles either accidentally or intentionally. Feeding strategy, nature of the particles and meteorological events throughout the year influenced on the type of microplastic ingested, as demonstrated by differences in the proportion and type of microplastics ingested by the species. Despite the differences in microplastics type and their proportions ingested by the species, no clear correlation could be found between feeding habit and contamination level. Complementary studies on the origin and dynamics of MPs in coastal marine environments, such as Jaguaribe Beach in Itamaracá Island, are needed to gain a better understanding of the forms of contamination by these materials, as well as potential associations with pathogenic agents and other contaminants, such as persistent organic pollutants. Solutions are needed to mitigate the entrance of these residues into the marine ecosystem. It is also necessary to estimate the risk that the ingestion of these particles can pose for marine aquatic biota, as well as the health of the human population that uses fishery resources to ensure food security and generation of income.

CRediT authorship contribution statement

P.G.F Nascimento Filho: Writing – original draft, Methodology, Formal analysis. **W. Severi**: Writing – review & editing, Supervision, Conceptualization, Data curation.

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.

Data availability

Data will be made available on request.

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References

AMORIM A.L.A., RAMOS J.A.A., JUNIOR M.N. (2020). Ingestion of microplastic by ontogenetic phases of *Stellifer brasiliensis* (Percifomes, Sciaenidae) from the surf zone of tropical beaches. **Mar Pollut Bull**, v.158, n. 111214, https://doi.org/10.1016/j.marpolbul.2020.111214.

AUTA H.S., EMENIKE C.U., FAUZIAH, S.H. (2017). Distribution and importance of microplastics in the marine environment:areview of the sources, fate, effects, and potential solutions. **Environ Int**, v.102, p. 165-176.

BESSA F., BARRIA P., NETO J.M., FRIAS J.P.G.L., OTERO V., SOBRAL P., MARQUES J.C. (2018). Occurrence of microplastics in commercial fish from a natural estuarine environment. **Mar Pollut Bull,** v.128, p. 575–584, http://dx.doi.org/10.1016/ j.marpolbul.2018.01.044.

BITTENCOURT F., SOUZA B.E., BOSCOLI W.R., RORATO R.R., FEIDEN A., NEU D.H. (2012). Benzocaína e eugenol como anestésicos para o quinguio (*Carassius auratus*). **Arq Brasileiro de Med Vet e Zootec**, v.64, p. 1597-1602.

BLABER S.J.M., BLABER T.J. (1980). Factors affecting the distribution of juvenile estuarine and inshore fish. **J of Fish Biol**, v.17, p. 143-162.

BOUCHER J., FRIOT D. (2017). Primary Microplastics in the Oceans: A Global Evaluation of Sources. Gland, Switzerland: **IUCN**, 43pp.

CASTRO R.O., SILVA M.L., ARAÚJO F.V. (2018) Review on microplastic studies in Brazilian aquatic ecosystems. **Ocean and Coast Manag**, v.165, p. 385-400.

CLARK B.M. (1997) Variation in surf-zone fish Community structure across a wave-exposure gradient. **Estuar, Coast and Shelf Sci**, v. 44, p. 659-674.

COLE M., LINDEQUE P., HALSBAND C., GALLOWAY T.S. (2011). Microplastics as contaminants in the marine environment: A review. **Mar Pollut Bull**. v.62, p. 2588-2597, https://doi.org/10.1016/marpolbull.2011.09.025.

DANTAS N.C.F.M., DUARTE O.S., FERREIRA W.C., AYALA A.P., REZENDE C.F., FEITOSA C.V. (2020). Plastic intake does not depend on fish eating habits: Identification of microplastics in the stomach contents of fish on an urban beach in Brazil. **Mar Pollut Bull,** v.153, n. 110959, https://doi.org/10.1016/j.marpolbul.2020.110959

ERIKSEN M., LEBRETON L.C.M., CARSON H.S., THIEL M., MOORE C.J., BORERRO J.C., GALGANI F., RYAN P.G., REISSER J. (2014). Plastic Pollution in the World´s Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. **PLOS ONE**, v. 9, n. 111913, https://doi.org/10.1371/journal.pone.0111913.

FAVERO F.D.L.T., ARAUJO DA SILVA I.M., SEVERI W. (2019). Structure of the fsh assemblage and functional guilds in the estuary of Maracaípe, northeast coast of Brazil. **Bol do Inst de Pesca**, v. 45, n. 1, 417.

FAZEY F.M., RYAN P.G. (2016). Biofouling on buoyant marine plastics: an experimental study into the effect of size on surface longevity. **Environ Pollut**, v. 210, p. 354-360.

FERREIRA G.V.B., BARLLETA M., LIMA A.R.A., MORLEY S.A., JUSTINO A.K.S., COSTA M.F. (2018). Altas taxas de ingestão de microplásticos em um peixe predador do Atlântico Ocidental e percepções de um efeito direto da pesca. **Ambient. Poluir**. v.236, p.706–717, http://dx.doi.org/10.1016/j.envpol.2018.01.095.

FERREIRA H.C., HAJDU G.L. (2023). Microplastics in coastal and oceanic surface waters and their role as carriers of pollutants of emerging concern in marine organisms. **Mar Environ Res**, v.188, 13p, https://doi.org/10.1016/j.marenvres.2023.106021.

FIGUEIREDO J.L., MENEZES N.A. (1978). **Manual de peixes marinhos do sudeste do Brasil. II. Teleostei (1).** Museu de Zoologia, Universidade de São Paulo, São Paulo. 110p.

FRANÇA V.F.C., SEVERI W. (2022). Ecomorphological relations of sympatric juveniles of Clupeiformes from a Brazilian sandy beach. **Iheringia, Ser Zool**, v.112, n. 2022011, https://doi.org/10.1590/1678-4766e2022011.

FRANÇA V.F.C., SEVERI W. (2024). Ecomorphological Relationships and Dissimilarities of Engraulidae Juveniles in a Brazilian Tropical Surf-Zone Environment. **Thalassas: An Int J of Mar Sci**, v. 40, https://doi.org/10.1007/s41208-024-00716-z.

GIBSON R.N. (1994). Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. **J of Sea Res**, v. 32, p. 191-206.

GOMES J.H.C., VERANI J.R. (2003). Alimentação de espécies de peixes no reservatório de Três Marias. In: GODINHO, H.P. & GODINHO, A.L. (Eds). **Águas, peixes e pescadores do São Francisco das Minas Gerais**. Belo Horizonte, CNPq/ PADCT, Editora PUC Minas, p. 195-227.

GUERRA N.C., KIANG C.H., SIAL A.N. (2005). Carbonate cements in contemporaneous beachrocks, Jaguaribe beach, Itamaracá island., Northeastern Brazil: petrographic, geochemicaland isotopic aspects. **Braz Acad of Sci**, v. 77, p. 343- 352.

HASTUTI A.R., LUMBANBATU D.T.F., WARDIATNO Y. (2019). The presence of microplastics in the digestive tract of commercial fishes off Pantai Indah Kapuk coast, Jakarta, Indonesia. **BIODIVERSITAS**, v. 20, p. 1233-1242.

ISMAIL M.R., LEWARU M.W., PRIHADI D.J. (2018). Microplastics Ingestion by Fish in the Biawak Island. **World Scientific News**, v. 106, p. 230-237.

JABEEN K., SU L., LI J., YANG D., TONG C., MU J., SHI H. (2017). Microplastics and mesoplastics in fish from coastal and fresh waters of China. **Environ Pollut**. v.221, p.141-149.

JAMBECK J.R., GEYER R., WILCOX C., SIEGLER T.R., PERRYMAN M., ANDRADY A., NARAYAN R., LAW K.L. (2015). Plastic waste inputs from land into the ocean. **Sci, v.**347, p. 768-771.

JUSTINO A.K.S., LENOBLE V., PELAGE L., FERREIRA G.V.B., PASSARONE R., FRÉDOU T., FRÉDOU F.L. (2021). Microplastic contamination in tropical fishes: An assessment of different feedings habits. **Reg Stud in Mar Sci**, v.45, p. 1-8.

KEMPF M. (1970). Nota Preliminar Sobre os Fundos Costeiros da Região de Itamaracá (Norte do Estado de Pernambuco). **Trabalhos Oceanogr da Universidade Federal de Pernambuco**, v. 9, p. 95-110.

LI C., BUSQUETS R., CAMPOS L.C. (2020). Assessment of microplastics in freswater systems: a review. **Sci of the Total Environ**, v.707, 12p, https://doi.org/10.1016/j.scitotenv.2019.135578.

LI J., LIU H., CHEN J.P. (2018). Microplastics in freswater systems: A review on occurrence, environmental effects, and methods for microplastics detection. **Water Res**, v.137, p. 362-374. https://doi.org/10.1016/j.watres.2017.12.056.

LI W.C., TSE H.F., FOK L. (2016). Plastic waste in the marine environment: A review of sources, occurrence and effects. **Sci of the Total Environ**,v.566, p.333-349, https://dx.doi.org/10.1016/j.scitotenv.2016.05.084.

LOPES P.R.D. (1999). Nota sobre a alimentação de *Albula vulpes* (Linnaeus, 1758) (Actinoptergii: Albulidae) na Praia de Jaguaribe (Ilha de Itamaracá), Pernambuco. **Stientibus**, v. 20, p. 15-22.

MAI L., SUN X.F., XIA L.L., BAO L.J., LIU L.Y., ZENG E.Y. (2020) Global riverine plastic outflows. **Environ Sci & Technol**. 54, p.10049-10056, https://dx.doi.org/10.1021/acs.est.0c02273.

MEDEIROS C., KJERFVE B. (1993). Hydrology of a tropical estuarine system: Itamaracá, Brazil. **Estuar, Coast and Shelf Sci**, v. 36, p. 495-515.

MIZRAJI R., AHRENDT C., PEREZ-VENEGAS D., VARGAS J., PULGAR J., ALDANA M., PATRICIO OJEDA, F., DUARTE C., GALBÁN-MALAGÓN C. (2017). Is the feeding type related with the content of microplastics in intertidal fish gut?. **Mar Pollut Bull**, v.116, p.498–500, http://dx.doi.org/10.1016/j.marpolbul.2017.01.008.

MUNROE T.A. (2002). Order Clupeiformes: Pristigasteridae. In: CARPENTER, K.E. (ed.). **The living marine resources of the Western Central Atlantic.Volume 2: Bony fishes part 1 (Acipenseridae to Grammatidae).** Rome: FAO, pp. 795-803.

NETO J.G.B. (2019). **INGESTÃO DE PLÁSTICOS POR PEIXES MARINHOS COMERCIALMENTE IMPORTANTES NO SUDESTE-SUL DO BRASIL**. Trabalho de dissertação (Programa de pós-graduação em Oceanografia Biológica- Universidade Federal do Rio Grande).

NIZINSKI M.S., MUNROE T.A. (2002a). Order Clupeiformes: Engraulidae. In: CARPENTER, K.E. (ed.). **The living marine resources of the Western Central Atlantic.Volume 2: Bony fishes part 1 (Acipenseridae to Grammatidae).** Rome: FAO, pp. 764-794.

NIZINSKI M.S., MUNROE T.A. (2002b). Order Clupeiformes: Clupeidae. In: CARPENTER, K.E. (ed.). **The living marine resources of the Western Central Atlantic.Volume 2: Bony fishes part 1 (Acipenseridae to Grammatidae).** Rome: FAO, pp. 804-830.

PAIVA A.C.G., CHAVES P.T.C., ARAÚJO M.E. (2008). Estrutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. **Rev Brasileira de Zool**,v. 25, n.4, p. 579-846.

R Core Team. R: **A language and environment for statistical computing**. R Foundation for Statistical Computing, Vienna, Austria. URL: R: The R Project for Statistical Computing (r-project.org), 2024. Acesso em: 10/06/2024.

RAZAVIARANI V., SAUDAGAR A., GALLAGE S., SHRINATH S., ARAB G. (2024). Comprehensive investigation on microplastics from source to sink. **Clean Technol and Environ Policy**, v. 26, p. 1755-1782.

ROBERTSON A.I., LENANTON R.C.J. (1984). Fish Community structure and food chain dynamics in the surf-zone of sandy beaches: the role of detached macrophyte detritus. **J of Exp Mar Biol and Ecol**, v. 84, p. 265-283.

ROSENBERG D.M., RESH V.H. (1993). Introduction to Freshwater Biomonitoring and Benthic Macroinvertebrates. In: Rosenberg, D.M. and Resh, V.H., Eds., **Freshw Biomonitoring and Benthic Macroinvertebrates**, Chapman/Hall, New York, 1-9.

ROTILI D.A., DEVENS M.A., DIEMER O., LORENZ E.K., LAZZARI R., BOSCOLO W.R.

(2012). Uso de eugenol como anestésico em pacu. **Pesqui Agropecu Trop**, v. 42, p. 288-294.

SANTANA F.M.S., SEVERI W. (2009). Composição e estrutura da assembleia de peixes da zona de arrebentação da praia de Jaguaribe, Itamaracá, PE. **Bioikos**, v. 23, p.3-17.

SANTANA F.M.S., SEVERI W., SOUZA F.E.S., ARAÚJO M.E. (2013). THE ICHTHYOFAUNA OF THE BRAZILIAN SURF ZONE: A COMPILATION FOR ECOLOGICAL COMPREHENSION PER REGION. **Trop Oceanogr**, v.41, p. 37-53.

SFRISO A.A., JUHMANI A.S., TOMIO Y., SFRISO A., RIZZOLIO F., ADEEL M., WAHSHA M., MUNARI C., MISTRI M. (2024). Microplastic accumulation and ecological impacts on benthic invertebrates: Insights from a microcosm experiment. **Mar Pollut Bull**, v. 202, n. 116231.

SILVA J.R.P. (2018). **DIETA E INGESTÃO DE MICROPLÁSTICOS EM PEIXES DO ESTUÁRIO DO RIO PARAÍBA, PARAÍBA, BRASIL**. Trabalho de conclusão de curso (Curso de graduação em Ciências Biológicas-Universidade Estadual da Paraíba).

SILVA V.C.C., ANDRADE R.C., VERNIN N.S., TORRES NETTO A. (2023). Estudo das fontes de poluição por microplásticos recorrentes na Baía de Guanabara, Rio de Janeiro. **Rev de Gest de Água da Am Lat**, v. 20, e5, https://doi.org/10.21168/rega.v20e5.

SMITH M., LOVE D.C., ROCHMAN C.M., NEFF R.A. (2018). Microplastics in Seafood and the Implications for Human Health. **Curr Environ Health Rep**, v.5, p. 375-386.

WANG W., GEB J., YU X. (2020). Bioavailability and toxicity of microplastics to fish species: A review. **Ecotoxicol and Environ Saf**, v.189,p. 1-10.

WARDLAW C.M., CORCORAN P.L., NEFF B.D. (2022). Factors influencing the variation of microplastic uptake in demersal fishes from the upper Thames River Ontario. **Environ Pollut**, v. 313, n. 120095.

WRIGHT S.L., KELLY F.J. (2017). Plastic and human health: a micro issue?. **Environ Sci & Technol**, v. 51, p. 6634-6647.

CONSIDERAÇÕES FINAIS

Os resultados apresentados constataram a contaminação por microplásticos dentre as espécies analisadas, bem como a influência do hábito alimentar das mesmas e sua interação com a sazonalidade na ingestão desses resíduos plásticos na zona de arrebentação da Praia de Jaguaribe.

A elevada ingestão de MPs por *Anchoviella lepidentostole,* como um carnívoro de 1°ordem, que se alimenta principalmente de invertebrados bentônicos, permite inferir que sua contaminação possivelmente ocorre via transferência trófica, pelo consumo direto desses invertebrados pela espécie. Desse modo, aceitamos a nossa primeira hipótese de que a ingestão de microplásticos poderia ocorrer via transferência trófica. Em contrapartida, refutamos a nossa segunda hipótese, que afirmava que haveria diferenças na quantidade e no tipo de microplásticos ingeridos entre as espécies analisadas, haja vista que todas as espécies apresentaram uma contaminação significativa por MPs e ingeriram, principalmente, o MP do tipo fibra.

No que diz respeito ao tipo de microplástico predominantemente encontrado em cada espécie, o mesmo variou, principalmente, nas espécies planctívoras, com destaque para *Anchovia clupeoides* e *Opisthonema oglinum*, que ingeriram, principalmente, o microplástico do tipo fragmento, contrapondo-se às demais espécies analisadas nesse estudo. Em relação às espécies carnívoras, não houve diferença entre o tipo de microplástico predominantemente encontrado, com predomínio do tipo fibra.

Por fim, nosso estudo concluiu que a área analisada está contaminada por resíduos plásticos, ingeridos por peixes de diferentes hábitos alimentares. A intensa atividade pesqueira no entorno da área de estudo no litoral da Ilha de Itamaracá pode contribuir como uma importante fonte de entrada de detritos plásticos no ambiente marinho, provenientes dos apetrechos de pesca, associada a outras fontes antrópicas de contaminação decorrentes do lançamento de lixo sólido proveniente da área urbana densamente povoada nessa parte do liroral norte de Pernambuco.

REFERÊNCIAS

AMORIM, A.L.A.; RAMOS, J.A.A.; JUNIOR, M.N. Ingestion of microplastic by ontogenetic phases of *Stellifer brasiliensis* (Percifomes, Sciaenidae) from the surf zone of tropical beaches. **Marine Pollution Bulletin**, v.158, n. 111214, 2020. DOI: https://doi.org/10.1016/j.marpolbul.2020.111214

BARNES, D. K. A.; GALGANI, F.; THOMPSON, R. C.; BARLAZ, M. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society. **Biological Sciences**, v. 364, n. 1526, p. 1985- 1998, 2009.

BERGMANN, M.; GUTOW, L.; KLAGES, M. Marine anthropogenic litter. **Springer**, p.447, 2015.

BLABER, S.J.M. & BLABER, T.J. Factors affecting the distribution of juvenile estuarine and inshore fish. **Journal of Fish Biology**, v.17, p. 143-162, 1980.

CALIFORNIA ACADEMY OF SCIENCES. Species by Family. Disponível em: CAS - Eschmeyer's Catalog of Fishes - Genera/Species by Family/Subfamily (calacademy.org). Acesso em: 29/08/2024.

CANNON, S.; JENNIFER, M.E.; LAVERS, L.;FIGUEIREDO, B. Plastic ingestion by fish in the Southern Hemisphere: A baseline study and review of methods. **Marine Pollution Bulletin**, v.170, p. 286-291, 2016.

CARPENTER, E.;SUSAN, J.; ANDERSON, J. GEORGE, R.;HARVEY, H.;MIKLAS, P.;BRADFORD, B.P. Polystyrene Spherules in Coastal Waters. **Science**, v. 175, p. 1240, 1975.

CARSON, H.S. The incidence of plastic ingestion by fishes: From the prey´s perspective. **Marine Pollution Bulletin**, v.74, p. 170-174, 2014.

CASTRO, R.O; SILVA, M.L.; ARAÚJO, F.V. Review on microplastic studies in Brazilian aquatic ecosystems. **Ocean and Coastal Management**, v.165, p. 385-400, 2018.

CAUWENBERGHE, L. V.; VANREUSEL, A.; MEES, J.; JANSSEN, C. R. Microplastic pollution in deep-sea sediments. **Environmental pollution**, v. 182, p. 495-499, 2013.

CLARK, B.M. Variation in surf-zone fish Community structure across a wave-exposure gradiente. **Estuarine, Coastal and Shelf Science**, v. 44, p. 659-674, 1997.

COLABUONO, FI, BARQUETE, V., DOMINGUES, BS, MONTONE, RC. Ingestão de plástico por Procellariiformes no sul do Brasil. Março. **Poluição**. Touro. v.58,p. 93–96, 2009.

COLE, M.; LINDEQUE, P.; HALSBAND, C.; GALLOWAY, T. S. MICROPLASTICS AS CONTAMINANTS IN THE MARINE ENVIRONMENT: A REVIEW. **Marine Pollution Bulletin** (v. 62, issue 12, p. 2588–2597). DOI: https://doi.org/10.1016/j.marpolbul.2011.09.025.

COLLARD F, BERNARD G, GAUTHIER E, LAETITIA R, COMPÈRE P, KRISHNA D, PARMENTIER E (2017) MORPHOLOGY OF THE FILTRATION APPARATUS OF THREE PLANKTIVOROUS FISHES AND RELATION WITH INGESTED ANTHROPOGENIC PARTICLES. **Marine Pollution Bulletin** 116:182-191.

COSTA, M. F. & BARLETTA, M. MICROPLÁSTICOS EM AMBIENTES COSTEIROS E MARINHOS DO OCEANO ATLÂNTICO TROPICAL E SUBTROPICAL OCIDENTAL. **Ciência ambiental: processos e impactos**, v. 17, n. 11, p. 1868-1879, 2015.

FAVERO, F.D.L.T., ARAUJO DA SILVA, I.M., SEVERI, W. Structure of the fsh assemblage and functional guilds in the estuary of Maracaípe, northeast coast of Brazil. **Boletim do Instituto de**

Pesca, v. 45, n. 1, 417. 2019.

FRANÇA, V.F.C. & SEVERI, W. Ecomorphological relations of sypmatric juveniles of Clupeiformes from a Brazilian sandy beach. **Iheringia, Série Zoologia**, v.112, n. 2022011 DOI: https://doi.org/10.1590/1678-4766e2022011, 2022.

GESAMP. SOURCES, FATE AND EFFECTS OF MICROPLASTICS IN THE MARINE ENVIRONMENT: A GLOBAL ASSESSMENT. **Join Group of Experts on the Scientific Aspects of Marine Environmental Protectio**n, 2015. Disponível em: <http://www.gesamp.org/publications/reports-and-studies-no-90> Acesso em: 08 de junho de 2024.

GIBSON, R.N. Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. **Journal of Sea Research**, v. 32, p. 191-206, 1994.

IVAR DO SUL, J. A.; BARNES, D. K. A.; COSTA, M. F.; CONVEY, P.; COSTA, E. S.; CAMPOS, L. Plastics in the Antarctic environment: are we looking only at the tip of the iceberg?. **Oecologia Australis**, v. 15, n. 1, p. 150-170, 2011.

JAMBECK, J.R.; GEYER, R.; WILCOX, C.; SIEGLER, T.R.;PERRYMAN,M.; M,ANDRADY,A.;NARAYAN, R.; LAW, K.L. Plastic waste inputs from land into the ocean. **Science, v.**347, p. 768-771, 2015.

JUSTINO, A.K.S.; LENOBLE, V.; PELAGE, L.; FERREIRA, G.V.B.; PASSARONE, R.; FRÉDOU, T.; FRÉDOU, F.L. Microplastic contamination in tropical fishes: An assessment of different feedings habits. **Regional Studies in Marine Science**, v.45, p. 1-8, 2021.

JUSTINO, A.K.S.; FERREIRA, G.V.B.; FAUVELLE, V.; SCHMIDT, N.; LENOBLE, V.; PELAGE, L.; MARTINS, K.; TRAVASSOS, P.; FREDOU, F.L. From prey to predators: Evidence of microplastic trophic transfer in tuna and large pelagic species in the southwestern Tropical Atlantic. **Environmental Pollution**, v. 327, n. 121532, 2023. DOI: https://doi.org/10.1016/j.envpol.2023.121532

KARAMI,A.;GOLIESKARDI,A.;LARAT,V.;KARBALAEI,S.;SALAMATINIA,B. Microplastic and mesoplastic contamination in canned sardines and sprats. Sci. **Total Environmental**. v. 612, p. 1380-1386, 2018.

KERSHAW, P. J.; TURRA, A.; GALGANI, F. **Guidelines for the monitoring and assessment of plastic litter and microplastics in the ocean**. http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean.2019. (Acesso em: 08 de jun 2024).

MIRANDA, D.A., & CARVALHO SOUZA, G.F. Are we eating plastic-ingesting fish?. **Marine Pollution Bulletin**, v.103, p. 109-114, 2016.

NAPPER, I. E., & THOMPSON, R. C.. Plastic debris in the marine environment: history and future challenges. **Global Challenges (Hoboken, NJ)**, v.4(6), n.1900081, 2020.

PLASTIC EUROPE. **Plastics: the facts**. An analysis of European plastics production, demand and waste data in 2017.https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_we.pdf. 2018. (acesso 09 de jun 2024).

ROBERTSON, A.I. & LENANTON, R.C.J. Fish Community structure and food chain dynamics in the surf-zone of sandy beaches: the role of detached macrophyte detritus. **Journal of Experimental Marine Biology and Ecology**, v. 84, p. 265-283, 1984.

SANTANA, F.M.S. & SEVERI, W. Composição e estrutura da assembleia de peixes da zona de arrebentação da praia de Jaguaribe, Itamaracá, PE. **Bioikos**, v. 23, p.3-17, 2009.

SANTANA, F.M.S.; SEVERI, W.; SOUZA, F.E.S.; ARAÚJO, M.E. THE ICHTHYOFAUNA OF THE BRAZILIAN SURF ZONE: A COMPILATION FOR ECOLOGICAL COMPREHENSION PER REGION. **Tropical Oceanography**, v.41, p. 37-53, 2013.

SMITH, M.; LOVE, D.C.; ROCHMAN, C.M.; NEFF, R.A. Microplastics in Seafood and the Implications for Human Health. **Current Environmental Health Reports**, v.5, p. 375-386, 2018.

TELES, D. B.; VIANNA, M.; MONTENEGRO, M. **Atlas do Plástico**. Rio de Janeiro. Disponível em: https://br.boell.org/pt-br/2020/11/29/atlas-do-plastico. p. 321-360, 2020. Acesso em 09 de junho de 2024.

TEUTEN, E. L.; SAQUING, J. M.; KNAPPE, D. R. U.; BARLAZ, M. A; JONSSON, S.; BJORN, A.; ROWLAND, S. J.; THOMPSON, R. C.; GALLOWAY. T. S.; YAMASHITA, R.; OCHI, D.; WATANUKI, Y.; MOORE, C.; VIET, P. H.; TANA, T. S.; PRUDENTE, M.; BOONYATUMANOND, R.; ZAKARIA, M. P.; AKKHAVONG, K.; OGATA, Y.; HIRAI, H.; IWASA, S.; MIZUKAWA, K.; HAGINO. Y.; IMAMURA, A.; AHA, M.; TAKADA, H. Transport and release of chemicals from plastics to the environment and to wildlife. **Philosophical Transactions of the Royal Society B: Biological Sciences**, v. 364, n. 1526, p. 2027-2045, 2009.

THOMPSON, R.; MOORE, C.; ANDRADY, A.; GREGORY, M.; TAKADA, H.; WEISBERG, S. New directions in plastic debris. **Science**, v. 310, n. 5751, p. 1117- 1117, 2005.

WANG, W.; GEB, J.; Y.U, X. Bioavailability and toxicity of microplastics to fish species: A review. **Ecotoxicology and Environmental Safety**, v.189, p. 1-10, 2020.