UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO

PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃOPROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

Avaliação do hábito alimentar e ingestão de microplásticos por juvenis de *Bairdiella goeldi* que habitam a zona de arrebentação da Costa Sul de Pernambuco, Brasil

Jenifer Katherine Dantas de Oliveira Barros

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 crescente de plásticos observada nos últimos anos tem ameaçado a vida marinha, cuja produção global chegou a 390 milhões de toneladas no ano de 2021 e estimativas indicam que esse número só aumente nas próximas décadas. A preocupação atrelada a produção desses plásticos se dá ao seu baixo custo de produção, alto tempo de degradação e grande abundância nos ecossistemas aquáticos. Provenientes dos macroplásticos e da matéria prima utilizada na sua produção, os microplásticos (>5mm) são responsáveis por inúmeros efeitos nocivos aos organismos aquáticos, causando impactos ao longo de toda a cadeia trófica em inúmeros ecossistemas marinhos, incluindo manguezais e zonas de arrebentação. A zona de arrebentação possui uma grande relevância ecológica, pois são ambientes que os animais utilizam para se proteger de predadores, como berçários, além de serem áreas de migração entre as espécies. Diante desta realidade, o presente estudo teve como objetivo avaliar a presença de contaminação por microplásticos em *Bairdiella goeldi* e determinar o seu hábito alimentar, realizando uma comparação ao longo do ciclo sazonal. Para a análise da contaminação por microplásticos foi realizado a digestão das amostras, utilizando NaOH (1 mol) e após esse processo, foram identificados e classificados em tipos e cores. Para a determinação do hábito alimentar, após a dissecação do espécime, os estômagos foram abertos e todo o conteúdo encontrado foi identificado e classificado com o auxílio do estereomicroscópio. Foram detectados 1,2 ± 1,3 microplásticos/individuo, e a maior abundância ocorreu no período chuvoso. Dentre as cores observadas, a cor azul obteve predominância e o tipo mais frequente encontrado foi a fibra. Para o hábito alimentar, o Índice de Importância Relativa (%IIR) indicou que *B. goeldi* se alimentou predominantemente de anfípodas independente da sazonalidade. Para os demais itens alimentares foi evidenciado uma diferenciação quanto à sazonalidade. A segunda presa mais encontrada foram os isópodes, sendo mais representativos no período seco e os poliquetas foram identificados apenas no período chuvoso. Este trabalho constatou a contaminação por microplásticos em peixes ecologicamente importantes da zona de arrebentação, além do diferencial da determinação do hábito alimentar, trazendo *insights* importantes para a poluição ambiental por microplásticos.

PALAVRAS-CHAVE: Impactos antrópicos; Ecologia Alimentar; Atlântico Tropical; Contaminantes emergentes

Abstract

The increasing plastic production observed in recent years has threatened marine life. The production reached 390 million tons in 2021, with estimates suggesting further increases in the coming years. Concerns linked to plastic production stem from its low cost, slow degradation, and high pollution levels in aquatic ecosystems. Microplastics (>5mm), originating from macroplastics and raw materials used in production, adversely affect aquatic organisms, impacting the entire trophic chain of several marine ecosystems, including mangroves and surf zones. Surf zones are ecologically important environments used by animals to protection from predators, serving as nurseries and migration areas among species. Given this reality, this study aimed to investigate the feeding habits of *Bairdiella goeldi* and to assess the microplastic contamination in relation to seasonality. For the microplastic contamination analysis, sample digestion was conducted using NaOH (1 mol), and after this process, microplastics were identified and classified by type and colour. For the determination of feeding habits, after specimen dissection, stomachs were opened, and all content found was identified and classified with the aid of a stereomicroscope. Results showed microplastic contamination of 1.2 ± 1.3 items/individual, with higher abundance during the rainy season. Blue was the predominant colour, and fibre was the most frequently type of microplastic found. Regarding feeding habits, the Relative Importance Index (%IIR) was calculated, and *B. goeldi* predominantly fed on amphipods regardless of seasonality. There was difference between seasons, with isopods being the second most found prey, more representative in the dry season, and polychaetes identified only in the rainy season. This study confirmed microplastic contamination in ecologically important fish from the surf zone, along with insights into feeding habits, providing important information for understanding environmental pollution by microplastics.

Keywords: Anthropogenic impacts; Tropical Atlantic; Feeding ecology; Emerging contaminants

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Sumário

1 INTRODUÇÃO GERAL

A problemática da ocorrência de resíduos sólidos em ambiente marinho tem sido amplamente discutida nos últimos anos, sendo objeto de estudos em todo o mundo e parte de um dos "Objetivos de Desenvolvimento Sustentável" (ODS) da Década dos Oceanos (ADIKA et al., 2020; DENG et al., 2020; LUSHER et al., 2016; PENG et al., 2018; ODS 12, 2019). Com a industrialização, o aumento da expectativa de vida e a crescente densificação urbana, caracterizada pelo aumento constante da população nas áreas metropolitanas, a produção de resíduos pela humanidade se torna maior a cada dia (GEYER et al., 2017).

A maior parte desses resíduos é composta por plásticos devido à sua baixa taxa de degradação. Quanto menor o custo de produção, mais produtos de uso único ou de curto prazo são produzidos (GALGANI et al., 1996). Em 2021, a produção global de plásticos ultrapassou a marca de 390 milhões de toneladas (PLASTIC EUROPE, 2022), e estimativas indicam que a produção de plástico pode atingir a marca de 1.100 milhões de toneladas até 2050 (GEYER, 2020). A contaminação por resíduos plásticos nos ecossistemas marinhos é atualmente considerada um dos maiores impactos globais, uma vez que esses poluentes afetam uma ampla variedade de habitats e contaminam os diferentes níveis tróficos da vida aquática (DANTAS et al., 2019; LUSHER et al., 2018).

Apesar de resistentes, esses resíduos plásticos disponíveis no ambiente, com o tempo, e influência dos fatores físicos ambientais vão se degradando em partículas cada vez menores (ANDRADY, 2011). Através de um estudo realizado por Thompson et al. (2004), o termo microplástico foi empregado pela primeira vez, ao descrever e identificar tamanhos microscópicos de plásticos. Os microplásticos compreendem todas as partículas plásticas com um tamanho inferior a 5 mm (ARTHUR et al., 2008; BARNES et al., 2009; COLE et al., 2011; ROJO-NIETO e MONTOTO, 2017; THOMPSON, 2015). Essas partículas podem ser divididas em fontes primárias ou secundárias: primárias são a matéria-prima originalmente manufaturada em uma forma e/ou tamanho microscópico para específica aplicação, como abrasivos e esfoliantes; e as secundárias são aquelas partículas resultadas da fragmentação ou degradação de partículas maiores (COMPA et al., 2018; HUANG et al., 2022).

Os microplásticos podem ser facilmente encontrados em ambientes costeiros que desempenham um papel crucial na sustentabilidade da vida marinha, como por exemplo as praias (LO et al., 2018; AMORIM et al., 2020). Nas praias arenosas, uma variedade de espécies marinhas, terrestres e semiterrestres ocupam habitats distintos e adotam diferentes estratégias alimentares (COSTA et al., 2023). Esses padrões são influenciados pela diversidade ambiental ao longo do gradiente oceano-continente, que também pode influenciar na deposição dos microplásticos (COSTA et al., 2023).

A zona de arrebentação, considerada um dos ambientes predominantes desse ecossistema (COSTA et al., 2023), é definida como a região que se estende desde o limite inferior da face da praia até a primeira linha de quebra de ondas (SANTANA, 2013). É uma região de extrema importância para o desenvolvimento das espécies, pois possui um papel ecológico, sendo utilizada principalmente por espécies em seus estágios iniciais de vida, para proteção contra predadores e área de alimentação (AMORIM et al., 2020; FAVERO, 2019; SANTANA, 2013). Embora as zonas de arrebentação sejam relativamente rasas, com cerca de 1,5 metros de profundidade, sua assembleia de peixes é composta por espécies demersais, bentônicas-pelágicas e pelágicas (MCLACHLAN e DEFEO, 2018), e são consideradas áreas de migração e de alimentação (FAVERO, 2019; SANTANA, 2013).

A área litorânea de Pernambuco tem cerca de 187 km de extensão, onde predominam-se as praias arenosas, pontais rochosos e estuários associados a manguezais (SACRAMENTO et al., 2007). Possuem diversas espécies de peixes que são encontradas com frequência em arrastos realizados na zona de arrebentação, como o barbudo *Polydactylus virginicus* (Linnaeus, 1758), o coró-branco *Haemulopsis corvinaeformis* (Steindachner, 1868) e a cangauá *Bairdiella goeldi* (Marceniuk, Molina, Caires, Rotundo, Wosiacki & Oliveira, 2019), sendo a última espécie pouco estudada, mas de grande importância ecológica para a região.

As espécies do gênero Bairdiella sp. possuem uma alimentação variável, podendo alimentar-se de pequenos crustáceos e peixes e pode chegar ao comprimento máximo de 35 cm (LIMA et al., 2021; VENDEL e CHAVES, 1998). E essas espécies são consideradas dominantes na zona de arrebentação, e a sua presença é constante ao longo de todo o ano nessas regiões, sendo registrada a utilização regular dessas áreas para reprodução e manguezais como áreas de berçário (CHAVES e BOUCHEREAU, 2004; SANTANA et al., 2009).

Dentre essas espécies, a *B. goeldi* era anteriormente identificada como *Bairdiella ronchus* (Cuvier, 1830), e por isso, a maioria dos estudos na região Nordeste do Brasil trazem essa identificação (ELLIOT et al., 2007; CASTRO et al., 1998; VENDELL e CHAVES, 1998; BOWMAN e HYSLOP, 2023). Entretanto, em um estudo recente desenvolvido por Marceniuk et al. (2019), através de dados genéticos e morfológicos, foi identificado que apenas a *B. goeldi* tem ocorrência e distribuição ao longo da costa do Atlântico, desde o Norte Equatorial do Pará até Santa Catarina (MARCENIUK et al., 2019). Portanto, neste estudo adotaremos a norma taxonômica mais recente para se referir aos peixes popularmente conhecidos como “Cangauá”, tratando-a como a espécie *B. goeldi*.

Esta espécie é reconhecida por utilizar uma variedade de habitats costeiros para realizar seu ciclo reprodutivo, incluindo manguezais, estuários e áreas costeiras adjacentes (CASTRO et al., 1999; CHAVES, 1995). Devido ao tamanho que os adultos podem atingir (35 cm), essa espécie não é considerada de importância comercial no Brasil. No entanto, é abundante e pode desempenhar um papel crucial em comunidades costeiras e estuarinas, servindo como presas para peixes maiores (ITAGAKI et al., 2007), possuindo também relativa importância para a pesca artesanal na região. Além disso, indivíduos do gênero Bairdiella, já foram reportados com contaminação por microplásticos em outro estudo na região do Nordeste do Brasil (JUSTINO et al., 2021).

As preocupações ambientais relacionadas aos microplásticos têm despertado atenção global devido a sua influência direta e indireta na vida selvagem, envolvendo contato e ingestão por parte da biota (ANDRADY, 2011; DEFORGES et al., 2015; SU et al., 2016). A gravidade do impacto da ingestão de plástico tende a variar de acordo com o tamanho da partícula e o organismo que a consome (LUSHER et al., 2015). Após a ingestão, o plástico pode desencadear problemas digestivos, diminuição da alimentação ou até mesmo perda total de apetite, causando impactos comportamentais, físicos, de crescimento, genéticos e reprodutivos (CHAE e AN, 2017; XIONG et al., 2018). Os organismos marinhos podem se alimentar dessas partículas de maneira direta, ingerindo acidentalmente ou confundindo com outro alimento, e de maneira indireta, através da transferência trófica, onde um animal se alimenta de uma presa contaminada, afetando diversos animais da cadeia trófica (ARAÚJO e MALAFAIA, 2021; BESSELING et al., 2015; FOSSI et al., 2014; MARKIC et al., 2018; VÁZQUEZ-ROWE et al., 2021).

Entender os padrões alimentares dos organismos é fundamental para a compreensão de diversos processos biológicos e para discernir as interações ecológicas entre as populações em um ecossistema e grau de exposição a poluições antrópicas. Essas informações desempenham um papel crucial no acompanhamento sustentável de um dos principais recursos alimentares, além disso, fornecem informações essenciais sobre a saúde ambiental, permitindo a implementação de ações de mitigação e preservação. Com isso, nesta dissertação analisaremos a espécie *B. goeldi* quanto ao seu hábito alimentar, identificando os principais itens alimentares, e verificando a suscetibilidade dessa espécie a contaminação por microplásticos em uma praia arenosa em Pernambuco. A hipótese avaliada neste estudo é a de que a sazonalidade pode influenciar na quantidade e tipo de microplástico ingerido pela espécie *B. goeldi* em uma zona de arrebentação em Pernambuco, Brasil.

OBJETIVOS

Objetivo Geral

Este estudo tem como objetivo principal investigar a influência da sazonalidade no hábito alimentar e na contaminação por microplásticos em *Bairdiella goeldi* que habitam a zona de arrebentação da praia de Serrambi, no litoral sul do estado de Pernambuco.

Objetivos Específicos

- Investigar o hábito alimentar de *Bairdiella goeldi*;
- Analisar a influência das variáveis ambientais sobre os itens alimentares encontrados em relação a sua abundância total;
- Identificar a sobreposição da dieta entre as estações seca e chuvosa;
- Investigar a contaminação por microplásticos em *Bairdiella goeldi*;
- Caracterizar os microplásticos encontrados em relação ao tipo, tamanho e coloração;
- Analisar a influência das variáveis ambientais sobre os microplásticos encontrados em relação a sua abundância total;
- Analisar a influência das estações, início e final da seca e início e final da chuva, na contaminação por microplásticos em *Bairdiella goeldi*.

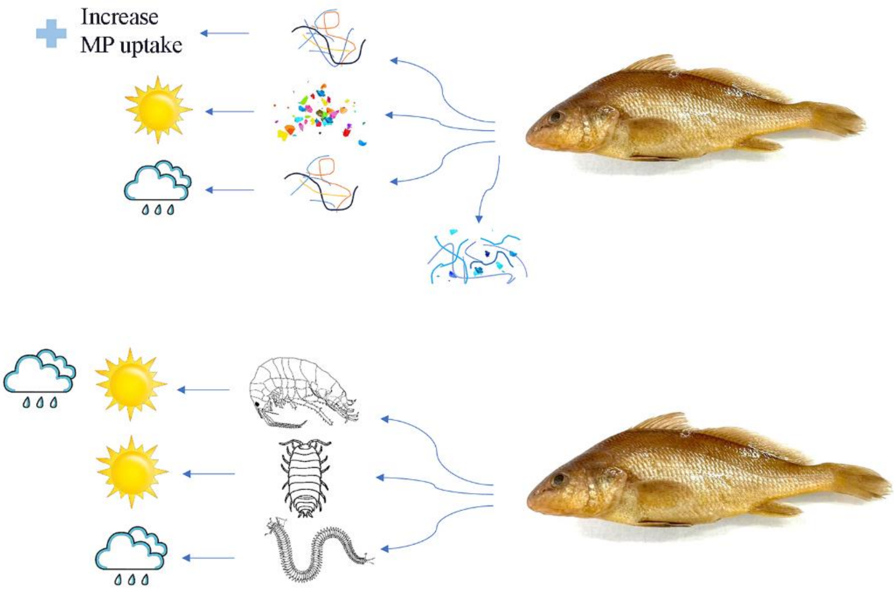
CAPÍTULO 1

Feeding ecology and microplastic contamination in juveniles of *Bairdiella goeldi* inhabiting a surf zone area in the Tropical Atlantic

Este artigo foi submetido à revista Marine Pollution Bulletin em 25/04/2024

Highlights

- Microplastic contamination in *Bairdiella goeldi*: seasonal trends revealed.
- Amphipods dominate *Bairdiella goeldi*'s diet: dry season preference.
- Microplastic prevalence: rainy season spike, mostly fibres.
- Abiotic factors influence diet and microplastic uptake.
- Insights into plastic pollution impact on coastal fish ecology



Feeding ecology and microplastic contamination in juveniles of *Bairdiella goeldi* inhabiting a surf zone area in the Tropical Atlantic

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Abstract

This study investigates microplastic contamination in Bairdiella goeldi, a common species in tropical coastal regions, and examines its feeding habits to assess the influence of seasonal variations in a surf zone off the coast of Pernambuco. Samples were collected between 2012 and 2013, with 60 individuals analysed for feeding ecology and 120 individuals examined for microplastic. Amphipods were the most consumed prey, followed by isopods, which were more abundant during the dry season. Polychaetes were only observed in the rainy season, characterising the species as zoobenthivores. Microplastic analysis revealed 146 items, averaging 1.2 ± 1.3 items per individual, with a frequency of occurrence of 64.2%. Rainy season exhibited a higher incidence, mainly fibres. A PERMANOVA analysis indicated that seasonality and abiotic parameters influenced the species' diet composition and contamination. This study enhances our understanding of microplastic contamination in surf zone environments and its implications for fish species.

Keywords: Feeding habits; Plastic pollution; Surf zone; Tropical Atlantic; Seasonal variability

Introduction

The use of and dependence on plastic materials by humanity has led to an increase in their production and has become one of the major environmental problems of the present day. The United Nations (UN) has underscored the contamination of aquatic ecosystems by plastics, coupled with climate change, as a key environmental challenge of the 21st century (UNEP, 2014). Projections by Geyer (2020) suggest that plastic production could soar to 1.1 billion tonnes by 2050, with global plastic production already surpassing 390 million tonnes in 2021 (Plastic Europe, 2022). Each year, vast quantities of plastic pollution enter the oceans, exacerbating the crisis (Focardi et al., 2022).

Among various aquatic ecosystems, coastal environments like estuaries, sandy beaches, and mangroves emerge as highly vulnerable to pollution due to their proximity to potential sources of contamination (Rummel et al., 2016; Mizraji et al., 2017; Amorim et al., 2020). Sandy beaches, in particular, serve as both sources and reservoirs of plastic waste, rendering them crucial ecosystems for ecological research on microplastic ingestion by marine and coastal organisms (Costa et al., 2023b; 2022). These environments host diverse marine, terrestrial, and semi-terrestrial species, as highlighted in studies exploring plastic ingestion in natural settings (Costa et al., 2023a).

Microplastics, defined as plastic particles smaller than 5 mm, are widely accessible and pose an increased risk of accidental ingestion by various organisms (Andrady, 2011). Several factors contribute to marine organisms' ingestion of these microplastics, including their size, density, abundance, and colour, all of which enhance their bioavailability compared to other anthropogenic waste (Ugwu et al., 2021). In terms of their origin, microplastics can be classified as primary or secondary (Karkanorachaki et al., 2018). Primary materials are initially manufactured in specific micro shapes or sizes for particular applications, such as abrasives in household products, cosmetics, industrial blasting, and cleaning agents (Thompson, 2015). Secondary plastics originate unintentionally from the fragmentation and degradation of macroscopic plastics due to biotic and abiotic weathering processes (Huang et al., 2022; Compa et al., 2018). Microplastics' persistence and accumulation in the ecosystem result from their durability, which is related to their origins (Barnes et al., 2009; Galgani et al., 1996). Once introduced into the marine environment, there is growing concern about their accumulation and fate due to the impossibility of removing them from the environment (Lusher et al., 2014).

Microplastics have been detected in the digestive tracts of various marine organisms, including benthic macroinvertebrates, zooplankton, fish, and mammals (Cole et al., 2013; Jabeen et al., 2017; Lusher et al., 2018; Xiong et al., 2019). Exposure to these particles in fish can lead to behavioural, physical, growth, genetic, and reproductive impacts (Chae and An, 2017; Xiong et al., 2018). They can adhere to fish skin, translocate to tissues such as gills, muscles, and liver, and penetrate the circulatory or lymphatic system, causing growth and nutritional disorders and affecting feeding, predatory activity, foraging, and swimming (Subaramaniyam et al., 2023). This ingestion can impact immunity, survival, metabolism, and other toxicity-related responses, such as oxidative stress (Subaramaniyam et al., 2023). Additionally, potentially harmful substances released by microplastics may contribute to their toxicity (Koelmans et al., 2016; Xiong et al., 2018). Moreover, the contamination rate can be intensified through transfer from prey to predator (Justino et al., 2023a; Lusher et al., 2018; Rochman et al., 2015).

Species from the Scianidae family have been previously studied concerning microplastic contamination (Ferreira et al., 2016; 2018; Amorim et al., 2020; Justino et al., 2021). *Bairdiella goeldi*, a dominant species in the surf zone, is consistently present in these areas throughout the year (Santana et al., 2009; Chaves and Bouchereau, 2004). This species is frequently observed using these areas for breeding and as nursery grounds (Chaves, 1995). *Bairdiella goeldi*, known for its adaptability during the reproductive cycle, is found in various coastal habitats, including mangroves, estuaries, and coastal areas (Chaves 1995; Castro et al. 1999).

Considering the frequent occurrence of *B. goeldi* in tropical regions, particularly as a resident species in surf zone areas (Santana et al., 2009), and acknowledging the ecological importance of surf zones for various species (Santana, 2013; Amorim et al., 2020), this study aimed to explore the feeding ecology and microplastic contamination in juvenile *B. goeldi*. The investigation was carried out on a tropical beach along the south coast of Pernambuco, Brazil, focusing on evaluating the influence of seasonality.

Materials and Methods

Study area and sampling

The study area is located on the Southern part of the coast of Pernambuco, Brazil, around 70 km from Recife, covering approximately 4 km in length (Figure 1). The Serrambi beach is characterised by sandstone reefs that extend over a large part of its area (Jales et al., 2012). Most local inhabitants depend on artisanal and subsistence fishing for income and food, totalling 4,300 residents. During high-season periods, this population doubles, considerably increasing the production of solid waste and debris (Jales et al., 2012).

According to the Köppen classification, the Pernambuco coast's climate is categorised as type As', which is designated as tropical hot and humid (Andrade and Lins, 1965). This climate is marked by two distinct periods of rainfall: a dry season, from September to February (spring-summer), and a rainy season, between March and August (autumn-winter) (Jales et al., 2012).

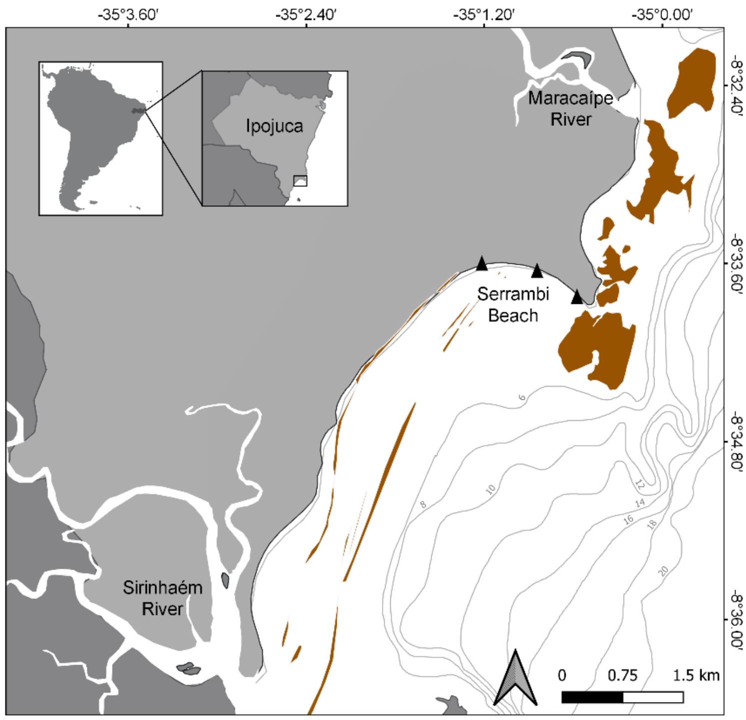

Figure 1 - Serrambi Beach in the Ipojuca district in Pernambuco. Triangles indicate the sampling points, and the brown spots delimit the extent of the coral reefs.

Samples were collected in the surf zone of Serrambi Beach (Ipojuca) during the dry season (September to February) and the rainy season (March to August) at three different locations, which were determined according to different physical characteristics, totalling two trawls at each point. The replicates were carried out monthly over one year, covering 2012 and 2013. The catches were made with authorisation from SISBIO (Authorisation No. 34250-1 from the Chico Mendes Institute for Biodiversity Conservation).

Trawling was performed parallel to the coastline, day and night, during the semi-diurnal neap and spring tides. Each trawl covered an area of 500 m^2 with a depth of less than 1.5 metres during low tide, following the direction of the prevailing current. The specimens were caught using a “picaré” type net measuring 20 m in length and 2 m in height and with mm mesh size of 5 mm between knots.

Rainfall data were obtained from the website of the Agronomic Institute of Pernambuco (IPA, 2014) to characterise the environment. Besides that, during the sampling, water temperature, salinity and dissolved oxygen were measured using a multiparameter (YSI-556). For turbidity, a water sample was collected in a 500 mL container for analysis in the laboratory using a bench turbidimeter. The variables were considered essential elements for determining the influence of these parameters on ecosystems. However, some elements can also contribute to this characterisation, such as water transparency, measured using the Secchi disc.

After trawling, the caught fish were immersed in a 10% formaldehyde solution and transported to the laboratory, where they were preserved in 70% ethyl alcohol.

Laboratory procedures

In the laboratory, the species were identified to the lowest possible taxonomic level (Figueireiro and Menezes, 1980; Marceniuk et al., 2019). The individuals of *B. goeldi* were separated to study feeding ecology and microplastic contamination. This species was selected due to its abundance and ecological importance in the surf zone region (Santana et al., 2009; Itagaki et al., 2007). Based on the seasonality of the study area and the number of individuals obtained in the trawls, 60 individuals were selected to analyse the species’ feeding habits and 120 individuals to analyse microplastic contamination. The fish were measured for total length (cm) and standard length (cm) and weighed (total weight) on a precision scale (0.0001g).

Feeding ecology

The stomach contents were extracted via a ventral incision, and their weight (0.0001g) was recorded for feeding habit analysis. Stomachs were then opened in a Petri dish, and food items were meticulously identified under a stereomicroscope, striving for the highest taxonomic precision possible (Brusca and Brusca, 2002; Ruppert et al., 2005).

After identification, the prey was categorised by taxonomic weight (0.0001g) and grouped into eleven categories based on previous studies (Vendell and Chaves, 1998). The "other" category encompassed items that could not be definitively identified. Categories like "organic matter," "digested matter," and "unidentified items and animals" were included due to the unique nature of the items found. The "digested matter" category contained only materials in an advanced stage of digestion, making it impossible to separate and identify individual items. Items classified as "unidentified animal items" were visible of animal origin but could not be specifically identified. A collector's curve was constructed using the number of prey items to assess whether the sample size was sufficient for determining the species' dietary spectrum (Chao and Jost, 2012; Chao et al., 2020) (Figure 2).

The collector curves were constructed using extrapolation and interpolation sampling curves based on sample size (Hsieh et al., 2016). The confidence intervals of the curves were calculated based on 1000 bootstraps. Statistical significance was assessed based on the overlap of the confidence intervals of the curves. Sample completeness evaluated sampling integrity (Chao and Jost, 2012). The analyses were carried out using the iNEXT package (Hsieh et al., 2016) in the R studio programme.

To determine the diet, we investigated the frequency of occurrence (FO%), numerical frequency (FN%), and frequency by weight (FP%) of the food items found, forming the Index of Relative Importance (%IRI) (Hyslop, 1980), which consists of the equation:

$$IRI = \%FO * (\%FN + \%FP)$$

%FO represents the Frequency of Occurrence per item, %FN represents the Numerical Frequency, and %FP represents the frequency by weight. To calculate the %IRI, we add all the IRI values and divide each value by the IRI of the respective item (Hyslop, 1980).

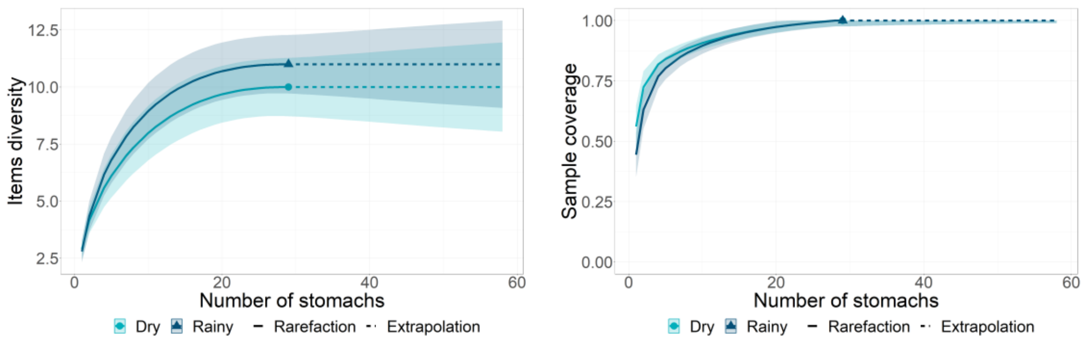

Figure 2 - Accumulation curve (a) and confidence intervals (b) for determining *n* sample and food items.

Contamination control

Specific protocols were followed within the laboratory to prevent possible cross-contamination in the samples and ensure quality assurance and quality control (QA/QC) of the analyses. Throughout the sample handling process, the working environment was kept free from external exposure to the laboratory, and latex gloves and 100% cotton lab coats were used. All the tools used to handle the samples were meticulously cleaned with filtered 70% ethanol (47 mm glass fibre filter (GF/F 0.7 µm - Whatman), rinsed with filtered distilled water and dried in an oven for 24 h at 60°C (Justino et al., 2021). The sample digestion and filtration steps were carried out in a laminar flow hood to prevent particles from entering. Blank procedures were performed for each analysis day before the sample digestion began. For these blanks, a beaker was filled with 50 ml of NaOH solution (1 mol/L) and sealed with a glass lid. These blanks were subjected to the same protocol used for the analysed samples. No microplastic particles were identified in the blank procedures, indicating no cross-contamination in the study.

Microplastic extraction

We followed the protocol by Justino et al. (2021) to extract the microplastic particles. This method uses a digestion protocol in which the fish's digestive tract is immersed in a solution of NaOH (1 MOL) and kept in an oven at 60ºC for 24 hours. Thus, the organic matter is digested, and the microplastic items are separated. After digestion, the fish and the blank samples underwent a vacuum filtration process using a 47 mm glass fibre filter (GF/F 0.7 µm - Whatman). The filters were then dried in an oven at 60ºC for 24 hours. The digestion protocol effectively separates organic materials and aids in visual identification, but it alone cannot identify polymers (Justino et al., 2021). Therefore, we also employed the method outlined by Ferreira et al. (2019), which involves drying the samples in an oven to assess any changes in their physical characteristics and to confirm the presence of plastic debris.

To visually identify the items considered microplastics, all the filters were thoroughly examined in a covered Petri dish using a stereomicroscope (Leica EZ4W) at 35x magnification for more precise identification. The items considered to be microplastics were classified according to their shape into fibres (filamentous shape), fragments (irregular shape), pellets (spherical shape), films and foams (as described by Justino et al., 2021). We recorded data on particle colour, size (in mm), and photographs.

Data analysis

A multivariate analysis was carried out to analyse the species' feeding habits and contamination by microplastics, using the number of samples, using matrices of items (prey/microplastics) as variables (columns) and individuals as samples (rows). Bray–Curtis dissimilarity matrices were generated and used for abundance analyses. The influence of environmental factors such as season (categorical variable) and continuous variables such as rainfall, water temperature, salinity and dissolved oxygen were assessed using Permutational Multivariate Analysis of Variance (PERMANOVA) (Anderson et al., 2001), applied to each dissimilarity matrix. The analysis of feeding habits was restricted to the dry and rainy season categories, while the analysis of microplastic contamination considered the following categories: ED – early dry; LD – late dry; ER – early rainy; LR – late rainy. This approach was made possible by more detailed sampling at different times of the year. Multilevel paired PERMANOVA was used for pairwise comparisons for the seasons and was tested using the '*pairwise. adonis' 2*' function (Arbizu, 2020).

Non-metric multidimensional scaling (NMDS) was used to graphically visualise the results found in the PERMANOVAs for the categorical variable (seasons) patterns based on the same dissimilarity matrices, using ellipses that covered 95% of the variation.

To confirm the presence of only position effects and to assess the absence of dispersion effects on the PERMANOVA analysis, we tested the homogeneity of the multivariate dispersion using a PERMDISP routine. Principal Coordinates Analysis (PCoA) was performed to visualise the PERMDISP results graphically. PERMANOVA and PERMDISP were conducted with 999 permutations. All analyses were carried out using the Vegan package (Oksanen, 2005) in the R 4.3.2 software (R Core Team, 2023).

Results

Environmental characterisation

The environmental characteristics in the area changed throughout the seasons: in the dry season, the minimum rainfall was 9.3 mm and the maximum 156.6 mm (62.8 ± 51.4 mm; mean ±standard deviation), and the water transparency was 0.4 m and 1.3 m (0.8 ± 0.2). Salinity varied throughout the year (34.9 ± 0.6), confirming the marine characteristics of this habitat, and water temperature varied between 24.5 ºC and 32.3 ºC (28.2 ± 1.6 ºC) (Table 1 and Figure 3).

During the rainy season, the highest rainfall values were recorded (187.6 ± 113.4 mm), reaching a monthly accumulation of 402.9 mm, and the lowest monthly accumulation was 37.5 mm. As a result, the Secchi disc ranged from 0.3 m to 1.4 m (0.7 ± 0.3 m). The water temperature was, on average, 28.1 ± 1.7 °C (min. 24.5 °C and max. 33.2 °C). The higher volumes of rainfall led to a decrease in salinity (32.8 ± 2.8), with a maximum monthly salinity of 36.1 and a minimum of 26.4.

Dissolved oxygen varied between 8.8mg/L ± 2.2 in the dry season and 7.9mg/L ± 1 in the rainy season. Between the seasons, the turbidity parameter showed a considerable variation between maximums, with the dry season having a maximum of 18.7 (7.4 ± 3.9) and the rainy season 23.0 (9.3 ± 4.9).

Table 1 - Environmental factors recorded during the dry and rainy seasons in 2012 and 2013 at Serrambi Beach, regarding the mean (±standard deviation – SD).

Environmental factors						
	Rainy season			Dry season		
	mean ±SD	Minimum	Maximum	mean ±SD	Minimum	Maximum
Rainfall (mm)	187.6 ± 113.4	37.5	402.9	62.8 ± 51.4	9.3	156.6
Temperature (°C)	28.11 ±1.7	24.50	33.26	28.26 ± 1.6	24.58	32.35
Salinity	32.83 ± 2.8	26.40	36.15	34.98 ±0.6	32.12	35.83
Dissolved oxygen (mg/L)	7.90 ± 1.0	6.17	10.97	8.85 ± 2.2	5.80	16.26
Turbidity	9.3 ± 4.9	2.7	23.0	7.4 ± 3.9	2.7	18.7

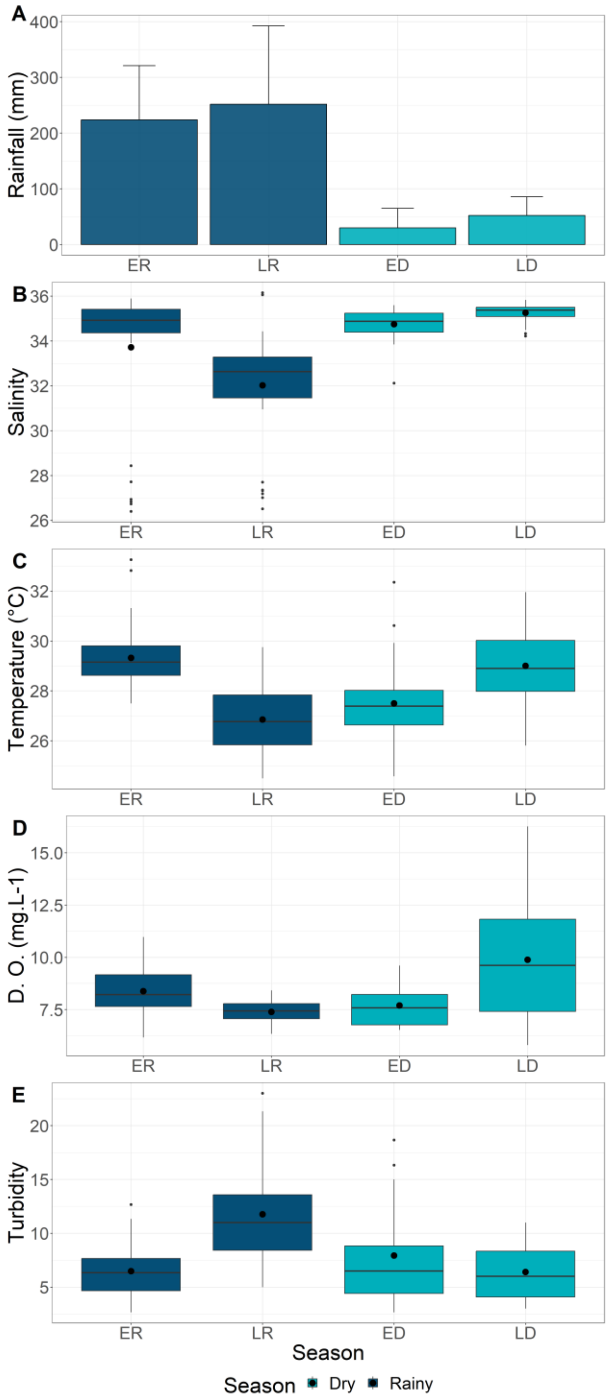

Figure 3 - Abiotic parameters obtained throughout 2012 and 2013 in the surf zone area of Serrambi Beach, according to the Early Dry (ED) and Late Dry (LD) seasons (light blue) and the Early Rainy (ER) and Late Rainy (LR) seasons (dark blue). (A) Mean accumulated monthly rainfall (mm), (B) salinity, (C) water temperature (Cº), (D) dissolved oxygen (mg.L^{-1}) and (E) turbidity.

Environmental variables influencing feeding patterns

Out of the 60 samples analysed to determine the feeding habits of *B. goeldi*, 30 were from the dry season, and the remaining 30 were from the rainy season. The individuals had an average length of 7.62 ± 1.7 cm and an average weight of 4.9 ± 3.4 g, and they were below sexual maturity at 158 mm (Bowman and Hyslop, 2023). Eleven food items were found, including Isopods, Amphipods, and Polychaetes (Figure 4).

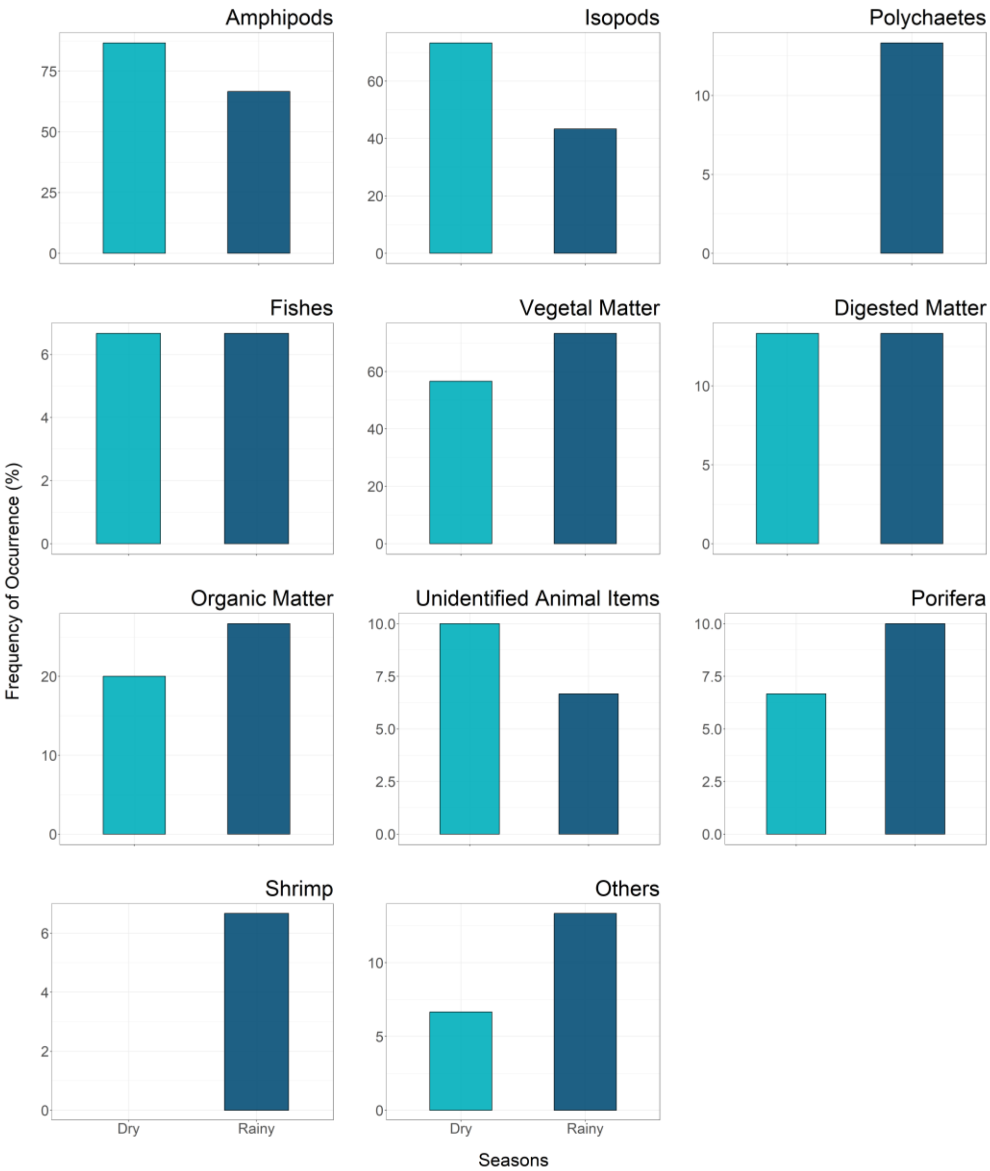

Figure 4 – The Frequency of Occurrence (FO%) of food items found in the stomach contents of *Bairdiella goeldi* according to the seasons (Dry and Rainy seasons).

Among the digestive tracts analysed, only three were empty, and according to the Frequency of Occurrence (FO%), the ingestion of Amphipods was higher (76.6%) than the other items found, regardless of seasons. Isopods were the second group with the highest FO% (58.3%), with more specimens collected in the dry season. The vegetal matter also had the highest FO% (65%) and was more prominent in the rainy season. Polychaetes and shrimps were only observed in the rainy season. According to the Index of Relative Importance (%IRI), the most important prey was Amphipods, regardless of season (81.4% for dry; 63.1% for rainy) (Table 2).

Table 2 - Relative Importance Index (IRI%) of the food items observed, separated into the eleven categories found, determined during the dry and rainy seasons.

Items	Dry season %IRI	Rainy season %IRI
Amphipods	81.447	63.097
Isopods	17.527	4.594
Polychaetes	0.000	0.804
Fishes	0.001	0.061
Vegetal matter	0.340	29.372
Digested matter	0.647	0.246
Organic matter	0.031	1.596
Unidentified animal items	0.004	0.061
Porifera	0.001	0.138
Shrimp	0.000	0.031
Others	0.000	0

The results of the PERMANOVA analysis for the abundance data in the number of food items in the diet of *B. goeldi* revealed a significant influence ($p<0.05$) of seasonality, rainfall, salinity and the interaction between seasonality and rainfall (Table 3). In contrast, the variables water temperature and dissolved oxygen showed no significant effects ($p>0.05$) on the composition of food items.

Table 3 - Results of the PERMANOVA (Bray–Curtis) used to determine the total abundance of food items under the influence of environmental variables (Df = Degrees of Freedom / Sum()FSqs = Supply Sum of Squares / R2 = Coefficient of Determination / F= F-statistic / Pr(>F) = *p*-value of the F-statistic). The significance level adopted was $p < 0.05$.

Variables	Df	Sum()FSqs	R2	F	Pr(>F)
Season	1	0.5771	0.04459	29.613	0.016
Rainfall	1	0.4498	0.03476	23.083	0.040
Water temperature	1	0.3359	0.02596	17.237	0.143
Salinity	1	0.9121	0.07049	46.808	0.002
Dissolved oxygen	1	0.2695	0.02083	13.831	0.227
Season*Rainfall	1	0.6527	0.05044	33.493	0.007

The NMDS illustrated an overlap in the species' diet between the dry and rainy seasons related to the abundance of items (Figure 5). The PERMDISP analysis showed no significant differences (p<0.05), indicating the absence of the dispersal effect on the analysis of how the seasons influence the species' diet.

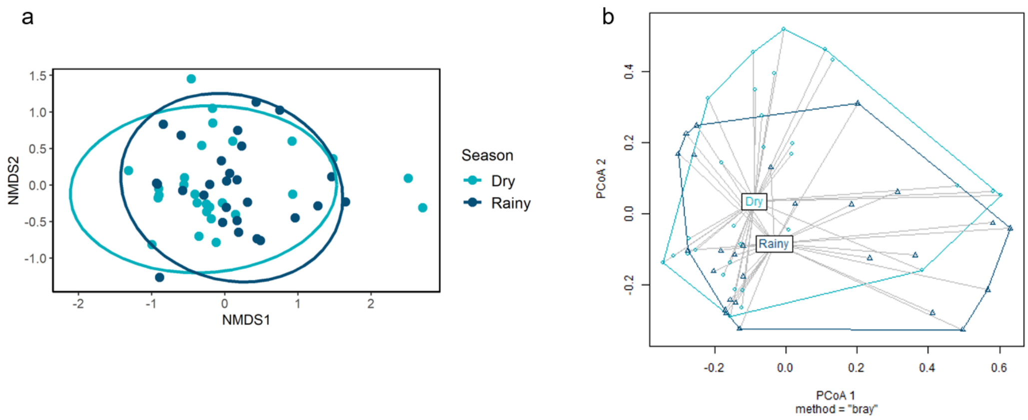

Figure 5 - NMDS and PERMDISP analyses of feeding habits (Bray–Curtis metrics). (A) NMDS analysis corresponds to the species' diet overlap between the dry and rainy seasons. (B) PERMDISP analysis corresponds to significant differences in the influence.

Seasonality driving microplastic contamination

The fishes used to analyse microplastic contamination had a mean size of 7.73 ± 1.4 cm and a mean weight of 5.06 ± 2.9 g. A total of 146 microplastic items were found in the 120 fish analysed, giving an average of 1.2 ± 1.3 microplastics per individual. Of the total, 84 microplastics came from the rainy season and 62 from the dry season (Table 4). Five shapes of microplastic were observed (Figure 6); the most frequent items were fibres and fragments (Figure 7).

The microplastics found ranged in size from 0.02 mm to 4.56 mm. In addition, seven plastics were identified in a filamentous shape, with dimensions greater than 5 mm, and categorised as mesoplastics. However, these items were not included in the analyses because they exceeded the size range established for microplastics (< 5 mm).

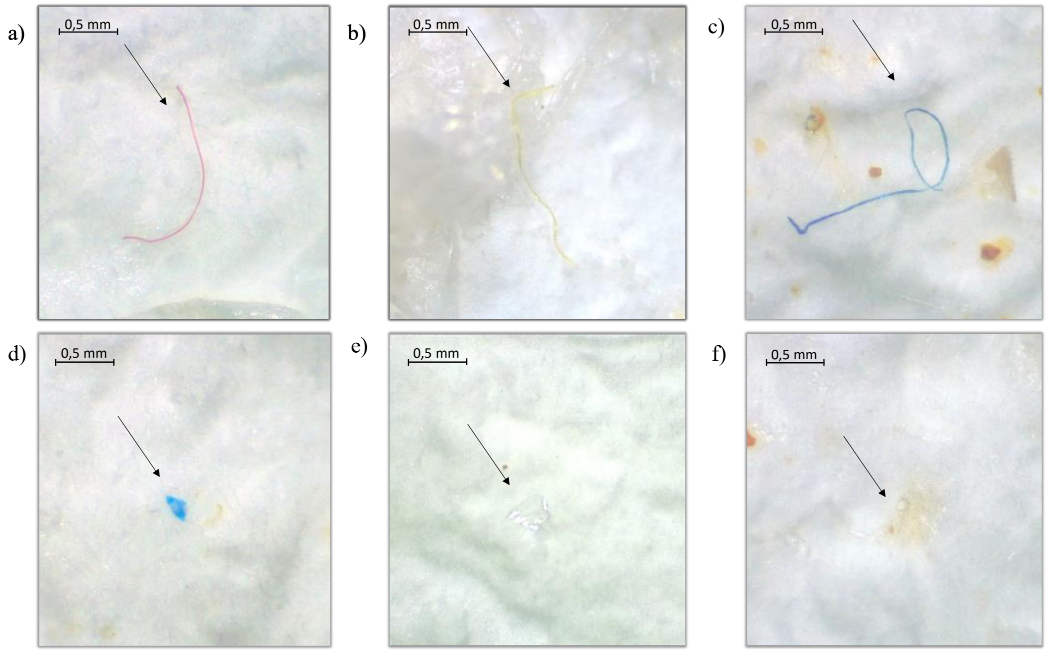

Figure 6 - Shapes of microplastics found in the gastrointestinal tracts of *Bairdiella goeldi* (A, B and C) Fibres in different colours, (D) a blue fragment, (E) a film and (F) a pellet.

The total frequency of occurrence of microplastics found among the individuals analysed was 64.2%. Among the particles found, fibres had the highest FO% at 62.5%, followed by fragments at 44.1%, pellets with 9.1%, foams with 4.1% and film with 1.6%. In comparing the frequency of occurrence between seasons, fibres were more representative in the rainy season, accounting for 46.6% and 36.6% in the early and late rainy seasons, respectively. Fragments were the most representative in the dry season, with 33.3% in the early dry season and 36.6% in the late dry season (Figure 7). The most representative colour was blue, regardless of season, followed by grey and white/transparent (Figure 8).

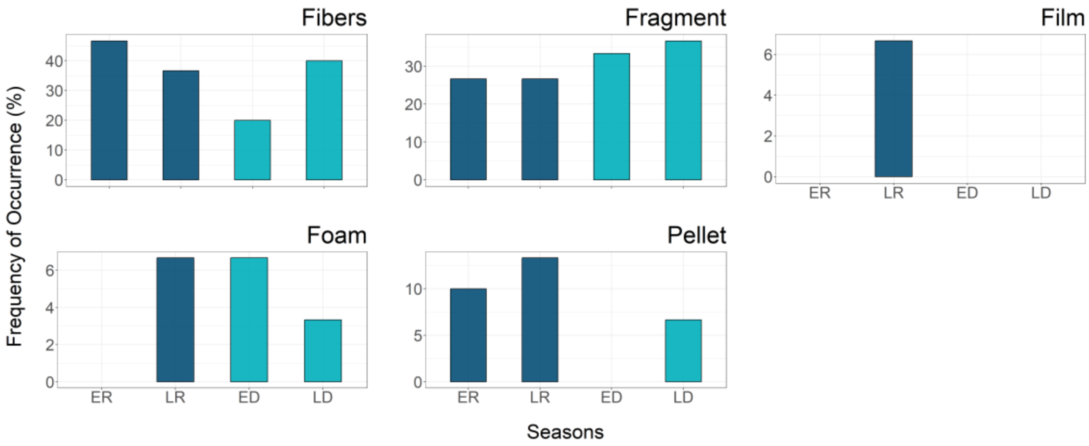

Figure 7 - The Frequency of Occurrence (FO%) of shapes of microplastics found in the gastrointestinal tracts of *Bairdiella goeldi* according to seasons (ER = Early rainy; LR = Late rainy; ED = Early dry; LD = Late dry).

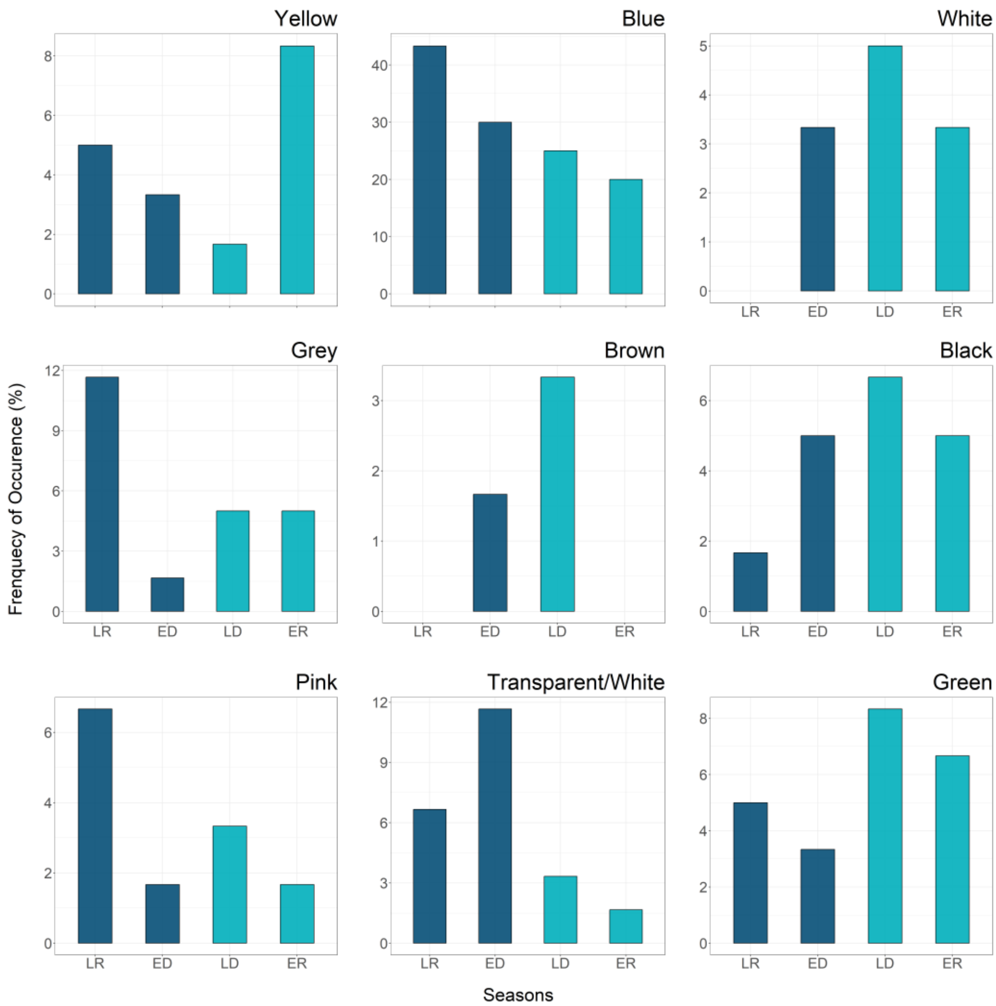

Figure 8 - The Frequency of Occurrence (FO%) of the colours of microplastics found in the gastrointestinal tracts of *Bairdiella goeldi* according to seasons (ER = Early rainy; LR = Late rainy; ED = Early dry; LD = Late dry).

Most of the microplastics found were less than 1 mm in size and measured an average of 0.51 mm ± 0.76, considered tiny microplastics, and the variations were relatively small when comparing the seasons. The mean of the four seasons was between 0.44 mm and 0.59 mm (Table 4).

Table 4 - Abundance and size of microplastics found in the gastrointestinal tracts of *Bairdiella goeldi*, shown as mean (±standard deviation – SD).

	Microplastics		
	Abundance		Size (mm)
	Mean ±standard deviation (items/individual)	Frequency of Occurrence (FO%)	Mean ±standard deviation
Early rainy – ER	1.6 ± 1.6	63.33%	0.59 mm ± 0.7
Late rainy – LR	1.2 ± 1.2	70%	0.49 mm ± 0.9
Early dry – ED	0.8 ± 1.1	46.66%	0.44 mm ± 0.8
Late dry – LD	1.2 ± 1.4	70%	0.52 mm ± 0.6

The abundance of microplastics throughout the study varied in some seasons, with the rainy season being the most representative. The early rainy season had the highest abundance, with 1.6 ± 1.6 items/individual, and the early dry season had the lowest abundance, with 0.8 ± 1.1 items/individual (Table 4).

The PERMANOVA analysis for the microplastic abundance data in *B. goeldi* reveals that seasonality and dissolved oxygen significantly (p<0.05) influence the composition of microplastics in the community (Table 5). This suggests differences between seasons that may affect the presence of microplastics in the community. In the *post-hoc* analysis, observing the differences between the seasonality groups, it was possible to identify significant differences (p<0.05) between the early rainy season and the early dry season, and the early dry season and the late dry season (Table 6).

Table 5 - Results of the PERMANOVA (Bray–Curtis) used to determine the total abundance of microplastic particles under the influence of environmental variables (Df = Degrees of Freedom / Sum()FSqs = Supply Sum of Squares / R2 = Coefficient of Determination / F= F-statistic / Pr(>F) = p-value of the F-statistic). The significance level adopted was $p < 0.05$.

Variables	**Df**	**Sum()FSqs**	**R2**	**F**	**Pr(>F)**
Season	3	16.380	0.08270	22,671	0.027*
Rainfall	1	0.2569	0.01297	10.667	0.335
Water temperature	1	0.1884	0.00951	0.7824	0.473
Salinity	1	0.3435	0.01734	14.261	0.203
Dissolved oxygen	1	0.7079	0.03574	29.392	0.049
Season*Rainfall	3	10.176	0.05738	14.084	0.187

Table 6 - Results of the reduced models using multilevel paired PERMANOVA between Seasons to compare total microplastics. The table shows the results of the *post-hoc* comparisons made between the four seasons ("Early dry season", "Late dry season", "Early rainy season", and "Late rainy season") concerning microplastic contamination. The values in the table represent the test statistics, including F-statistics, R^2 coefficients and p-values, highlighting the significant differences between the seasons. The significance level adopted was $p < 0.05$.

Comparisons	Df	Sum()FSqss	R2	F	Pr(>F)
LR_vs_ER	1	0.4210	0.0408	1.5738	0.185
LR_vs_ED	1	0.4488	0.04101	1.625	0.187
LR_vs_LD	1	0.4114	0.04225	1.5438	0.209
ER_vs_ED	1	0.8891	0.09137	3.7209	0.029
ER_vs_LD	1	0.3308	0.04133	1.4658	0.226
ED_vs_LD	1	0.7651	0.08467	3.2375	0.04

On the other hand, the PERMDISP indicates no significant differences(p>0.05), indicating the absence of a dispersion effect on the analysis of how the periods influence microplastic contamination. NMDS was used graphically to illustrate the overlap of microplastics between the dry and rainy seasons, divided into early and late, about item abundance (Figure 9).

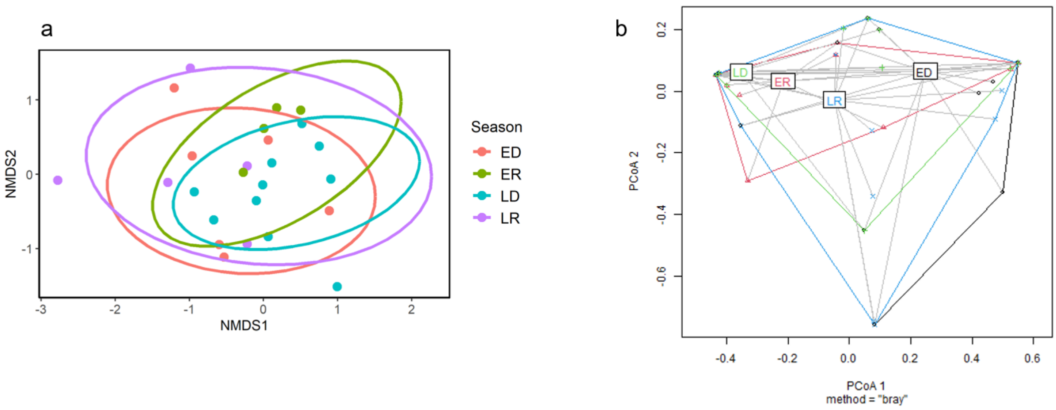

Figure 9 – a) NMDS analysis, corresponding to the overlap of microplastic contamination between the four seasons, early and late dry season and early and late rainy season. b) PERMDISP analysis corresponds to significant differences in the influence of the early and late dry seasons and early and late rainy seasons on microplastic contamination.

Discussion

The variability of abiotic parameters is a key factor in structuring aquatic ecosystems, impacting the composition of fish communities, their migration and breeding patterns, prey preferences, and even the presence of contaminants (Andradu-Tubino et al., 2019; Souza et al., 2018). Nevertheless, numerous studies point out the lack of research into the temporal impacts of microplastic pollution in aquatic environments (Kittipongvises et al., 2022; Thompson, 2015; Xia et al., 2021). This study aimed to investigate the impact of seasonality on the diet and microplastic contamination in *B. goeldi*. The findings reveal that fluctuations in environmental parameters throughout the seasons significantly influenced the microplastic contamination and food items consumed by *B. goeldi*.

Bairdiella goeldi is recognised as one of Brazil's most abundant demersal fish, holding an important position in coastal and estuarine ecosystems as prey for numerous economically significant fish species (Itagaki et al., 2007). Studies analysing the diet have shown that *B. goeldi* is a zoobenthivore species (Elliot et al., 2007; Castro et al., 1998; Vendell and Chaves, 1998; Bowman and Hyslop, 2023). The individuals analysed in our study, conducted on the coast of Pernambuco, preferred Amphipods as their primary food source, regardless of the season. This behaviour resamples the findings from a study conducted in Jamaica by Bowman and Hyslop (2023), who also observed a preference for Amphipods among juvenile individuals below sexual maturity (<158 mm), further supporting our findings.

Despite seasonal variations in salinity, species of the genus Bairdiella sp. demonstrate adaptability to a wide range of salinity fluctuations, enabling them to extend their distribution within their habitats and facilitating their predatory behaviour (Bowman and Hyslop, 2023; Marceniuk et al., 2019). The decrease in salinity observed during the rainy season is attributed to the increased influence of freshwater from the Sirinhaém River (Jales et al., 2012). Alongside Amphipods, Isopods and Polychaetes also play a significant role in the diet of these individuals (Bowman and Hyslop, 2023; Vendel and Chaves, 1998).

In contrast to the consistently present food items throughout the seasonal cycle, the abundance of food items consumed by *B. goeldi* was primarily influenced by seasonality in the Serrambi Beach region. It was evident that during the dry season, Isopods predominated. Conversely, polychaetes were exclusively observed during the rainy season, consistent with studies conducted in Guanabara Bay in southern Brazil (Vendel and Chaves, 1998). This area shares similar environmental characteristics with our study area, including species diversity and providing feeding, reproduction, and shelter habitats. Conversely, during the rainy season, the increased abundance of prey is linked to the greater presence of organic matter in the environment, thereby enhancing trophic activity. This is reflected in the species' dietary spectrum expansion during this time of the year (Vendel and Chaves, 1998; Chaves, 1995). The rainy season is distinguished by heightened precipitation, leading to increased surface runoff, affecting the transportation of nutrients, sediments, and microplastics to the coastal environment (Nascimento et al., 2021; Chen et al., 2021).

Whether intentional or accidental, plastic ingestion by fish appears to be influenced by the species' feeding behaviour (Xiong et al., 2019; McGregor and Strydom, 2020; Justino et al., 2021). Fish may inadvertently consume plastic particles while foraging, a process influenced by the abundance and size of plastic particles in both sediment and the water column (Cole et al., 2011; Possatto et al., 2011; Justino et al., 2023b). These particles become accessible to fish during feeding, increasing the likelihood of accidental ingestion (Cole et al., 2013; Besseling et al., 2015).

Seasonality played a decisive role, revealing significant differences between the seasons. The abundance of microplastics in *B. goeldi* was notably affected by seasonality, with higher numbers found during the rainy season, particularly in the early rainy, negatively impacting the environment. This finding aligns with previous studies that have reported increased microplastic abundance during this season (Ferreira et al., 2019; 2018). Oxygen levels are directly linked to environmental factors like seasons and waves in the region. Although our study identified a significant difference, the variability observed was not substantial.

The prevalence of fibres among microplastics could be attributed to domestic sewage discharges (Phillips and Bonner, 2015; Amorim et al., 2020; Justino et al., 2021; 2023b). Many microfibres may originate from textile products during washing, entering sewage systems and eventually reaching the oceans, as most sewage treatment systems are not designed to capture microplastics (Mcgregor and Strydom, 2020; Browne et al., 2011). Another contributor could be the fragmentation of fishing gear, recognised as a significant source of contamination (Mcgregor and Strydom, 2020; Amorim et al., 2020).

Fragments are usually the second most representative group in several studies (Neves et al., 2015; Vries et al., 2020; Dantas et al., 2020), as observed in our results. Fragment abundance was higher during the dry season, possibly due to dispersal patterns, seasonal pollution sources like tourism, and/or the nature of the microplastics (GESAMP, 2019; Galgani, 2000). According to Jales et al. (2012), the dry season is considered the high season, and an increase in the region's population is seen, leading to greater waste production. This could explain the study's results, as small coastal towns typically host various urban activities (Zhao et al., 2024) coupled with inefficient public waste management systems. Furthermore, environmental factors such as changes in temperature, water currents, and winds can affect the distribution and concentration of microplastics in aquatic environments (Amorim et al., 2020). The combination of high temperatures, intense solar radiation, strong winds, and waves creates favourable conditions on sandy beaches for breaking down large plastic objects into smaller fragments (Pegado et al., 2024).

In our study, we observed a wide range of microplastic colours, including blue, green, transparent, pink, and black, which are commonly reported in studies worldwide (Dantas et al., 2020; Xiong et al., 2019; Vries et al., 2020). Microplastics originate from various manufactured products and undergo degradation, resulting in different colours based on their source, production, and environmental degradation level (Rebelein et al., 2021). Blue microplastics were the most common colour identified in our study, followed by grey and transparent/white. These findings are consistent with the research by Amorim et al. (2020), who also observed a prevalence of blue microplastics in the stomachs of a species from the Scianidae family collected in the surf zone of tropical beaches in northeastern Brazil. The prevalence of blue microplastics in the stomachs of various fish species has been reported in other studies (Lusher et al., 2016; Dantas et al., 2020; Amorim et al., 2020), indicating their widespread presence in the marine environment. It is worth noting that blue fibres appear to be the most common type of microplastic in the oceans and are frequently ingested by fish (Dantas et al., 2020; Justino et al., 2023b; Ferreira et al., 2023).

The predatory behaviour of species can influence microplastic contamination, and feeding habits may affect the outcomes of our study. *Bairdiella goeldi* is a demersal zoobenthivore species, which means it interacts directly with sediment in environments known to retain microplastics (Justino et al., 2021), including in surf zone areas. These areas are highly susceptible to pollution and are ecologically significant, as highlighted in numerous studies (Chen et al., 2021; Sa et al., 2022; Karkanorachaki et al., 2018). The microplastic contamination rate in *B. goeldi* in our study aligns with findings reported by

Justino et al. (2021) for the same species, at approximately 1.2 ± 1.3 microplastics per individual, with fibres being the most commonly identified shape. Moreover, Thompson et al. (2004) reported the ingestion of microplastics by a *B. goeldi* prey, such as amphipods, indicating that plastic particles are consumed not only by fish species but also by their prey. Nonetheless, further studies are required to investigate the potential trophic transfer of microplastics from prey to the species.

Demersal species like *B. goeldi* are recognised as abundant and an important fishery resource, playing a key role in estuarine and coastal communities (Marceniuk et al., 2019). Future research should consider broadening the scope to encompass other species inhabiting surf zone areas while accounting for distinct microplastic sources across different seasons. Furthermore, it is imperative to explore additional environmental and ecological factors that may interact with seasonal variations in microplastic contamination and to investigate potential trophic transfers between species and their prey.

Conclusion

The research findings show significant seasonal variations in understanding feeding habits and microplastic contamination within a surf zone of the Tropical Atlantic. *Bairdiella goeldi* was identified as a zoobenthivore species, displaying a preference for feeding on amphipods. Notably, a shift in the diet spectrum was observed during the rainy season, with additional prey items such as polychaetes and shrimp likely linked to increased organic matter from the river runoff.

Nevertheless, microplastic contamination levels appeared to be influenced by the species' feeding habits and seasonality, with the rainy season showing the highest ingestion rates of particles. The incidence of microplastics in *B. goeldi* averaged 1.2 ± 1.3 items per individual, with fibres being the most frequently encountered shape, followed by fragments. Various colours of microplastics were identified, with blue being the most predominant.

Finally, preserving biodiversity and the health of coastal ecosystems necessitates implementing conservation measures and integrated management strategies. These efforts must consider natural factors and address the growing concern surrounding microplastic contamination.

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CONSIDERAÇÕES FINAIS

Os resultados obtidos através deste projeto de pesquisa destacam a influência significativa da sazonalidade na ecologia da espécie *Bairdiella goeldi*, tanto no comportamento alimentar como na ingestão de microplásticos, ressaltando a importância de que as estratégias de gestão levem em consideração as variações sazonais, especialmente no contexto das mudanças climáticas e seus efeitos sobre os ecossistemas aquáticos costeiros.

A análise do hábito alimentar da *B. goeldi* revelou uma preferência consistente por anfípodas, isópodes e poliquetas, com variações sazonais nas presas dominantes. A classificação da espécie como zoobentívora, corroborada por diversos estudos, ressalta sua posição chave na cadeia trófica costeira. Com a variação na alimentação e o consumo de presas ocorrendo apenas em determinados períodos, é provável que a sazonalidade indique uma possível variação na abundância de presas. Isso destaca a importância da compreensão dessas dinâmicas para a conservação eficaz da ictiofauna.

A contaminação de microplásticos nos tratos digestivos de uma espécie ecologicamente importante, como a retratada no estudo, evidencia a capacidade de dispersão, e o impacto que essas partículas plásticas têm causado na ictiofauna marinha. Isso ressalta os desafios enfrentados diariamente pelas espécies marinhas durante a alimentação, indicando a sua suscetibilidade e vulnerabilidade a esses contaminantes.

A presença de microplásticos nos tratos digestivos dos peixes reforça a necessidade urgente de abordagens eficazes na gestão de resíduos plásticos. A identificação de fibras, possivelmente provenientes de fontes domésticas, destaca a complexidade dessa questão, que requerem ações coordenadas em várias frentes, desde a conscientização pública até melhorias nas práticas de descarte.

O estudo destaca também algumas lacunas no entendimento das interações entre sazonalidade, variações ambientais e ingestão de microplásticos, indicando a necessidade de pesquisas contínuas para a obtenção de uma compreensão mais aprofundada desses fenômenos, visando orientar estratégias de conservação mais eficazes nos ecossistemas costeiros.

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