



**UNIVERSIDADE FEDERAL FLUMINENSE
INSTITUTO DE BIOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM
BIOLOGIA MARINHA E AMBIENTES COSTEIROS**

**AVALIAÇÃO DA INGESTÃO DE RESÍDUOS SÓLIDOS
POR TARTARUGAS-VERDES, *Chelonia mydas*
(Linnaeus, 1758), NO LITORAL CENTRO-SUL DO
ESTADO DO RIO DE JANEIRO, BRASIL**

BEATRIZ GUIMARÃES GOMES

**Niterói
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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Biologia Marinha do Departamento de Biologia Marinha Instituto de Biologia Universidade Federal Fluminense, como requisito parcial para a obtenção do Grau de Mestre em Biologia Marinha e Ambientes Costeiros.

Orientador: Prof. Dr. Fábio Vieira de Araújo
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Avaliação da ingestão de resíduos sólidos por tartarugas-verdes, *Chelonia mydas* (Linnaeus, 1758), no litoral centro-sul do estado do Rio de Janeiro, Brasil

Dissertação aprovada em 10 de setembro de 2021 pelo Programa de Pós-Graduação em Biologia Marinha e Ambientes Costeiros, como requisito parcial à obtenção do título de Mestre em Biologia Marinha e Ambientes Costeiros.

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RESUMO

Nos últimos anos, um crescente número de estudos aponta a poluição dos oceanos por detritos antropogênicos como uma das maiores ameaças ao ambiente marinho e à sua biodiversidade. As tartarugas marinhas vêm sofrendo ameaças ao longo de sua vida, como a captura incidental na pesca, o desenvolvimento costeiro, com consequente perda de habitat, e impacto por poluição química e resíduos sólidos nos oceanos e áreas costeiras, sendo o lixo marinho uma das ameaças para a conservação desses animais atualmente. Este trabalho tem como objetivo avaliar o impacto da ingestão de resíduos sólidos por tartarugas marinhas, para isso, 66 tartarugas-verdes encontradas encalhadas ao longo do litoral centro-sul do Rio de Janeiro pelo Projeto de Monitoramento de Praias da Bacia de Santos, tiveram o conteúdo gastrointestinal analisados. Em 69,7% dos indivíduos analisados foi detectada a presença de resíduos sólidos, com maior concentração no intestino grosso. Foi encontrado um total de 1.683 itens ingeridos, sendo 1 e 373, o mínimo e máximo, respectivamente, de itens encontrados no trato gastrointestinal de um só indivíduo. O resíduo do tipo plástico flexível (50,5%; 850 itens), da cor âmbar/marrom (36,5%; 614 itens) e de tamanho entre 0,5 mm e 2,5 cm (41,2%; 693 itens) foram os mais frequentemente encontrados. Não foi encontrada diferença significativa entre tartarugas coletadas dentro e fora de baías. Nossos resultados mostram os principais tipos, tamanhos e cores de resíduos que são ingeridos por esses animais na região costeira, a fim de identificar a gravidade do impacto pela ingestão de resíduos sólidos em tartarugas marinhas. Também fornecem informações para o desenvolvimento de planos de gestão que visem a redução ou modificação do consumo de plástico e para identificar o grau de ameaças que esse tipo de impacto causa em tartarugas marinhas.

Palavras-chave: Plástico, Poluição, Lixo marinho.

ABSTRACT

In recent years, a growing number of studies point to the pollution of the oceans by anthropogenic debris as one of the greatest threats to the marine environment and its biodiversity. Sea turtles have been suffering threats throughout their lives, such as incidental capture in fishing, coastal development, with consequent loss of habitat, and impact by chemical pollution and anthropogenic debris in the oceans and coastal areas, with marine litter being one of the threats for the conservation of these animals today. This work aims to evaluate the impact of anthropogenic debris ingestion by sea turtles, so, 66 green turtles found stranded along the south-central coast of Rio de Janeiro by the Santos Basin Beach Monitoring Project, had the gastrointestinal content analyzed. In 69.7% of the individuals analyzed, the presence of anthropogenic debris was detected, with a higher concentration in the large intestine. A total of 1,683 items ingested were found, with 1 and 373 being the minimum and maximum, respectively, of items found in the gastrointestinal tract of a single individual. Flexible plastic waste type (50.5%; 850 items), amber/brown color (36.5%; 614 items) and of size between 0.5 mm and 2.5 cm (41.2%; 693 items) were the most frequently found. No significant difference was found between turtles collected inside and outside the bays. Our results show the main types, sizes, and colors of debris ingested by these animals in the coastal region to identify the severity of the impact caused by the ingestion of anthropogenic debris in sea turtles. They also provide information for the development of management plans to reduce or modify plastic consumption and identify the degree of threat that this type of impact causes to marine turtles.

Keywords: Plastic, Pollution, Marine debris

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INTRODUÇÃO GERAL

O aumento da produção global e do uso de plásticos adicionado ao descarte inadequado gerou um acúmulo de resíduos sólidos, principalmente plástico, em diferentes ambientes, como o oceano. Jambeck *et al.* (2015) estimou que 275 milhões de toneladas de resíduos plásticos foram geradas em 192 países costeiros em 2010, com 4,8 a 12,7 milhões de toneladas entrando no oceano. Nesse estudo, o Brasil foi considerado um dos 20 principais países que emitem resíduos plásticos para os oceanos. Por possuírem características como a alta durabilidade, os plásticos permanecem no ambiente marinho por muitos anos, sendo levados por correntes, ondas, marés, ventos e outros fenômenos. Formam grandes ilhas de lixo em todos os oceanos, sendo a do Pacífico a maior delas, ocupando uma área de 1,6 milhões de quilômetros quadrados (Lebreton *et al.*, 2018). Além disso, esses resíduos possivelmente transportam organismos sésseis em um fenômeno conhecido como rafting onde causam danos à diversidade dos ambientes marinhos como a introdução de espécies exóticas, que podem se tornar invasoras quando ocasionam impactos para a fauna nativa (Póvoa *et al.*, 2021). No caso de alguns microorganismos patogênicos, também podem se tornar invasores quando estão incrustados em resíduos de plástico, e esse fenômeno é conhecido como plastisfera (Lacerda, 2019).

A Organização das Nações Unidas (ONU) propôs em 2015 uma nova agenda de desenvolvimento sustentável, da qual o Brasil é signatário, composta por 17 Objetivos de Desenvolvimento Sustentável (ODS) para serem cumpridos até 2030. Um desses objetivos diz respeito à vida na água, buscando preservar a diversidade marinha através da conservação e do uso sustentável dos oceanos, mares e recursos marinhos. Portanto, a redução e a prevenção significativa da poluição marinha de todos os tipos, principalmente as de atividades terrestres, incluindo detritos marinhos, se encontra como uma das metas a serem alcançadas até 2025 (Nações Unidas Brasil, 2021).

A poluição dos oceanos por resíduos sólidos, atualmente, é considerada como um dos principais impactos antrópicos sobre os ecossistemas marinhos, problema que representa uma enorme ameaça para os animais marinhos (Laist, 1987; Laist, 1997; Derraik, 2002; Sazima *et al.*, 2002; Barnes *et al.*, 2009;

Gregory, 2009; da Silva *et al.*, 2018; Moura *et al.*, 2020). Eles ingerem os resíduos sólidos de forma acidental, por confundirem com alimento e, mesmo quando ingeridos em pequena quantidade, geram efeitos que podem variar de subletais, como redução da absorção de nutrientes, reduzindo a taxa de crescimento, a letais, como a obstrução do trato digestório, podendo levar a morte do animal (Ryan, 1987; Bjorndal *et al.*, 1994; McCauley & Bjorndal, 1999; Derraik, 2002; Gregory, 2009; Bucci *et al.*, 2019; Marn *et al.*, 2020; Santos *et al.*, 2020). Dentre os diversos organismos marinhos, as tartarugas estão entre as espécies mais impactadas pela presença do lixo no mar (Bjorndal *et al.*, 1994; Lazar & Gračan, 2011; Schuyler *et al.*, 2014; Carvalho *et al.*, 2015; Mendes *et al.*, 2015).

Existem no mundo sete espécies de tartarugas marinhas, agrupadas na ordem dos Testudines e divididas em duas famílias. As espécies *Chelonia mydas* (Linnaeus, 1758) (tartaruga-verde), *Eretmochelys imbricata* (Linnaeus 1766) (tartaruga-de-pente), *Caretta caretta* (Linnaeus 1758) (tartaruga-cabeçuda), *Lepidochelys olivacea* (Eschscholtz 1829) (tartaruga-oliva), *Natator depressus* (Garman 1880) (tartaruga-marinha-australiana) e *Lepidochelys kempii* (Garman 1880) (tartaruga-de-kempi) pertencem à família Cheloniidae. A espécie *Dermochelys coriacea* (Vandelli 1761) (tartaruga-de-couro) pertence à família Dermochelyidae. *Natator depressus* e *L. kempii* ocorrem somente na Austrália e no Golfo do México, respectivamente, e as demais ocorrem no Brasil (Marcovaldi & Marcovaldi, 1999).

As tartarugas marinhas vêm sofrendo ameaças que incidem ao longo de todas as fases de seu ciclo de vida, como a captura incidental na pesca, o desenvolvimento urbano das praias de desova com conseqüente redução destas áreas na costa e os impactos por poluição química e por resíduos nos oceanos e áreas costeiras (Epperly *et al.*, 1996; Lutcavage *et al.*, 1997; Domingo *et al.*, 2006; Hamann *et al.*, 2010; Santos *et al.*, 2011). A interação com resíduos antropogênicos vem sendo crescentemente relatada nas últimas duas décadas (Schuyler *et al.*, 2013; Santos *et al.*, 2015a; Santos *et al.*, 2020) e todas as sete espécies já foram reportadas com ingestão de resíduos sólidos (Kühn *et al.* 2015). Uma das causas propostas para explicar essa incidência de casos seria a similaridade visual do resíduo com seu alimento natural (Schuyler *et al.* 2014b; Santos *et al.*, 2016; Andrades *et al.*, 2019; Duncan *et al.*, 2021; Santos *et al.*,

2021). Portanto, se faz necessário compreender a vulnerabilidade desses animais, estabelecer prioridades de pesquisas e desenvolver estratégias de conservação apropriadas (Schuyler *et al.*, 2014; Vegter *et al.*, 2014).

O estudo de Santos *et al.* (2015a), realizado na costa brasileira, mostrou que uma quantidade pequena de resíduos é suficiente para bloquear o trato digestivo e causar a morte de uma tartaruga. Os autores demonstraram também que uma parte desses resíduos ingeridos era originária de produtos descartáveis e de vida curta. Bugoni *et al.* (2001), em uma pesquisa realizada no Sul do Brasil, mostraram que 23 de 38 tartarugas marinhas examinadas possuíam resíduos antropogênicos no estômago indicando que a origem desses resíduos poderia ser, além da atividade pesqueira, por atividade turística nas praias da região. Os resultados destes estudos mostram ser imprescindível adotar ações mais efetivas em relação à redução da produção e do uso de materiais sólidos descartáveis. Indicam também que deve ser dado foco nos itens plásticos, uma vez que são descartados diretamente em áreas costeiras ou chegam nessas áreas através da poluição (Morales-Caselles *et al.*, 2021). Portanto, a sociedade em geral deve receber orientação quanto às formas de descarte dos resíduos sólidos, com incentivos à coleta seletiva e reciclagem, além de olhar para toda a cadeia produtiva do plástico (Awabdi *et al.*, 2013; Simon *et al.*, 2021). Adicionalmente, as comunidades pesqueiras também devem ser orientadas quanto a melhor forma de descarte dos artefatos de pesca, a fim de minimizar a poluição por esses materiais nos oceanos e, conseqüentemente, o risco de sua interação com as tartarugas marinhas. Essas medidas contribuiriam para a conservação desses animais, além de outras espécies marinhas e da saúde dos ecossistemas marinhos costeiros.

O capítulo 1 desta dissertação aborda o levantamento da ocorrência da ingestão de resíduos sólidos em tartarugas-verdes no litoral centro-sul do estado do Rio de Janeiro. Para isso, foram considerados os tipos, cores e tamanhos mais encontrados nos tratos digestórios dos animais encalhados mortos na região, comparando locais de encalhe mais poluídos (no interior de baías; região central) e menos poluídos (fora de baías; região sul), a fim de verificar o estado desse impacto nessa região. Este artigo foi submetido na revista *Marine Pollution Bulletin*. Até o momento a revisão dos revisores da revista não foi realizada e o artigo no presente documento deverá sofrer modificações.

OBJETIVOS

Objetivo Geral

Avaliar o impacto da poluição marinha em tartarugas-verdes através de uma avaliação qualitativa e quantitativa dos resíduos sólidos encontrados no conteúdo gastrointestinal de indivíduos encontrados mortos no litoral centro-sul do estado do Estado do Rio de Janeiro – RJ.

Objetivos Específicos

- (1) Analisar qualitativamente e quantitativamente a composição e a frequência dos resíduos sólidos encontrados no trato gastrointestinal de tartarugas marinhas da espécie *Chelonia mydas* encontradas mortas no litoral centro-sul do estado do Rio de Janeiro.
- (2) Comparar a composição e a frequência dos resíduos sólidos encontrados no trato gastrointestinal de tartarugas marinhas da espécie *Chelonia mydas* encontradas mortas no interior de baías e nas praias fora de baías no litoral centro-sul do estado do Rio de Janeiro.
- (3) Avaliar em que parte do sistema digestório se concentram os resíduos sólidos.

CAPITULO 1: ASSESSMENT OF ANTHROPOGENIC DEBRIS INGESTION BY GREEN TURTLES, *Chelonia mydas* (Linnaeus, 1758), IN THE SOUTH-CENTRAL COAST OF THE STATE OF RIO DE JANEIRO, BRAZIL

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Abstract

Sea turtles have been suffering threats, such as incidental capture by fishing activities, habitat loss and the impact of pollution all due to urban development. Among different types of pollution, anthropogenic debris has been widely reported in numerous cases of ingestion, entanglement, and untimely death of sea turtles. The south-central coast of Rio de Janeiro is characterized by a large human population density. This coastal region contains three bays, one of which is Guanabara Bay, one of the most polluted in the country. To assess the impact of sea based anthropogenic debris on sea turtles, this study's research team analyzed the gastrointestinal tracts of 66 green turtles found stranded along the south-central coast of Rio de Janeiro by the Santos Basin Beach Monitoring Project. Anthropogenic debris was detected in 69.7% of the individuals analyzed, with a higher concentration in the large intestine than any other organ. A total of 1,683 items ingested were found between all surveyed turtles, with 1 and 373 being the minimum and maximum, respectively, of items found in the

gastrointestinal tract of a single individual. Flexible plastic waste type (50.5%; 850 items), amber/brown color (36.5%; 614 items) and fragments with size between 0.5 mm and 2.5 cm (41.2%; 693 items) were the most frequently found. No significant difference in ingested plastic was found between turtles collected inside and outside the bays. The large number of individuals with debris in their gastrointestinal tract shows the severity of the impact of these residues on sea turtles in this region.

Keywords: Bays, *Chelonia mydas*, Marine waste, Plastic, Pollution.

1. Introduction

In recent decades, the number of studies concerning anthropogenic debris ingestion by marine fauna has increased, and many of these studies conclude that the ingestion of waste (mainly plastics) is the main threat to ecosystem sustainability (e.g. Laist, 1997; Derraik, 2002; Barnes et al., 2009; Browne et al., 2011; Cole et al., 2011; Moura et al., 2020; Santos et al., 2021). The impacts caused by the accumulation of anthropogenic debris, such as ingestion of unnatural material by marine fauna, are public knowledge, but the production and discharge of debris into the environment continue to increase (Thompson et al., 2009; Rochman et al., 2013; Plastic Europe, 2019). In addition to ingestion, the entanglement of marine species in these residues, such as in ghost nets and plastic ropes, can also lead to an animal's death (Laist, 1997; Gall et al., 2015). Sea turtles are one of the main groups that suffer as a result of these pollutants infesting the waters (Gall et al., 2015; Nelms et al., 2016; Santos et al., 2020).

Five of the seven species of sea turtles exist in Brazil - *Chelonia mydas* (green turtle), *Eretmochelys imbricata* (hawksbill turtle), *Caretta caretta* (loggerhead turtle), *Lepidochelys olivacea* (olive turtle), and *Dermochelys coriacea* (leatherback turtle) (Marcovaldi et al., 1999). All five of these species use the Brazilian coast as a feeding and reproduction area, with the northernmost state of Rio de Janeiro being the southern limit of nesting areas in Brazil (Marcovaldi et al., 1999).

Surveyors have reported debris ingestion at all life cycle stages of all sea turtle species (e.g. Mrosovsky et al., 2009; Schuyler et al., 2012; Kühn et al., 2015). One possible cause of ingestion could be the visual similarity of the debris with the turtles' natural food, such as macroalgae (Schuyler et al., 2014b). For the green turtle, accidental ingestion is also common, since the anthropogenic debris can be aggregated to macroalgae, used as a food source by them (Di Benedetto et al., 2014).

Chelonia mydas is the species with the most coastal habits (Bugoni et al. 2001; Schuyler et al., 2014a; Santos et al. 2015b). Thus, it is more exposed to the effects of anthropogenic actions than any other turtle species, with greater probability of being run over by boats, more significant contact with chemical and residual pollution and accidental fishing (Tagliolatto et al., 2019; Gomes et al., 2021). This species preferentially consumes algae and marine grasses. However, it can also feed on other resources depending on food availability in its foraging site, being considered opportunist (Mortimer, 1982; Bjorndal, 1997; Hirth, 1997; Esteban et al., 2020).

The south-central coast of Rio de Janeiro state is characterized by a presence of large industrial enterprises, ports, urban centers, significant tourist activity, heavy boat traffic, intense artisanal and industrial fishing activity, and its three distinguished bays, Guanabara Bay, Sepetiba Bay, Ilha Grande Bay. As it is a popular feeding area, a significant number of turtles can be found throughout this region (Tagliolatto et al. 2019; Gomes et al., 2021). Guanabara Bay is reportedly one of the most polluted in the country, and subsequently, an number of sea turtle deaths can be correlated to the heavy pollution rate of this area (Amador, 1997; Valentin et al., 1999; Neto et al., 2011; Amador, 2012; INEA, 2015). The aim of the present study was address the survey of the occurrence of anthropogenic debris ingestion in green turtles on the south-central coast of Rio de Janeiro state. For this, the types, colors and sizes most found in the digestive tracts of dead stranded animals in the region were considered, comparing more polluted stranding sites (inside bays; central region) and less polluted (outside bays; southern region). Therefore, evaluating the ingestion of anthropogenic debris by sea turtles in feeding areas, such as the coast of Rio de Janeiro, becomes essential to obtain information about the impact of debris on sea turtles

populations. In addition, this information can help in the work of population management and conservation of these species (Bjorndal, 2000).

2. Material and Methods

2.1 Study area

The municipalities that constitute the south-central region of Rio de Janeiro state are Paraty, Angra dos Reis, Mangaratiba, Itaguaí (southern region), Rio de Janeiro, Duque de Caxias, Magé, Guapimirim, Itaboraí, São Gonçalo, Niterói, Maricá and Saquarema (central region). In this area, there is the Guanabara, Sepetiba, and Ilha Grande Bays (Fig. 1). These municipalities are in the operating area of the Santos Basin Beach Monitoring Project (BMP-BS) in the Rio de Janeiro state (up to Praia da Vila, in Saquarema). This project is an environmental requirement for the oil exploration and production of activities conducted by Petrobras on the coast of Brazil. The main goal of a BMP is to record the occurrence of stranded marine animals, especially chelonians, mammals, and seabirds, and determine whether there is a relationship between the stranding of these animals with the activities conducted (Werneck et al., 2018).

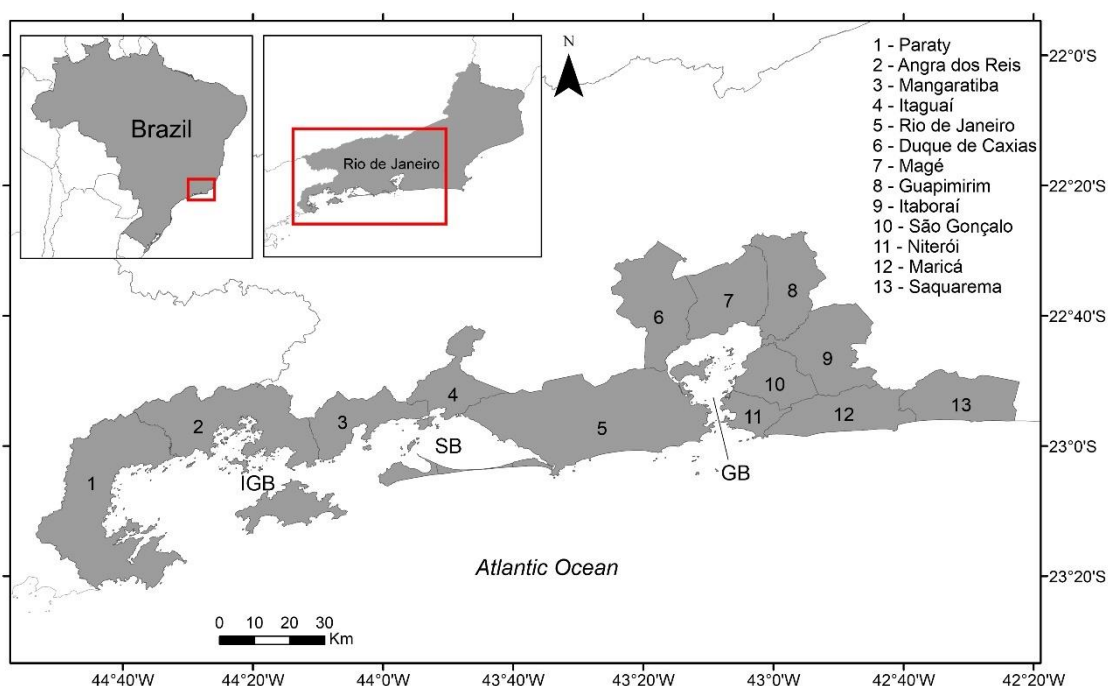


Fig. 1 Municipalities in Rio de Janeiro state that are covered by the Santos Basin Beach Monitoring Program (BMP-BS). IGB: Ilha Grande Bay. SB:Sepetiba Bay and GB:Guanabara Bay.

The coast of Rio de Janeiro is influenced by marine currents and water masses that determine the flow of water in the region, such as the South Atlantic Central Water (SACW), formed in the Subtropical Convergence, present on the southeastern Brazilian coast (Silva et al., 1984). Upwellings also occur, with the emerging of the SACW on the continental platform of Rio de Janeiro, in the Cabo Frio region, during spring and summer due to the northeast winds that affect the area. This water mass may extend as far as the municipality of Rio de Janeiro (Torres, 1995).

Guanabara Bay is considered a semi-enclosed coastal ecosystem. Additionally, it is home to a group of estuarine ecosystems that shelters a high diversity of species (Amador, 1980; Amador, 1997). Guanabara Bay is located in the metropolitan region of Rio de Janeiro state, which is home to large urban centers and the second-largest metropolis in the country. It has intense economic activity, with the presence of ports, industrial complexes, tourist attractions and fishing activities. Due to the significant human presence, domestic sewage and industrial effluents discharge into the Bay on a daily/weekly basis, which is one of the contributing factors to why Guanabara Bay is one of the most polluted bays on the Brazilian coast (Amador, 1997; Valentin et al., 1999; Neto et al., 2011; Amador, 2012).

Ilha Grande and Sepetiba Bays are located in the South Coast of the state, known as Costa Verde. Ilha Grande Bay has a wide opening to the ocean, being influenced by cooler and saltier waters. In contrast, Sepetiba Bay is contains mostly freshwater from canals and rivers. Sepetiba Bay is also influenced by the presence of Restinga da Marambaia, which acts as a barrier, making it difficult to exchange water with the ocean. Thus, these bays have different hydrodynamics, but a central connecting channel, forming an estuarine system with exchanges of ocean circulations (Signorini, 1980; Fragoso, 1999; Godoi et al., 2011). Despite the lower population density, Sepetiba Bay and Ilha Grande Bay are marked by the presence of large ports, nuclear power plants, and distinguished tourist and fishing activities (Bastos et al., 2009; INEA, 2015).

2.2 Data and sample collection

Data and samples provided by the companies executing the BMP-BS, [CTA – Serviços em Meio Ambiente and Econservation – Estudos e Projetos Ambientais], in the Rio de Janeiro state were used to carry out this study. These data were registered between May 2019 and March 2021, except the period between April and June 2020, when no animal was collected due to the COVID-19 Pandemic. The gastrointestinal tract contents (GIT) of *Chelonia mydas* were collected directly by the Projeto Aruanã team, at the headquarters in Rio de Janeiro city, or by the veterinary team, which send it later to the project (headquarters in Rio de Janeiro and Angra dos Reis). Only individuals presenting a stage of decomposition up to code 3 (**Table 1**) had their contents collected for evaluation because most of the GIT organs were still intact. The data provided were: location of stranding (latitude, longitude, city name, and beach name), stage of carcass decomposition, and curvilinear carapace length and width (in cm) (CCC and LCC).

All data on individuals collected by the BMP-BS are publicly available in the Aquatic Biota Information System (SIMBA, <https://simba.petrobras.com.br/simba/web/>).

Table 1 - State of carcass decomposition and their respective codes (Code). Adapted from Geraci, J.R. & Lounsbury, V.J. (2005) Marine Mammals Ashore: A Field Guide for Strandings.

Code	Condition	Characteristics
1	Alive	--
2	Carcass in good condition	Normal appearance, little action of necrophagous animals, little skin loss, firm musculature and fat, intact organs, intestine with little quantity of gas
3	Moderate decomposition	Carcass intact, protrusion of tongue and genital organ, eyes dry or absent, skin loss, hemolyzed blood, fat affected, muscles brittle, intestine dilated with gas.
4	Advanced decomposition	Considerable skin loss, intensive action of necrophagous animals, strong odor, smooth fat with gas bubbles, muscles nearly liquified, viscera brittle, intestine filled with gas
5	Carcass mummified or skeletal remains	--

2.3 Collection, storage, and screening of the contents of the gastrointestinal tract (GIT)

The GIT was removed entirely and closed, through bindings at the ends. Then, the wet weighing (in g) of each organ separately (esophagus, stomach, small intestine, and large intestine) was performed. After that, the contents of each organ were removed, stored in glass jars covered with 92.8° alcohol, and properly identified. Finally, each organ, without its gastrointestinal contents, was weighed separately. To know the weight of content present in each organ,

weighings were performed to obtain the value of the difference between the weight of the entire organ and the weight of the empty organ.

To screen the contents of the GIT, a 1 mm mesh sieve was used. All contents were washed under running water to separate food contents from anthropogenic debris. Afterward, the debris were weighed on a digital scale (accurate to 1 g), quantified and categorized according to nature (type) of the material, color (visual observation), and size (micro <0.5 mm, meso from 0.5 mm to 2.5 mm and macro > 2.5 mm) according to GESAMP (2019).

2.4 Data analyses

The frequency of occurrence (%) of each of the studied categories was calculated using the formula $FO = (N \times 100) / NT$, where N is the number of times an item of a given category was present in the contents of an organ and NT is the total number of debris found in all the individuals that ingested debris.

To analyze whether there is a difference between the number of debris ingested by turtles found dead inside or outside the bays, the Wilcoxon-Mann-Whitney statistical test was performed. The Shapiro-Wilk statistical W test tested data normality.

To assess whether there is a difference between the number of debris ingested by type of material, the Kruskal-Wallis test was performed, followed by the a posteriori Dunn test for multiple comparisons.

To assess the main factors that influence anthropogenic debris ingestion, two tests were performed using Generalized Linear Models (GLMs). In the first, the number of items ingested per turtle was included as the response variable as a function of three explanatory variables, (i) type of material, (ii) color, and (iii) stranding location (in and out of bays). In the second, the number of items ingested per turtle was included as the response variable as a function of three variables (i) type of material, (ii) debris size (Micro, Meso, and Macro), and (iii) stranding location (inside and outside of bays). Since the occurrences of debris ingestion were not accounted for to allow analysis by color and size in the same statistical test two separate tests were performed, one including color and the other including size. Records were counted by color and size separately, and one

analysis altogether could generate inflated results, generating a systematic bias. The models were built from combinations of the global model variables (i.e., model with all explanatory variables included), using the negative binomial distribution. The selected models were those whose difference between the second-order Akaike's Information Criterion (AICc) of the model in question and the model with the lowest AICc value was from 0 to 2 ($\Delta\text{AICc} \leq 2$), considering the estimated parameters of the Generalized Linear Model - Average (Burnham et al., 2002). The importance value for each fixed explanatory variable was calculated as the sum of the Akaike weights in the selected models that included that variable (Burnham et al., 2002).

Statistical analyzes were conducted in the R statistical program (version 3.1.1, R Core Team, 2021).

3. Results

From May 2019 to March 2021, a total of 1,616 marine turtles were collected between Paraty and Praia da Vila (Saquarema), approximately 985 km of beaches, 1,376 of which from the *Chelonia mydas* species. Of these, 1,218 were found dead, 319 were sent for necropsy, and 158 were found alive. However, 104 of them died after collection and were sent for necropsy. Therefore, of the 423 green turtles necropsied, 66 individuals, collected at the Angra and Rio de Janeiro headquarters, were analyzed in the present study regarding the composition of the gastrointestinal contents. Regarding the stage of decomposition of the analyzed turtles, 19 (28.78 %) were classified as Code 2, 46 (69.69 %) as Code 3, and one (1.51 %) as Code 4. Although the analyzes were performed on individuals who presented up to Code 3, the single Code 4 individual was analyzed by having the entire contents of the gastrointestinal tract preserved. The curvilinear carapace length of the individuals analyzed ranged from 30 cm to 76.3 cm (mean \pm SD: 76.8 cm \pm 8.5 cm).

After examining the contents of each turtle's GIT, the research team tallied a total count of 1,683 solid anthropogenic debris items. In 46 sea turtles (69.7%), at least one item of anthropogenic debris was found. Of the 20 individuals who did not ingest debris, 14 were found in the southern region, 13 within bays and 1

outside the bay, and 6 were found in the central region, 5 within bays and 1 outside the bay. In total, 18 individuals were found inside the bays.

The wet weight of anthropogenic debris found in the GIT of the individuals in this study ranged from 0 to 203 g. The average weight of debris in the esophagus was $0.32 \text{ g} \pm 0.82 \text{ g}$, in the stomach was $0.78 \text{ g} \pm 2.85 \text{ g}$, in the small intestine was $0.90 \text{ g} \pm 3.11 \text{ g}$, and in the large intestine, it was $4.07 \text{ g} \pm 7.14 \text{ g}$. Regarding the total weight of debris per individual, 20 individuals (43.5%) had less than 1 g, 13 individuals (28.3%) had between 1 and 10 g, 8 individuals (17.4 %) between 10 and 20 grams, 1 individual (2.2 %) between 20 and 30 grams, 3 individuals (6.5 %) between 30 and 40 grams and 1 individual (2.2 %) had 203 g in their GIT.

Regarding the nature (type) of the debris found, flexible plastic was the most ingested by the animals analyzed in this study (Fig.2), corresponding to 50.5% of the total items ($n = 850$), followed by line/rope (28.5 %, $n = 479$ items), rigid plastic (12.7 %; $n = 214$ items), styrofoam (5.8 %; $n = 97$ items), rubber (1.7 %; $n = 28$ items), foam (0.8 %; $n = 13$ items) and pellets (0.1 %; $n = 2$ items). Of the 46 sea turtles that ingested debris, flexible plastic and line/rope debris were found in 38 individuals (82.6 %), rigid plastics in 26 individuals (56.5 %), styrofoam in 11 individuals (23.9 %), rubber in 10 individuals (21.7 %), pellets in 2 individuals (4.3 %) and foam in 2 individuals (4.3 %).



Fig. 2 Diversity of types, colors and sizes of the anthropogenic debris found in the gastrointestinal contents of stranded green turtles on the south-central coast of Rio de Janeiro state.

The average number of debris ingested differed significantly (Kruskal-Wallis chi-squared = 114.8757, df = 6, $p < 0,001$) by type. From Dun's a posteriori test for multiple comparisons, the significant difference was between line/rope and flexible and rigid plastics compared to the other items and between rigid plastic and line/rope (**Table 2**).

Table 2 - Comparison of the median number of debris ingested by type (No adjustment) by Kruskal Wallis test (Kruskal-Wallis chi-squared= 114.8757, df = 6, p-value < 0,001).

Col Mean-Row Mean	Rubber	Foam	Styrofoam	Line/ Rope	Pellets	Plastic
Foam	1.290333 0.0985 -	-				
Styrofoam	0.327868 0.3715 -	1.618201 0.0528				
Line/ Rope	5.831575 0.0000*	7.121909 0.0000*	-5.503707 0.0000*			
Pellets	1.128264 0.1296 -	0.162068 0.4356 -	1.456132 0.0727	6.959840 0.0000*		
Plastic	5.796758 0.0000*	7.087091 0.0000*	-5.468890 0.0000*	0.034817 0.4861	6.925022 0.0000*	
Plastic	3.095472 0.0010*	4.385806 0.0000*	-2.767604 0.0028*	2.736102 0.0031*	4.223737 0.0000*	2.701285 0.0035*

Of the colors identified, amber/brown was the predominant among those found in the anthropogenic debris of the analyzed TGI, corresponding to 36.5% (n = 614 items), followed by white (18.1%; n = 304 items), blue (13.7%; n = 231 items), translucent (11.9%; n = 200 items), black (5.5%; n = 93 items), green (4.6%; n = 78 items), yellow (4.4%; n = 74 items), red (1.6%; n = 27 items), gray (1.5%; n = 26 items), orange (1.3%; n = 22 items), pink (0.6%; n = 10 items) and purple (0.2%; n = 4 items). It was also identified that, of the 46 sea turtles that ingested debris, 84.8% of the individuals (n = 39) ingested antropogenic debris of amber/brown color, followed by white (65.2%; n = 30 individuals), blue (65.2%;

n = 30), black (60.9%; n = 28), green (47.8%; n = 22), yellow (45.7%; n = 21), gray (30.4%; n = 14), red (26.1%; n = 12), orange (15.2%; n = 7), pink (10.9%; n = 5) and purple (4.3%; n = 2).

Regarding the analysis by study site (inside and outside the bays), there was no significant difference between the mean number of debris ingested by sea turtles found inside bays (n = 53) and the average of debris ingested by turtles found outside bays (n = 13) (Figures 3 and 4).

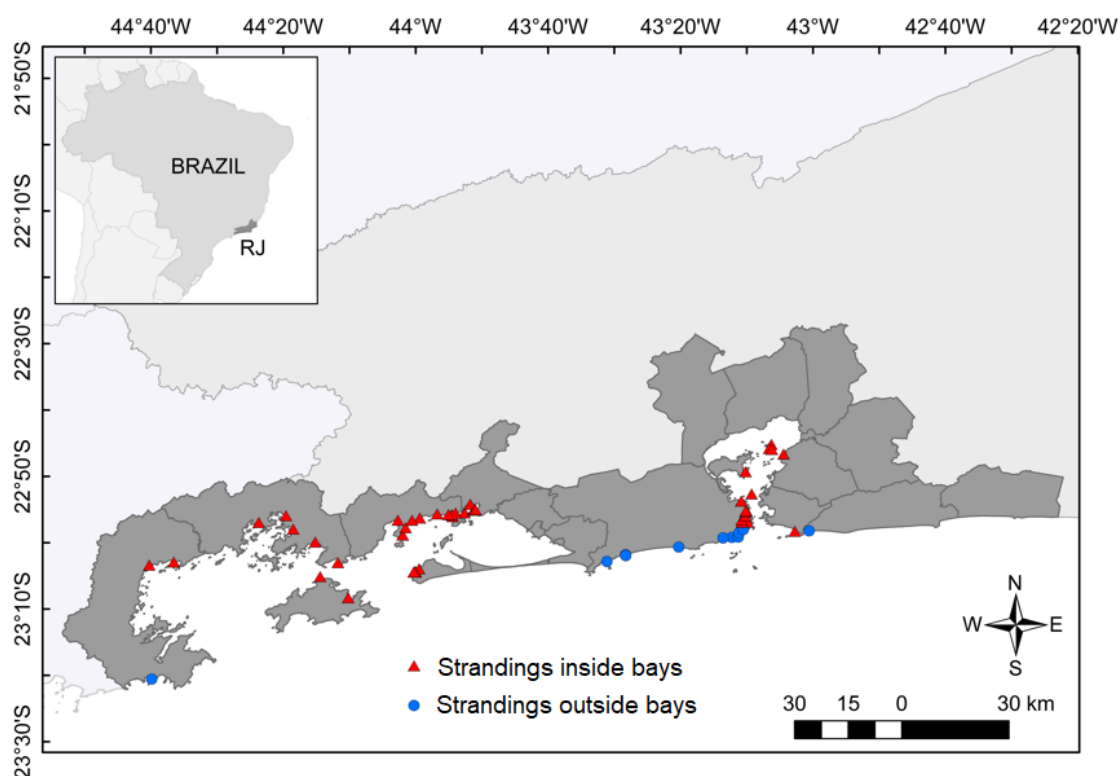


Fig. 3 Locations of green turtle strandings analyzed for the content of the gastrointestinal tract (GIT) inside the bays (red) (n = 53) and outside the bays (blue) (n = 13) on the south-central coast of Rio de Janeiro state.

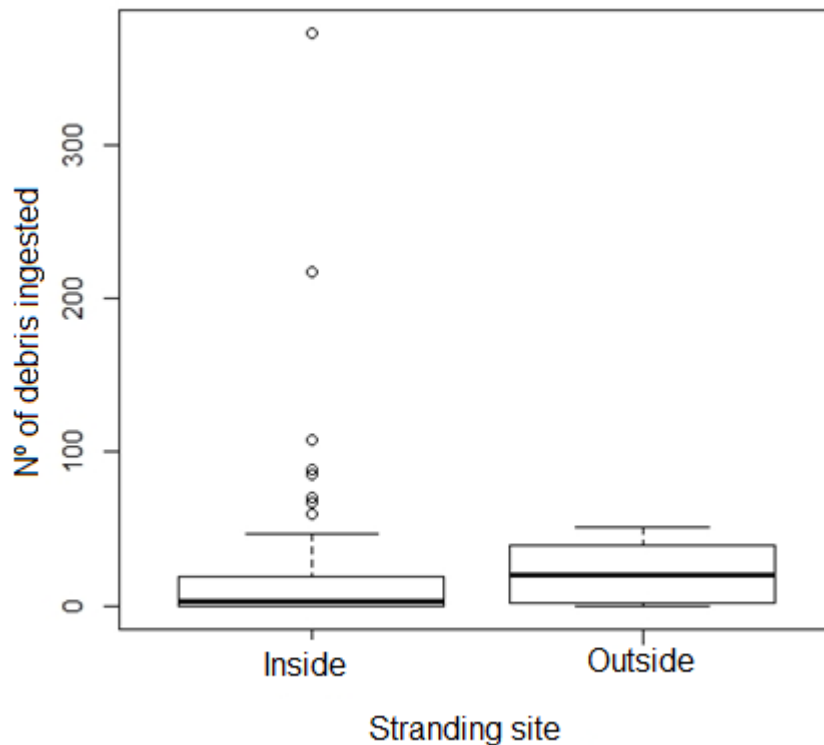


Fig. 4 Mean number, standard deviation and range of residues ingested by green turtles found dead on beaches inside and outside the bays on the south-central coast of Rio de Janeiro state. Symbol o indicates an outlier.

Regarding the quantitative difference in the type, color, and size of debris found in the GIT of turtles found dead inside the bays and outside the bays, it was seen that only the type of debris was different between the study sites. The most common type of debris within the bays was flexible plastic, corresponding to 52% (722 items; $n = 1388$), and that outside the bays was line/rope, 49% (144 items; $n = 295$) (**Table 3**).

It was observed a greater number of residues ingested in turtles found in the central region (912 items; 41.1 items/individual), compared to those found in the south coast (771 items; 32.1 items/individual). However, there was no difference regarding the type, color and size of the debris between regions - the flexible plastic type, the amber color and the size of the meso class were the most ingested in both places at the time of collection and analysis.

The organ in which most anthropogenic debris was found was the large intestine, corresponding to 83% ($n = 1390$ items) of the total items found, followed

by the stomach (8%; n = 139 items), small intestine (6%; n = 108 items) and esophagus (3%; n = 46 items). Of the 46 sea turtles that ingested debris in this study's collection process, anthropogenic debris was found in the the large intestine of 37 individuals (80.4%), followed by esophagus (34.8%; n = 16), stomach and small intestine (each one with 32.6%; n = 15) (**Table 3**).

Table 3 - Percentage of anthropogenic debris ingested by organ, type, color, and size by turtles found inside and outside the bays (n = 1683 items).

		Stranding location	
		Inside the bays (n = 53) (%)	Outside the bays (n = 13) (%)
N° of debris found in each organ	Esophagus	1.5	8.8
	Stomach	7.6	11.2
	Small Int	3.0	22.0
	Large Int	87.8	58.0
N° of items ingested by debris type	Hard Plastic	13.2	10.5
	Soft Plastic	52.0	36.3
	Line/ Rope	24.1	48.8
	Styrofoam	3.3	2.4
	Pellets	4.8	0.0
	Foam	0.9	0.0
	Rubber	1.6	2.0
N° of items ingested by debris color	Blue	12.2	21.0
	Green	4.4	5.8
	Red	1.7	1.4
	Yellow	4.0	6.4
	Orange	1.5	0.3
	Purple	0.3	0.0
	Pink	0.6	0.3
	Grey	1.6	1.4
	Black	5.0	8.1
	White	18.8	14.6
	Translucent	13.8	3.1
	Amber/Brown	36.2	37.6
N° of items ingested by debris size	MICRO < 0.5 mm	5.3	1.7
	MESO 0.5 mm-2.5 cm	41.2	41.0
	2.5-5 cm	26.2	30.2
	5-10 cm	18.0	15.9
	10-15 cm	4.5	7.1
	15-20 cm	2.1	3.4
	20-25 cm	1.1	0.3
	MACRO 25-30 cm	0.4	0.3
	30-35 cm	0.2	0.0
	35-40 cm	0.2	0.0
	40-45 cm	0.1	0.0
	45-50 cm	0.2	0.0
	>50 cm	0.3	0.0

Two models with the variables material type, color, and stranding location (inside and outside the bays) ($AICc \leq 2$) were selected to explain the numbers of anthropogenic debris items ingested by stranded sea turtles (**Table 4**). According to the estimates of the model-averaged parameters, the number of items ingested was mainly affected by the color of debris. The intake of amber, blue and white colors were significantly higher, and the ingestion of gray, orange, pink, purple, and red was significantly smaller. The type of debris, flexible plastic, line/rope, and rigid plastic, was significantly higher, and foam and pellets were significantly lower (**Table 5**).

Table 4 - The best-fit generalized linear negative binomial distribution models ($\Delta AICc \leq 2$) to explain the numbers of anthropogenic debris items ingested by stranded turtles as a function of the explanatory variables. $AICc$ = second-order Akaike Information Criterion; w = Akaike weights.

Response variable	Selected important models	$AICc$	$\Delta AICc$	w
Number of anthropogenic debris items ingested	= Debris color + Debris type + Stranding location	3764.7	0.00	0.56
	= Debris Color + Debris Type	3765.2	0.50	0.44

Table 5 - Estimates of model-averaged parameters to explain the numbers of anthropogenic debris ingested by stranded sea turtles as a function of the explanatory variables. Significant variables ($p < 0.05$) are marked in bold. CI = confidence intervals.

Model-averaged coefficients	Estimate	2.5% CI	97.5% CI	Z value	P-value
Intercept	0	0	0	—	—
Color					
(Amber/Brown)	0.29	0.22	0.36	8.48	<2e-16
(Blue) color	0.10	0.03	0.17	2.72	0.007
Color (white)	0.17	0.10	0.24	4.91	0.000001
(Gray) color	-0.14	-0.22	-0.05	3.12	0.002
(Orange) color	-0.12	-0.21	-0.04	2.86	0.004
(Black) color	0.0004	-0.07	0.08	0.01	0.99
(Pink) color	-0.21	-0.31	-0.12	4.28	0.00002
(Purple) color	-0.33	-0.46	-0.20	4.95	0.000001
Color (Translucent)	0.06	-0.01	0.13	1.68	0.09
(Green) color	-0.01	-0.08	0.07	0.24	0.81
Color (Red)	-0.11	-0.19	-0.02	2.51	0.01
Location (Outside Bays)	-0.05	-0.11	0.01	1.61	0.11
Type (Foam)	-0.18	-0.31	-0.06	2.83	0.005
Type (Styrofoam)	0.09	-0.004	0.18	1.87	0.06
Type (Line/Rope)	0.42	0.34	0.50	10.19	<2e-16
Type (Pellets)	-0.43	-0.66	-0.20	3.69	0.0002
Type (Flexible Plastic)	0.48	0.40	0.56	11.67	<2e-16
Type (Rigid Plastic)	0.30	0.21	0.38	7.04	<2e-16

The most commonly found size of debris items was the meso class, corresponding to the range of 0.5 mm to 2.5 cm, totaling 41.2% (693 items) of the items found ($n = 1683$), followed by the macro class range of 2, 5 cm to 5.0 cm (27.0%; 455 items), macro class from 5 cm to 10 cm (17.4 %; $n=293$), macro class from 10 cm to 15 cm (5%; $n=84$), micro class (4.8%; $n=81$), macro class from 15 cm to 20 cm (2.3%; $n=39$), macro class from 20 cm to 25 cm (1.0%; $n=16$), macro class 25 cm to 30 cm (0.4%; $n=7$), macro class in the intervals of 30 to 35 cm, 35 to 40 cm, 45 to 50 cm with 0. 2% ($n = 3$) each interval, greater than 50 cm (0.2 %; $n = 4$), and macro class from 40 to 45 cm (0.1 %. $n= 2$).

It was seen that 82.6% (38 individuals; n=46) of the sea turtles in this study ingested anthropogenic debris categorized in the meso class. From the macro class, 73.9% (34 individuals; n=46) of the individuals ingested from the interval of 2.5 cm to 5.0 cm, 67.4% (31 individuals; n=46) ingested from the interval of 5.0 cm to 10.0 cm, 63% (29 individuals, n=46) of the 10 to 15 cm range, 50% (23 individuals, n=46) of the 15 to 20 cm range, 17.4% (8 individuals, n=46) from the 20 to 25 cm range, 13% (6 individuals, n=46) from the 25 to 30 cm range, 6.5% (3 individuals, n=46) from the intervals of 30 to 35 cm, 35 to 40 cm, 45 to 50 and greater than 50 cm and 4.3% (2 individuals, n=46) from the range of 40 to 45 cm and 41.3% (19 individuals, n=46) of the micro class.

Two models with the variables material type, debris size (Micro, Meso, and Macro), and stranding location (inside and outside the bays) ($\Delta AICc \leq 2$) were selected to explain the numbers of anthropogenic debris items ingested by stranded sea turtles (**Table 6**). According to the estimates of the model-averaged parameters, the number of items ingested was mainly affected by the size of the debris, being significantly smaller than Micro residues; and by the type of debris, being significantly higher for Styrofoam, flexible plastic, line/rope and rigid plastic and significantly lower for pellets (**Table 7**).

Table 6 - The best-fit generalized linear negative binomial distribution models ($\Delta AICc \leq 2$) to explain the numbers of anthropogenic debris items ingested by stranded sea turtles as a function of the explanatory variables. AICc = second-order Akaike Information Criterion; w = Akaike weights.

Response variable	Selected important models	AICc	$\Delta AICc$	w
Number of ingested debris items	= Stranding location + Debris size + Debris type	2158.8	0.00	0.61
	= Debris Size + Debris Type	2159.7	0.93	0.39

Table 7 - Estimates of model-averaged parameters to explain the numbers of anthropogenic debris items ingested by stranded sea turtles as a function of explanatory variables. Significant variables ($p < 0.05$) are marked in bold. CI = confidence intervals.

Model-averaged coefficients	Estimate	2.5% CI	97.5% CI	Z value	P value
Intercept	0	0	0	—	—
Location (Outside Bays)	-0.03	-0.06	0.003	1.77	0.08
Size (Meso)	0.02	-0.02	0.05	0.97	0.33
Size (Micro)	-0.12	-0.16	-0.08	6.23	<2e-16
Type (Foam)	-0.04	-0.09	0.009	1.61	0.11
Type (Styrofoam)	0.11	0.07	0.15	5.06	0.0000004
Type (Line/Rope)	0.15	0.11	0.19	7.20	<2e-16
Type (Pellets)	-0.13	-0.22	-0.05	3.15	0,002
Type (Flexible Plastic)	0.18	0.14	0.22	8.50	<2e-16
Type (Rigid Plastic)	0.12	0.07	0.16	5.45	0.0000001

4. Discussion

From the results obtained in this work, 69.7% of the analyzed green turtles were identified with ingestion of at least one solid debris item. Similar numbers have been obtained by other recent studies (69.7% by Guebert-Bartholo et al., (2011); 70.6% by Santos (2015a) and 70% by Velez-Rubio et al. (2018)). The high frequency of ingestion (> 50%) of anthropogenic debris by green turtles is reported in several other areas of the world as well, such as the United States, Brazil, Australia, and Uruguay (e.g. Bjorndal et al., 1994; Bugoni et al., 2001; Boyle et al., 2008; Tourinho et al., 2010; Guebert-Bartholo et al., 2011; Macedo, 2011; Velez-Rubio et al., 2018).

Seventy percent of individuals (14) who did not have residues in their gastrointestinal tract (GIT) were found in the southern region of this study's site area. Debris quantification studies carried out on beaches in this region (Póvoa et al., 2021 on press; Macedo et al., 2019), where there are conservation units

and environmental protection areas (INEA, 2015), show a smaller amount of debris per area (2.78 itens/m² by Póvoa et al. (2021) on press) when compared to the results of works carried out on beaches in the central region, especially inside and around Guanabara Bay. One possible explanation of this trend is that the the lesser presence of debris in the water minimizes the chances of encounter and possible ingestion of these by the turtles (Santos et al., 2021).

The south-central coast of the state of Rio de Janeiro is a foraging area for green turtles, where they develop, grow and feed (Guimarães et al., 2009; Nunes, 2016; Guimarães et al., 2017; Reis et al., 2017; Gomes et al., 2021). The presence of debris in foraging areas can increase the probability of accidental ingestion of anthropogenic debris (Sigler, 2014). Gonzalez-Carman et al. (2014) reported a high frequency of anthropogenic debris ingested by turtles with feeding areas with high permanence of juvenile green turtles superimposed on sites with a high concentration of marine plastic debris. The high concentration of debris in the marine environment favors the distribution of these residues to the foraging areas of marine organisms. The increase in ingestion records follows the increase in the concentration of debris in the sea, wich has been occurring over the years (Williams et al., 2011). These residues can be found both suspended in the water column and at the bottom, and both places are used by green turtles (Schuyler et al., 2014a).

The curvilinear carapace length of the individuals analyzed with a range from 30 cm to 76.3 cm (mean±SD: 76.8 ± 8.5 cm), corresponds to juvenile individuals (Bjørndal, 1997; Colman et al., 2014). When green turtle juveniles start using more coastal regions, they change their eating habits from omnivores to herbivores. However, depending on the availability of these foods in the environment, they can feed on other available resources, being considered opportunistic (Mortimer, 1982; Bjørndal, 1997; Hirth, 1997). This opportunistic foraging behavior can influence the ingestion of anthropogenic debris (Santos et al., 2015; Andrades et al., 2019; Santos et al., 2020).

Considering that sea turtles forage using sight and smell, the high frequency of ingestion of anthropogenic debris, such as flexible plastic, has been associated with the similarity with the natural food of these animals, such as algae, seagrass, and gelatinous organisms (jellyfish, salt, and ctenophores)

(Schuyler et al., 2014b; Pfaller et al., 2020). Another explanation can be due these residues are attached to their foods resulting in accidental ingestion (Tourinho et al., 2010; Schuyler et al., 2012; Camedda et al., 2014; Di Benedetto et al., 2014; Hoarau et al., 2014; Rizzi et al., 2019). Santos et al. (2021), address debris ingestion as one of the examples of an evolutionary trap, defined as a sub-optimal choice made by organisms that were following a decision rule shaped by natural selection. Another factor that can favor the ingestion of these materials is the presence of microbial biofilm in plastic debris, which can act as an attraction for sea turtles (Reisser et al., 2014; Pfaller et al., 2020). The permanence of debris in the marine environment, meaning debris's ability to not decompose and instead remain intact while floating through water bodies, favors the formation of these biofilms (De-la-Torre et al., 2021).

Although some studies demonstrate a greater amount of waste in areas within bays compared to areas of open sea (Macedo et al. 2019; Silva et al. 2020), this study did not find significant difference between the average number of debris items ingested by green turtles found inside or outside the bays. Additionally, the stranding site does not always reflect the animal's foraging site since the turtle may have fed outside the bay and entered it already dead or dying. Residence verification would be necessary for better inferences (Tagliolatto et al., 2019). It was found that the type of debris in the GIT of turtles collected inside and outside the bays differs, with more flexible plastics being found in animals stranded inside the bay. This result may be a reflection of the type of garbage found in the bay regions, such as plastic bags, improperly discarded by the population living in its surroundings (Neto et al., 2011). Outside the bays, the most commonly found debris type was lines/ropes, which can be explained by the presence of fishing vessels in the offshore region (Macedo et al., 2019).

The residues found in the GIT of the turtles analyzed in this work support the work carried out on residues on the studied coast, (Bernardino et al., 2016; Ferreira et al., 2011; Macedo et al., 2017; Macedo et al., 2019), with plastics (soft and hard) being the most commonly found, followed by styrofoam, nylon and rope. A survey carried out in southern Brazil (Bugoni et al., 2001) showed that 23 of the 38 sea turtles examined (60.5%) had anthropogenic residues in their

stomachs and that these would come from fishing and tourist activities on the beaches in the region.

The fact that the largest number of individuals have been found in areas within bays where debris items, such as flexible plastics prevail, may explain the higher values of this type of debris, such as plastic bags, in the individuals analyzed, corresponding to 50.5% of the total items found. Among the anthropogenic debris affecting marine animals, plastic is the material most frequently reported for sea turtles (Balazs, 1985; Plotkin et al., 1990; Sadove et al., 1990; Shaver, 1991; Bjorndal et al., 1994; Bugoni et al., 2001; Mascarenhas et al., 2004; Campani et al., 2013; Camedda et al., 2014; Poli et al., 2015; Santos et al., 2015a; Abreo, 2016), as reported in this study.

In this work, amber and white debris were the most ingested (36.5% and 18.1%, respectively). The high frequency of amber color found in debris within the GIT of sampled organisms could be explained by the fact that this color is more similar to that of natural foods. The amber color is also a result of the aging of plastics in the marine environment, showing that ingested waste may have been available for a long time in this environment, allowing them to be ingested by marine organisms. Swimmer (2005) showed through an experiment with dyed squid, that sea turtles are able to distinguish colors from, and this ability affects their food selection behavior. Santos et al. (2016) found that the color of plastic debris influences its detection by the animal. It was found that white or transparente are in fact the most consumed (Tourinho et al., 2010; Schuyler et al., 2012; Camedda et al., 2014; Hoarau et al., 2014; Rizzi et al., 2019). For residues of other less influential colors like gray, orange, pink, purple, and red, it is possible that ingestion occurred accidentally, being consumed with their natural food (Tomas et al., 2002; Mendes et al., 2015). Also, red and orange colored items are in the longer visible light spectrum (560-700 nm) of the visible spectrum for turtles, which ranges from 450 nm to 620 nm (Bartol el al., 2003).

In this study, the debris size class with the highest frequency of collection was the range from 0.5 mm to 2.5 cm (41.2%). Similar results were observed by Gonzalez-Carman et al. (2014), where the ingested waste had sizes ranging from 0.5 to 3.0 cm and by Mendes et al. (2015) who showed that 76% of the residues found were in the range of 0 and 5 cm. The high consumption of these residues

can be explained by the predominance of fragmented items in the marine environment, a result of mechanical abrasion by waves and photochemical breakage, caused by the long residence time of this material in the ocean (Corcoran et al., 2009; Wabnitz et al., 2010; Possatto et al., 2011; Andrady, 2015). Microdebris were the items less found in the GIT of the analyzed turtles. Because they belong to a relatively small size range, these items may not be the result of active selection, having been ingested passively, as they are associated with natural foods (Tomas et al., 2002; Di Benedetto et al., 2014; Mendes et al., 2015).

Bjorndal et al. (1994) showed that debris ingestion was recorded in 56% of surveyed sea turtles with their entire digestive tract analyzed and only 14% when it was restricted to the esophagus and stomach. This study analyzed all the gastrointestinal tract organs. In this study, the large intestine was the organ in which more debris was found, corresponding to 83% of the total items found. Our result reinforces the importance of analyzing all the gastrointestinal tract organs in such a manner that there is no underestimation of the number of debris ingested. Studies that examined only the stomach had a lower debris intake percentage, such as 25% and 45% (Mendes et al., 2015; Ng et al., 2016). The studies that analyzed all organs of the digestive tract were able to verify a higher percentage of ingestion, such as 85.7% and 70% (Velez-Rubio et al., 2018; Yaghmour et al., 2018), and when specified, the higher concentration of debris was found in the intestine. One explanation for the high occurrence of debris in the large intestine may be due to its curvature, which makes debris stay longer in the animal's digestive tract (Schulman et al., 1992).

In 43% of the analyzed turtles were found amounts of residues weighing less than 1 g. Santos et al. (2015), in a study carried out on the Brazilian coast, showed that only 0.5 g of waste was enough to block the digestive tract and cause the death of a turtle. Despite the small volume needed to block the digestive tract causing the death of an individual, we found an individual with 313 items ingested, corresponding to 203 g (wet weight).

The ingestion of debris poses several risks to sea turtles, which can lead to intoxication and death due to obstruction of the gastrointestinal tract (Lutz, 1990; Bjorndal et al., 1994; Bjorndal, 1997; Derraik, 2002; Koch et al., 2009;

Oehlmann et al., 2009; Teuten et al., 2009; Santos et al., 2015a). The consequences generated depend on the type, size, and amount of debris ingested. Plastic debris can cause constipation if ingested in large quantities. A small hook ingested, despite its size and weight, can cause perforations and subsequently lead to death. Nylon threads can interfere with the function of the digestive tract and can cause intussusception, which is when there is obstruction caused by a linear foreign body (Bjorndal et al., 1994; Orós, 2004). The ingestion of debris can generate several consequences for animals, such as inducing the formation of fecalomas, which are masses of hardened fecal material that obstruct the intestine of these animals, and cause the false sense of satiety, reducing food frequency and leading to a condition of malnutrition and cachexia (Lutz, 1990; Bjorndal et al., 1994; Bjorndal, 1997; Santos et al., 2015a). In addition, the buoyancy of turtles can also be affected, as gases are formed due to ingestion and accumulation of debris in the gastrointestinal tract, and ingested plastic fragments can transfer chemicals, which can be associated with possible carcinogenic effects and endocrine disruption (Laist, 1987; Koch et al., 2009; Oehlmann et al., 2009; Teuten et al., 2009).

Some studies have already been carried out in southeastern Brazil to identify the contents consumed by sea turtles. Most of these studies are with green turtles, and in all, there is a record of ingestion of anthropogenic debris ranging from flexible and rigid plastics, rubber, foam, styrofoam, hook, among others and vary by color, from transparent to colorful and by size, from the micro to the macro classification (Reis et al., 2010; Awabdi et al., 2013; Bezerra, 2014; Di Benedetto et al., 2014; Ferreira, 2015; Mendes et al., 2015; Santos et al., 2015a; Nunes, 2016).

5. Conclusions

The results of our work support the previously published studies with green turtles in Brazil and bring as a novelty the comparison analysis of more polluted areas (inside the bays; central region) and less polluted (outside the bays, southern region), evaluating the type, color, and size of the residues found in the gastrointestinal tract of the animals, in order to understand how different

classifications of debris are affecting animals in each region. In addition, this study is the first work that analyzes the contents arising from strandings collected by the BMP, thus bringing the first data referring to the first three years of activity on the central-south coast.

Our results reinforce the importance of more quantitative studies on the ingestion of marine litter by sea turtles to assess the impact on these animals and, consequently, on the marine environment. Also, the large amount of debris found in the GIT of surveyed specimen suggests that debris plays an important role in the death of sea turtles in the studied region; irregardless of the area's concentration of waste. We suggest that future works on this topic have a methodological standardization of each category for better comparative analysis over time. In this work, there was difficulty standardizing the collections due to the methodology used by the BMP. Furthermore, future investigations must aim to collect information at smaller geographic scales, in places where pollution by anthropogenic debris, mainly plastic, has affected sea turtles in feeding areas. Likewise, it is also important to identify the main sources of marine debris at regional scales to develop better solutions for the proper disposal of this debris in specific geographic areas.

CONCLUSÃO GERAL

Foi observada a presença de resíduos sólidos em 69,7% dos indivíduos analisados, com maior concentração no intestino grosso, sendo os resíduos do tipo plástico flexível, da cor âmbar/marrom e do tamanho entre 0,5 mm e 2,5 cm os mais frequentemente encontrados. Não foi encontrada diferença significativa da ingestão de resíduos entre tartarugas coletadas dentro e fora de baías, mas o tipo de resíduo mais encontrado diferiu pelos locais, sendo o plástico flexível o tipo mais encontrado dentro de baías e o tipo linha/ corda o mais encontrado fora de baías.

Os nossos resultados mostram que os resíduos antropogênicos vêm impactando bastante as tartarugas marinhas, independentemente do tamanho, local, tipo e cor. Também foi possível observar que há necessidade de aumentar esforços e quantificar as ameaças potenciais que os resíduos antropogênicos possam representar, não só às tartarugas marinhas, mas também à biota marinha, uma vez que o aumento da preocupação leva ao aumento do esforço amostral do tema. Além disso, a falta de padronização dos estudos e reporte inadequado da descrição dos resíduos comprometem a identificação de padrões, portanto é necessária a padronização metodológica de cada categoria para melhor análise comparativa ao longo do tempo. Também a falta de dados aumenta a necessidade de propor a ciência cidadã como uma forma de troca de informações e coletas de dados. Essas medidas contribuiriam para a conservação não só dessa espécie, mas também das outras espécies marinhas e da saúde dos ecossistemas marinhos costeiros.

REFERÊNCIAS BIBLIOGRÁFICAS

- Abreo N, Macusi ED, Blatchley DD, Cuenca GC (2016) Ingestion of Marine Plastic Debris by Green Turtle (*Chelonia mydas*) in Davao Gulf, Mindanao, Philippines. *Philippine Journal of Science*, 145(1):17-23.
- Amador ES (1980) Assoreamento da Baía de Guanabara – taxas de sedimentação. *Anais da Academia Brasileira de Ciências*, 52(4):723-742.
- Amador ES (1997) Baía de Guanabara e ecossistemas periféricos – Homem e Natureza. *Retroarte Gráfica e Editora*, p.539.
- Amador ES (2012) Bacia da Baía de Guanabara: características geoambientais e ecossistemas. Rio de Janeiro: Interciência.
- Andrades R, dos Santos RA, Martins AS, Teles D, Santos RG (2019) Scavenging as a pathway for plastic ingestion by marine animals. *Environmental Pollution*. 248:159–165.
- Andrady AL (2015) Persistence of plastic litter in the oceans. In: Bergmann, M., Gutow L, Klages M (Eds.), *Marine Anthropogenic Litter*. Springer, p.57–72.
- Awabdi DR, Siciliano S, Di Benedetto APM (2013) Ingestão de resíduos sólidos por tartarugas-verdes juvenis, *Chelonia mydas* (L. 1758), na costa leste do estado do Rio de Janeiro, Brasil. *Biotemas*, 26(1):197-200.
- Balazs GH (1985) Status and ecology of marine turtles at Johnston Atoll. *Atoll Research Bulletin*, 285:1–46.
- Barnes DK, Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526):1985-1998.
- Bastos MP, Callado CH (2009) (Org.). *O ambiente da Ilha Grande*. Universidade do Estado do Rio de Janeiro. Centro de Estudos Ambientais e Desenvolvimento Sustentavel. Rio de Janeiro: UERJ-CEAD: Editora Imprinta Express, p. 562.
- Barnes DK, Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526):1985-1998.

- Bartol SM, Musick JA (2003) Sensory biology of sea turtles. In: P. L. Lutz, J. A. Musick, & J. Wyneken (Eds.), The biology of sea turtles. Boca Raton: CRC Press, Boca Raton, Fla. Volume II, p. 79– 102.
- Bernardino D, Franz B (2016) Lixo flutuante na Baía de Guanabara: passado, presente e perspectivas para o futuro. *Desenvolvimento e Meio Ambiente*, 38:231-252.
- Bezerra DP (2014) Ingestão de resíduos sólidos por tartarugas-verdes (*Chelonia mydas*) em área de alimentação dentro de um mosaico de unidades de conservação no sul do estado de São Paulo, Brasil Dissertação de Mestrado no Programa de pós graduação da Universidade Federal do Paraná, Brasil.
- Bjorndal KA, Bolten AB, Lagueux CJ (1994) Ingestion of Marine Debris by Juvenile Sea Turtles in Coastal Florida Habitats. *Marine Pollution Bulletin*, 28(3):154-158.
- Bjorndal KA (1997) Foraging Ecology and Nutrition of Sea Turtles. In: Lutz PL and Musick JA Eds., The Biology of Sea Turtles, CRC Press, Boca Raton, FL, p. 199-231.
- Bjorndal KA (2000) Prioridad em la pesquisa em áreas de alimentación. In: Eckert KL et al. Técnicas de investigación y manejo para la conservación de las tortugas marinas. Pennsylvania: IUCN/CSE. p.13-15.
- Boyle MC, Limpus CJ (2008) The stomach contents of post-hatchling green and loggerhead sea turtles in the southwest Pacific: an insight into habitat association. *Marine Biology*, 155(2):233-241.
- Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Galloway T, Thompson R., (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks. *Environmental Science&Technology*, 45:9175– 9179.
- Bucci K, Tulio M, Rochman CM (2019) What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. *Ecological Applications* 30(2).
- Bugoni L, Krause, L, Petry MV (2001) Marine debris and human impacts on sea turtles in southern Brazil. *Marine Pollution Bulletin*, 42(12):1330-1334.
- Burnham, KP, Anderson, DR (2002) Model selection and multimodel inference. NY: Springer.

- Camedda A, Marra S, Matiddi M, Massaro G, Coppa S, Perilli A, Ruiu A, Briguglio P, Lucia GA, (2014) Interaction between loggerhead sea turtles (*Caretta caretta*) and marine litter in Sardinia (Western Mediterranean Sea). *Marine Environmental Research*, 100: 25-32.
- Campani T, Bains M, Giannetti M, Cancelli F, Mancusi C, Serena F, Marsili L, Casini S, Fossi MC (2013) Presence of plastic debris in loggerhead turtle stranded along the Tuscany coasts of the Pelagos Sanctuary for Mediterranean Marine Mammals (Italy). *Marine Pollution Bulletin*. 74:1330–1334.
- Carvalho, RH, Lacerda, PD, da Silva Mendes, S, Barbosa, BC, Paschoalini, M, Prezoto, F, de Sousa, BM, (2015) Marine debris ingestion by sea turtles (Testudines) on the Brazilian coast: an underestimated threat?. *Marine Pollution Bulletin* 101(2):746–749.
- Cole M, Lindeque P, Halsband C, Galloway TS (2011) Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin*, 62(12):2588-2597.
- Colman LP, Patrício ARC, McGowan A, Santos AJB, Marcovaldi MA, Bellini C & Godley BJ (2014) Long-term growth and survival dynamics of green turtles (*Chelonia mydas*) at an isolated tropical archipelago in Brazil. *Marine Biology*, 162(1):111-122.
- Corcoran PL, Biesinger MC, Grifi, M (2009) Plastics and beaches: a degrading relationship. *Marine Pollution Bulletin*, 58(1):80-84.
- Derraik JGB (2002) The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, 44(9):842–852.
- De-la-Torre G, Dioses-Salinas DC, Pérez-Baca BL, Cumpa LAM, Pizarro-Ortega CVI, Torres FG, Gonzalez KN, Santillán L (2021) Marine macroinvertebrates inhabiting plastic litter in Peru *Marine Pollution Bulletin* 167:1–10.
- Di Benedetto AP, Awabdi DR (2014) How marine debris ingestion differs among megafauna species in a tropical coastal area. *Marine Pollution Bulletin*, 88 (1-2):86-90.
- Domingo A, Bugoni L, Prosdocimi L, Miller P, Laporta M, Monteiro DS, Estrades A, Albareda D (2006) The impact generated by fisheries on Sea Turtles in

the Southwestern Atlantic. WWF Progama Marino para Latinoamérica y el Caribe, San José, Costa Rica, p.70.

Duncan EM, Broderick AC, Critchell K, Galloway TS, Hamann M, Limpus CJ, Lindeque PK, Santillo D, Tucker AD, Whiting S, Young EJ, Godley BJ (2021) Plastic Pollution and Small Juvenile Marine Turtles: A Potential Evolutionary Trap. *Frontiers in Marine Science*. 8:699521.

Epperly SP, Braun J, Chester AJ, Cross FA, Merriner JV, Tester PA, Churchill JH, (1996) Beach strandings as an indicator of at-sea mortality of sea turtles. *Bulletin of Marine Science*, 59(2):289-297.

Esteban N, Mortimer JÁ, Stokes HJ, Laloe JO, Unsworth RKF, Hays GC (2020) A global review of green turtle diet: sea surface temperature as a potential driver of omnivory levels. *Marine Biology* 167:183.

Ferreira JA, Silva CA, Resende AT (2011) Projeto Baía Limpa: Monitoração de Ambientes Marinhos Degredados por Resíduos Sólidos na Baía de Guanabara, Rio de Janeiro, Brasil. *Revista da Gestão Costeira Integrada* 11(1):103-113.

Ferreira JS (2015) Impacto ambiental e ingestão de lixo pelas tartarugas verdes (*Chelonia mydas*) na praia de Regência, norte do Espírito Santo. Monografia em Ciências Biológicas, Universidade Federal do Espírito Santo, Espírito Santo, Brasil.

Fragoso MR (1999) Estudo Numérico da Circulação Marinha da Região das Baías de Sepetiba e Ilha Grande. Dissertação de Mestrado. Universidade de São Paulo, p.115.

Gall SC, Thompson RC (2015) The impact of debris on marine life. *Marine Pollution Bulletin*, 92(1-2):170-179.

Geraci JR, Lounsbury VJ (2005) *Marine Mammals Ashore: A Field Guide for strandings*. 2ed. National Aquarium in Baltimore.

Gesamp (2019) Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). 99:130.

Godoi VA, Calado L, Watanabe WB, Yaguna LE, Bastos M (2011) Evento extremo de ondas na Baía da Ilha Grande: um estudo de caso *Boletim do Observatório Ambiental Alberto Ribeiro Lamego* 5(2):2744.

- Gregory MR (2009) Environmental implications of plastic debris in marine settings--entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 364(1526):2013–2025.
- Gomes BG, Tagliolatto AB, Guimarães SM (2021) Occurrence of Sea Turtles on Niterói City Beaches, Rio de Janeiro, Brazil. *Marine Turtle Newsletter* 163:10-14.
- Gonzalez-Carman V, Acha EM, Maxwell SM, Albareda D, Campagna C, Mianzan H (2014) Young green turtles, *Chelonia mydas*, exposed to plastic in a frontal area of the SW Atlantic. *Marine Pollution Bulletin*, 78(1-2),56-62.
- Guebert-Bartholo FM, Barletta M, Costa MF, Monteiro-Filho ELA (2011) Using gut contents to assess foraging patterns of juvenile green turtles *Chelonia mydas* in the Paranaguá Estuary, Brazil. *Endangered Species Research*, 13(2):131-143.
- Guimarães SM, Gitirana HM, Vidal AW (2009) Região costeira de Itaipu, Niterói: uma estação de alimentação e desenvolvimento de tartarugas marinhas da espécie *Chelonia mydas* (tartaruga-verde) no litoral Estado do Rio de Janeiro. ANAIS DO 2º CONGRESSO BRASILEIRO DE BIOLOGIA MARINHA, Búzios, Rio de Janeiro.
- Guimarães SM, Tavares DC, Monteiro-Neto C (2017) Incidental capture of sea turtles by industrial bottom trawl fishery in the Tropical South-western Atlantic. *Journal of the Marine Biological Association of the United Kingdom*, 98(6):1525-1531.
- Guimarães SM (2017) Ecologia Populacional de Juvenis de Tartaruga-Verde (*Chelonia mydas*, Linnaeus 1758) da área de alimentação da região costeira de Itaipu, Niterói – RJ. Tese de Doutorado apresentada ao Programa de Pós-Graduação em Biologia Marinha do Departamento de Biologia Marinha, Instituto de Biologia, Universidade Federal Fluminense, como requisito parcial para a obtenção do Grau de Doutor em Biologia Marinha.
- Hamann M, Godfrey MH, Seminoff JÁ, et al. (2010) Global research priorities for sea turtles: informing management and conservation in the 21st century. *Endangered Species Research*, 11:245-269.

- Hirth HF (1997) Synopsis of the biological data on the green turtle *Chelonia mydas* (Linnaeus 1758). US Fish and Wildlife Service. Biological Report. Washington, DC, 97(1).
- Hoarau L, Ainley L, Jean C, Ciccione S (2014) Ingestion and defecation of marine debris by loggerhead sea turtles, *Caretta caretta*, from by-catches in the South-West Indian Ocean. *Marine Pollution Bulletin*, 84(1-2):90-96.
- Inea (2015) Diagnóstico Do Setor Costeiro Da Baía Da Ilha Grande Subsídios À Elaboração Do Zoneamento Ecológico-Econômico Costeiro. Vol 1.
- Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Narayan R, Law KL (2015) Plastic waste inputs from land into the ocean. *Marine Pollution Bulletin*. 347:768–771.
- Koch HM, Calafat AM (2009) Human body burdens of chemicals used in plastic manufacture. *Philosophical Transactions of the Royal Society B Biological Sciences*, 364(1526): 2063-2078.
- Kühn S, Bravo Rebolledo EL, Van Franeker JA (2015) Deleterious Effects of Litter on Marine Life. In: In: Bergmann M., Gutow L., Klages M. (eds). *Marine Anthropogenic Litter*. Chapter 4, p.75-116.
- Lacerda ALF, Rodrigues LS, Seville EV, Rodrigues FL, Ribeiro L, Secchi ER, Kessler F, Proietti MC (2019) Plastics in sea surface waters around the Antarctic Peninsula. *Scientific Reports* 9:3977.
- Laist DW (1987) Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin*, 18(68)319–326.
- Laist DW (1997) Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion Records. In: J. Coe & D. Rogers (Eds.), *Marine Debris SE – 10:99–139*. Springer New York.
- Lazar B, Gračan R (2011) Ingestion of marine debris by loggerhead sea turtles, *Caretta caretta*, in the Adriatic Sea. *Marine Pollution Bulletin* 62:43–47.
- Lebreton L, Slat B, Ferrari F, Sainte-Rose B, Aitken J, Marthouse R, Hajbane S, Cunsolo S, Schwartz A, Levivier A, Noble K, Debeljak P, Maral H, Schoeneich-Argent R, Brambini R, Reisser J (2018) Evidence that the great Pacific garbage patch is rapidly accumulating plastic. *Sci. Rep.* 8:4666.

- Lutcavage ME; Plotkin P; Witherington B; Lutz PL (1997) Human impacts on sea turtle survival. In: Lutz PL, Musick, J.A., editors. *The Biology of Sea Turtles*. CRC Press, Boca Raton, FL. 1:387–409.
- Lutz P (1990) Studies on the ingestion of plastic and latex by sea turtles. In *Proceedings of the Second International Conference on Marine Debris*, pp. 2–7, Ed. by R. S. Shomura, and M. L. Godfrey. US Department of Commerce NOM Tech Memo, NMFS. NOMTM-NMFS-SUFSC-15, Honolulu, Hawaii.
- Macedo GRF, CR Garcez Neto AF, Goldberg DW, Leal DC, Pires, TT, Rostán G (2011) Ingestão de resíduos antropogênicos por tartarugas marinhas no litoral norte do estado da Bahia, Brasil. *Ciência Rural*, Santa Maria, 41(11): 1938-1941.
- Macedo A, Silva ALC, Madureira EAL, Silvestre CP (2017) Poluição por lixo nas praias de Abraão e Preta na borda setentrional-oriental da Ilha Grande (Angra dos Reis, RJ) e o impacto socio-ambiental. In book: *Os Desafios da Geografia Física na Fronteira do Conhecimento* p.3009-3014.
- Macedo A, Silva ALC, Madureira E, Diniz L & Pinheiro AB (2019) Poluição por resíduos sólidos em praias da Baía da Ilha Grande: Angra dos Reis e Paraty (RJ). *Mares – Revista de Geografia e Etnociências*. 1 (2).
- McCauley SJ, Bjorndal KA (1999) Conservation implications of dietary dilution from debris ingestion: sublethal effects in post-hatchling loggerhead sea turtles. *Conservation Biology*, 13(4):925–929.
- Marcovaldi MA; Marcovaldi G (1999) Marine turtles of Brazil: the history and structure of Projeto TAMAR-IBAMA. *Biological Conservation*, 91:35-41.
- Marn N, Jusup M, Sebastiann ALM, Kooijman, Tin Klanjscek (2020) Quantifying impacts of plastic debris on marine wildlife identifies ecological breakpoints. *Ecology Letters* 23(10).
- Mascarenhas R; Santos R; Zeppelini D (2004) Plastic debris ingestion by sea turtle in Paraiba, Brazil. *Marine Pollution Bulletin*, 49(4):354-355.
- Mendes SS; De Carvalho RH; De Faria AF; De Sousa BM (2015) Marine debris ingestion by *Chelonia mydas* (Testudines: Cheloniidae) on the Brazilian coast. *Marine Pollution Bulletin*, 92(1-2):8-10.

- Morales-Caselles C, Viejo J, Cózar A (2021) An inshore–offshore sorting system revealed from global classification of ocean litter. *Nature Sustainability* 4:484–493.
- Mortimer J (1982) Feeding ecology of sea turtles. Pp.103-109 *In*: Bjorndal, K. (ed.) *Biology and Conservation of Sea Turtles: Proceedings of the World Conference on Sea Turtle Conservation*: Smithsonian Institution Press, p. 583.
- Moura, MS & Vianna, M (2020) A new threat: assessing the main interactions between marine fish and plastic debris from a scientometric perspective. *Reviews in Fish Biology and Fisheries*, 30(4):623-636.
- Mrosofsky N, Ryan GD, James MC (2009) Leatherback turtles: the menace of plastic. *Marine Pollution Bulletin*, 58(2):287-289.
- Nações Unidas Brasil (2021) Os Objetivos de Desenvolvimento Sustentável no Brasil [Acesso em: 23 de agosto de 2021] <https://brasil.un.org/pt-br>.
- Nelms SE, Duncan EM, Broderick AC, Galloway TS, Godfrey MH, Hamann M, Lindeque PK, Godley BJ (2016) Plastic and marine turtles: a review and call for research. *ICES Journal of Marine Science: Journal du Conseil*, 73(2): 165-181.
- Neto JAB, Fonseca EM (2011) Variação sazonal, espacial e composicional de lixo ao longo das praias da margem oriental da Baía de Guanabara (Rio de Janeiro) no período de 1999-2008. *Revista da Gestão Costeira Integrada* 11(1):31-39.
- Ng CKY, Ang PO, Russell DJ, Balazs GH, Murphy MB (2016) Marine Macrophytes and Plastics Consumed by Green Turtles (*Chelonia mydas*) in Hong Kong, South China Sea Region. *Chelonian Conservation and Biology*, 15(2):289-292.
- Nunes LA (2016) Ecologia alimentar de juvenis de tartaruga-verde (*Chelonia mydas*, Linnaeus, 1758) da Baía de Guanabara e adjacências. Dissertação de Mestrado apresentada no Programa de Pós-Graduação em Biologia Marinha e Ecossistemas Costeiros do Departamento de Biologia Marinha, do Instituto de Biologia Marinhas da Universidade Federal Fluminense, Niterói – RJ, p.51.
- Oehlmann J, Schulte-Oehlmann U, Kloas W, Jagnytsch O, Lutz I, Kusk KO, Wollenberger L, Santos EM, Paull GC, Van Loo KJW, Tyler, CR (2009) A

- critical analysis of the biological impacts of plasticizers on wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526):2047-2062.
- Orós JCP, Déniz S (2004) Digestive pathology of sea turtles stranded in the Canary Islands between 1993 and 2001. *Veterinary Record*, 155:169-174.
- Pfaller JB., Goforth KM, Gil MA, Savoca MS, & Lohmann KJ (2020) Odors from marine plastic debris elicit foraging behavior in sea turtles. *Current Biology*, 30(5):R213-R214.
- Plastic Europe (2019) *Plastics – the facts*, Brussels, Belgium. [Acesso em 25 de julho de 2020]. https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf
- Plotkin P, Amos A (1990) Effects of antropogenic debris on sea turtles in the northwestern gulf of mexico. *Proceedings of the Second International Conference on Marine Debris*, p.736–743.
- Poli C, Mesquita DO, Saska C, Mascarenhas R (2015) Plastic ingestion by sea turtles in Paraíba State, Northeast Brazil. *Iheringia. Série Zoologia*, 105(3):265-270.
- Possato FE, Barletta M, Costa MF, Ivar-do-Sul JA, Dantas DV (2011) Plastic debris ingestion by marine catfish: an unexpected fisheries impact. *Marine Pollution Bulletin*, 62(5):1098-1102.
- Póvoa AA, Skinner LF, Araújo FV (2021) Fouling organisms in marine litter (rafting on abiogenic substrates): A global review of literature. *Marine Pollution Bulletin* 166(2021):112189.
- Póvoa AA, Araújo FV, Skinner LF (2021) Rafting: Fouling organisms in anthropogenic litter around a tropical bay in the Southwest Atlantic, Ilha Grande Bay, Brazil. *Marine Pollution Bulletin*. On press.
- R Development Core Team, (2021) *A language and environment for statistical computing*. version 3.1.1. Vienna, Austria. R Foundation for Statistical Computing.
- Reis, EC, Pereira CS, Rodrigues DP, Secco HKC, Siciliano S (2010) *Condição De Saúde Das Tartarugas Marinhas Do Litoral Centro-Norte Do Estado Do Rio De Janeiro, Brasil: Avaliação Sobre a Presença de Agentes*

- Bacterianos, Fibropapilomatose E Interação Com Resíduos Antropogênicos. *Oecologia Australis*, 14(3):756-765.
- Reis EC, Goldberg DW, Lopez GG (2017) Diversidade e distribuição de tartarugas marinhas na área de influência das atividades de E&P na Bacia de Campos. In: *Mamíferos, Quelônios e Aves*, 7:121-159.
- Reisser J, Slat B, Noble K, Plessis K, Epp M, Proietti M (2014) The vertical distribution of buoyant plastics at sea. *Biogeosciences Discuss*, 11:16207–16226.
- Rizzi M, Rodrigues FL, Medeiros L, Ortega I, Rodrigues L, Monteiro DS, Kessler F & Proietti M (2019) Ingestion of plastic marine litter by sea turtles in southern Brazil: abundance, characteristics and potential selectivity. *Marine Pollution Bulletin*, 140:536-548.
- Rochman CM, Browne MA, Halpern BS, Hentschel BT, Hoh E, Karapanagioti HK, Rios-Mendoza L, Takada H, The S, Thompson RC (2013) Policy: Classify plastic waste as hazardous. *Nature*, 494(7436):169-171.
- Ryan PG (1987) The incidence and characteristics of plastic particles ingested by seabirds. *Marine Environmental Research*, 23(3):175–206.
- Sadove S, Morreale S (1990) Marine mammal and sea turtle encounters with marine debris in the New York Bight and the northeast Atlantic. *Proceedings of the 2nd International Conference on Marine Debris*, National Oceanic and Atmospheric Administration, Honolulu., p.2-7.
- Santos AS, Almeida AP, Santos AJB, Gallo B, Giffoni B, Baptistotte C et al., (2011) Plano de Ação Nacional para Conservação das Tartarugas Marinhas. *Série Espécies Ameaçadas* nº25.
- Santos, R (2014) Variação na dieta da tartaruga verde, *Chelonia mydas*, e o impacto da ingestão de lixo ao longo da costa brasileira. Tese de Doutorado apresentada ao Programa de Pós-Graduação em Ciências Biológicas (Biologia Animal) da Universidade Federal do Espírito Santo como requisito parcial para a obtenção do Grau de Doutor em Biologia Animal.
- Santos RG, Andrade R, Boldrini, MA, Martins AS (2015a) Debris ingestion by juvenile marine turtles: an underestimated problem. *Marine Pollution Bulletin*, 93(1-2):37-43.

- Santos RG, Martins AS, Batista MB, Horta PA (2015b) Regional and local factors determining green turtle *Chelonia mydas* foraging relationships with the environment. *Marine Ecology Progress Series* 529:265-277.
- Santos RG, Andrades, R, Fardim, LM, Martins, AS (2016) Marine debris ingestion and Thayer's law - The importance of plastic color. *Environmental Pollution*, 214:585-588.
- Santos RG, Andrades R, Demetrio GR, Kuwai GM, Sobral MF, Vieira JS, Machovsky-Capuska GE (2020) Exploring plastic-induced satiety in foraging green turtles. *Environmental Pollution*. 265:114918.
- Santos RG, Machovsky-Capuska GE, Andrades R (2021) Plastic ingestion as an evolutionary trap: Toward a holistic understanding. *Science*, 373(6550):56-60.
- Sazima I, Gadig OB, Namora RC, Motta FS (2002) Plastic debris collars on juvenile carcharhinid sharks (*Rhizoprionodon lalandii*) in southwest Atlantic. *Marine Pollution Bulletin* 44(10):1149–1151.
- Schulman AA, Lutz P (1992) The effect of plastic ingestion on lipid metabolism in the green sea turtle (*Chelonia mydas*). In: ANNUAL WORKSHOP ON SEA TURTLE BIOLOGY AND CONSERVATION, 12. Georgia. Proceedings Flórida: NOAA, 1995. p.122-124.
- Schuyler Q, Hardesty BD, Wilcox C, Townsend K (2012) To eat or not to eat? Debris selectivity by marine turtles. *PLoS One*, 7(7):e40884.
- Schuyler Q, Hardesty BD, Wilcox C, Townsend K (2014a) Global analysis of anthropogenic debris ingestion by sea turtles. *Conservation Biology*, 28(1):129-139.
- Schuyler Q, Wilcox C, Townsend K, Hardesty BD, Marshall NJ (2014b) Mistaken identity? Visual similarities of marine debris to natural prey items of sea turtles. *BMC Ecology* 14(1):12.
- Shaver DJ (1991) Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters. *Journal of Herpetology*, 25:327–334.
- Sigler M (2014) The Effects of Plastic Pollution on Aquatic Wildlife: Current Situations and Future Solutions. *Water Air Soil Pollution* 225(11):1-9.
- Signorini SR (1980) A study of circulation in Bay of Ilha Grande and Bay of Sepetiba. *Bolm Instituto Oceanográfico, São Paulo*, 29(1):41-55.

- Silva LCF, Albuquerque CAM, Cavalheiro WW, Hansen CMP (1984) Gabarito Tentativo para as Massas de Água da Costa Sudeste Brasileira. Anais Hidrográficos, Tomo XLI, DHN.
- Silva ML, Castro RO, Sales AS, de Araujo FV (2018) Marine debris on beaches of Arraial do Cabo, RJ, Brazil: an important coastal tourist destination. *Marine Pollution Bulletin* 130:153–158.
- Simon N, Raubenheimer K, Weiland L (2021) A binding global agreement to address the life cycle of plastics. *Science* 373(6550):43-47.
- Swimmer Y, Arauz R, Higgins B, McNaughton L, McCracken M, Ballestero J, Brill R (2005) Food color and marine turtle feeding behavior: can blue bait reduce turtle bycatch in commercial fisheries? *Marine Ecology Progress Series*, 295:273-278.
- Tagliolatto AB, Goldberg DW, Godfrey MH, Monteiro-Neto C (2019) Spatio-temporal distribution of sea turtle strandings and factors contributing to their mortality in south-eastern Brazil. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 30(2):331-350.
- Teuten EL, Saquing JM, Knappe DRU, Barlaz MA et al. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364 (1526):2027–2045.
- Thompson RC, Swan SH, Moore CJ, Vom Saal FS (2009) Our plastic age. *Philos Trans R Soc Lond B Biol Sci*, 364(1526):1973-1976.
- Tomas J, Guitart R, Mateo R, Raga, JA (2002) Marine debris ingestion in loggerhead sea turtles, *Caretta caretta* from the Western Mediterranean. *Marine Pollution Bulletin*, 44:211–216.
- Torres JAR (1995) Resposta da Ressurgência Costeira de Cabo Frio a Forçantes Locais. Dissertação de Mestrado. COPPE/UFRJ.
- Tourinho PS, Ivar Do Sul JÁ, Fillmann G (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? *Marine Pollution Bulletin*, 60(3):396-401.
- Valentin J, Tenenbaum D, Bonecker A, Bonecker S, Nogueira CE, Villac M (1999) O Sistema Plânctônico da Baía de Guanabara: Síntese do Conhecimento. *Ecologia dos Ambientes Costeiros do Estado do Rio de Janeiro. Série Oecologia Brasiliensis*, VII p.35-39.

- Vegter AC, Barletta M, Beck C, Borrero J et al. (2014) Global research priorities to mitigate plastic pollution impacts on marine wildlife. *Endangered Species Research*. 25:225-247.
- Vélez-Rubio GM, Teryda N, Asaroff PE, Estrades A, Rodriguez D, Tomás J (2018) Differential impact of marine debris ingestion during ontogenetic dietary shift of green turtles in Uruguayan Waters. *Marine Pollution Bulletin*. 127:603-611.
- Wabnitz C, Nichols WJ (2010) Editorial: Plastic pollution: An ocean emergency. *Marine Turtle Newsletter* 129:1.
- Werneck MR, Almeida, LG, Baldassin P, Guimarães S, Nunes LA, Lacerda PD, Oliveira ALM (2018) Sea Turtle Beach Monitoring Program in Brazil. In: *Reptiles and Amphibians*, Chapter 3.
- Williams R, Ashe E, O'hara, PD (2011) Marine mammals and debris in coastal waters of British Columbia, Canada. *Marine Pollution Bulletin*. 62(6):1303–1316.
- Yagmour F, Al Bousi M, Whittington-Jones B, Pereira J, Garcia-Nunes S, Budd J (2018) Marine debris ingestion of green sea turtles, *Chelonia mydas*, (Linnaeus, 1758) from the eastern coast of the United Arab Emirates. *Marine Pollution Bulletin*, 135:55-61.

APÊNDICES

Marine Pollution Bulletin

ASSESSMENT OF ANTHROPOGENIC DEBRIS INGESTION BY GREEN TURTLES
IN THE SOUTH-CENTRAL COAST OF THE STATE OF RIO DE JANEIRO, BRAZIL
--Manuscript Draft--

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Abstract:	The south-central coast of Rio de Janeiro is characterized by a large human population density. This coastal region contains three bays, one of which is Guanabara Bay, one of the most polluted in the country. To assess the impact of sea based anthropogenic debris on sea turtles, this work analyzed 66 green turtles found stranded along the south-central coast of RJ by the Santos Basin Beach Monitoring Project. Debris was detected in 69.7% of the individuals analyzed, with a higher concentration in the large intestine. A total of 1,683 items ingested were found between all surveyed turtles, with 1 and 373 being the minimum and maximum, respectively, of items found in the gastrointestinal tract of a single individual. Flexible plastic type, amber/brown color, fragments with size between 0.5 mm and 2.5 cm were the most frequently found. No significant difference was found between turtles collected inside and outside the bays.
Suggested Reviewers:	Christophe Eizaguirre c.eizaguirre@qmul.ac.uk Because he works with marine turtles conservation. Gabriela Velez-Rubio gabriela.velez@uv.es Because she works with sea turtles.