



SENTINELS OF THE SEAS

GUIDELINE DOCUMENT TO REDUCE PLASTIC
POLLUTION AND ITS EFFECTS ON MARINE BIOTA
IN THE NORTHEAST OF BRAZIL



AQUASIS
ASSOCIAÇÃO DE PESQUISA E PRESERVAÇÃO
DE ECOSISTEMAS AQUÁTICOS



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BACKGROUND

Plastic pollution is a global issue of interrelated causes and effects, i.e., mutual relations between different pollutant sources, absence or inefficiency of management and lack of knowledge of the problem, for example, affect directly and indirectly biota and the human population. Thus, plastic pollution cannot be comprehended or addressed without a general contextualisation that includes various sectors and stakeholders. In terms of the Northeastern regional context, the participation of stakeholders from different areas of activity allowed the sharing and learning of different experiences for the elaboration of solutions and the indication of stakeholders more suitable to the problem at a regional and local level, whenever possible.

Given the urgency of the issue at a global level comparable to the climate emergency, it is necessary to discuss the local and regional levels in addressing the problem. Plastic pollution has been the focus of several programmes and projects worldwide, including as a target in the UN Agenda 2030 in Sustainable Development Goal 14 (SDG 14 - Life Below Water, Target 14.1 - Reduce Marine Pollution), which states: *By 2025, prevent and significantly reduce marine pollution of all*

kinds, in particular from land-based activities, including marine debris and nutrient pollution.

Nevertheless, it is important to highlight that all the other SDGs can be included directly or indirectly in the fight against plastic pollution when interrelating the different stages or stages of the Plastics Cycle. Here we highlight SDG 01 – No poverty, when it ensures that traditional populations have access to fish free from plastic contamination; SDG 11 – Sustainable Cities and Communities, when there is proper management of solid waste, including plastic, and policies to reduce the use of disposables; and lastly, SDG 12 – Responsible Consumption and Production, when taxes and fines can be created for plastic and waste producers, investments in biodegradable plastics or new technologies for plastic substitution. Considering this global agenda, in February 2022, the United Nations Environment Assembly (UNEA) approved an agreement to create the first global treaty to tackle plastic pollution due to come into force by 2024.

Therefore, these agendas, programs and global treaties reinforce the urgency to face plastic pollution in the prevention and mitigation of its harmful effects. Main-

ly on the impacts on coastal and marine ecosystems of environmental, social and cultural relevance, such as the Northeast region of Brazil, and their ecosystem services that include: food provisioning, fauna protection and shoreline protection.

The reporting of the occurrence and effects of plastic pollution is increasing every year in Brazil. However, few studies focus on the Northeastern coastline. The published articles (n = 35) deal mainly with plastic ingestion by fish, turtles, and a limited number of aquatic mammals, and only a few deal with entanglement and ghost fishing. However, fishing is an activity of great economic importance in the region (Viana et al., 2021). In those, it is possible to identify the analysed species, quantities and types of plastics ingested; however, it is virtually impossible to determine the pollutant sources and the effects at the species and/or population level.

The effects of plastic pollution on biota are mostly irreversible, and the most deleterious effects are those related to the ingestion of plastic and microplastic waste or the trapping and entanglement of organisms, causing physical injury and often the death of the animal. The effects of plastic pollution occur at individual and ecosystem levels in different food webs on land and sea, with a potentially more significant impact on endangered species or isolated environments such as oceanic islands.

In this respect, Brazil, with its coastline of more than 8. thousand kilometres of shore, presents relevant marine coastal environments such as the Atol das Rocas and the archipelagos of São Pedro e São Paulo, Fernando de Noronha and Abrolhos, as well as coral reef ecosystems, mangroves and tidelands that shelter several residents and migratory species that use the environment for feeding and reproduction, such as the manatee (*Trichechus manatus manatus* Linnaeus, 1758) in Ceará and humpback whales (*Megap-*

tera novaeangliae Borowski, 1781) in the Abrolhos Archipelago.

Thus, *Aquasis, Associação de Pesquisa e Preservação de Ecossistemas Aquáticos*, an NGO with more than 28 years of work on behalf of biodiversity conservation in the state of Ceará, has been implementing, under its Marine Mammals Programme (PMM), the Sentinels of the Seas Project, an initiative supported by the National Geographic Society.

The project started in 2020 and focused on assessing the contamination by plastic waste in endangered coastal marine mammals. Thus, the I and II Workshop Sentinels of the Seas were held in 2022 to promote discussion and dissemination of the threats of plastic pollution in the environment and marine fauna, as well as the challenges of implementing policies for plastic waste management. In addition, we had the participation of experts on the subject from different governments, third sector and research institutions from the Brazilian Northeast.

This document is the result of the expertise and dedication of each participant, the facilitation team and *Aquasis*, who, through a collaborative process, discussed the causes, effects and solutions to the plastic pollution problem in the Northeastern coastline. We hope this document will guide future actions to reduce plastic waste at its origin and mitigate its effects on marine biota through the creation of new legislation, guidelines and public policy to address the problem, as well as the development of a collaborative network of stakeholders.

From now on, we rely on you to act against plastic pollution and its effects on biota in the Northeast, aiming to conserve and preserve our ecosystems that are vital to the survival of marine species and, consequently, human health.

TABLE OF CONTENTS

1. INTRODUCTION	6
1.1 PLASTICS: A TOXIC RELATIONSHIP	6
1.2 THE NORTHEASTERN COAST	8
1.3 GENERAL OBJECTIVE	9
2. DIAGNOSIS OF PLASTIC POLLUTION IN THE NORTHEAST	9
3. WHAT IS THE “SENTINELS OF THE SEAS” PROJECT?	12
3.1 IDENTIFICATION OF PARTICIPANTS IN THE II WORKSHOP SENTINELS OF THE SEAS	13
3.2 WORKSHOP IMPLEMENTATION PROCESS	14
4. CAUSES, EFFECTS, SOLUTIONS AND STAKEHOLDERS INVOLVED IN TACKLING PLASTIC POLLUTION IN THE NORTHEAST	15
1. FINAL REMARKS	20
REFERENCES	21



Photo: Heideger Nascimento

1. INTRODUCTION

1.1 PLASTICS: A TOXIC RELATIONSHIP

The first commercially viable synthetic polymer was developed at the beginning of the 20th century and was called *Bakelite*. The plastic precursor was created by Leo Baekeland, who soon after opened the General Bakelite Company for the industrial exploitation of this polymer, which was widely used in the production of musical records, pot handles, and telephones, among other objects. Then began the creation and production of plastic polymers by petrochemical industries and companies such as polyester (1932), PVC (1933), nylon (1938), polyurethane (1939), Teflon (1941) and silicone (1943) for various purposes (Freinkel, 2011).

Versatile, durable, and low-cost, plastics are part of everyday life. The annual global production of plastic has increased considerably since the 1950s and is expected to reach the unbelievable mark of 1100 million tons by 2050 (Geyer, 2020). Society's growing dependence on plastics, coupled with low recycling rates and inadequate disposal of solid waste, means that today plastics are a challenging global problem (Geyer, 2020).

The coastal region of Northeastern Brazil is recognised worldwide for its beaches, which receive tourists throughout the year (IBGE, 2011; CEMBRA, 2012). In addition to tourism, the main economic sources are located in or near the coastal region, represented by industries, agriculture and commercial and subsistence fishing (IBGE, 2011; IBAMA, 2007). The increasing anthropic activities have been gradually modifying ecosystems, polluting and contaminating these environments. Once available in the environment, plastics, with time and exposure to physical environmental conditions (e.g., ocean currents and solar radiation), can be transported, deposited and undergo fragmentation of their particles (Browne et al., 2007; Wang et al., 2016). Readily distributed from rivers to distant ocean regions, plastic pollution alters ecosystem functionality and harms water quality and marine organisms (Koelmans et al., 2017; Meijer et al., 2021; Gregory, 2009).

Plastics in the environment can pose significant health risks to ecosystems and wildlife by causing entanglement, accidental

ingestion, and the degradation of important marine habitats (Barnes et al., 2009; Gall and Thompson, 2015). The fragmentation of plastics gives rise to what we call microplastics, which are particles smaller than 5 mm (Arthur et al., 2009). These small particles are also dangerous as they can cause malnutrition in individuals due to blockage of the digestive system (Cole et al., 2013), and even lethal effects as they can adsorb other contaminants such as trace metals, biocides and persistent organic pollutants (POPs) (Moore, 2008; Frias et al., 2010; Turner, 2010).

Worldwide, studies on the causes and consequences of contaminants in fauna have made valuable contributions to the understanding of ecosystem quality and the health of organisms (Kehrig & Moreira 1998; Costa et al., 2009; Talsness et al., 2009; Cole et al., 2013). In Brazil, studies on plastic ingestion by marine organisms are mainly focused on fish groups (Possatto et al., 2011; Ramos et al., 2012; Dantas et al., 2012; Ferreira et al., 2016; Vendel et al., 2017), seabirds (Petry et al., 2009; Colabuono et al., 2010), turtles (Tourinho et al., 2010; Guebert-Bartholo et al.,

2011; da Silva Mendes et al., 2015), invertebrates (Ferreira et al., 2022; Bruzaca et al., 2022) and mammals (Beneditto & Awabdi, 2014). However, when we focus on the northeast region of Brazil, we verify the absence of basic baseline data information on the impacts of plastic pollution on fauna (Figure 1).

Plastic pollution is recognised as a global threat by many governments, as is the climate emergency. Given the issue's urgency, the world is moving towards a global agreement to tackle the problem by 2024. The resolution approved by the United Nations Environment Assembly (UNEA) affirms the commitment to create the first global treaty to fight plastic pollution. In addition, other international initiatives, such as the Ocean Decade established by the United Nations in 2015, SDG 14 – Life Below Water, has as one of the main objectives a Clean Ocean directly related to target 14.1, which states: “By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution”.

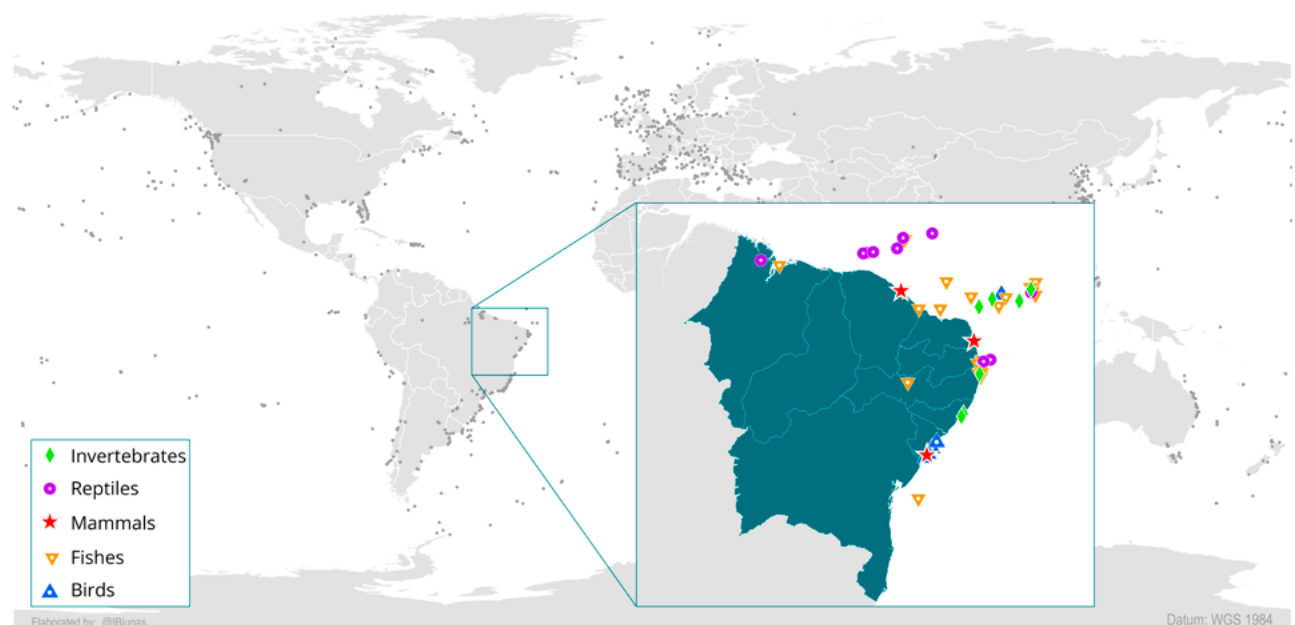


Figure 1: Diagram illustrating the occurrence of biota studies associated with plastic pollution (ingestion or entanglement) in Northeastern Brazil. Grey dots: occurrence of plastic ingestion studies around the world until 2020, Source: Glove Database, available at <https://gloveinitiative.shinyapps.io/Glove/>.

1.2 THE NORTHEASTERN COAST

The Brazilian coast, with its more than 8 thousand kilometres of extension, can be divided into five large coastal regions, these being: the Amazon or Equatorial coast (from the mouth of the Oiapoque to the Eastern Maranhão), the Northeastern coast (from the Parnaíba Delta to the Bahian Recôncavo), the Eastern coast (from the Bay of All Saints to Cabo Frio), the Southeastern or Crystalline Scarps coast (from southern Espírito Santo to Cabo de Santa Marta) and the Southern or Sub-tropical coast (from Laguna to Arroio Chuí). The northeastern coast alone occupies over 3 thousand kilometres of the Brazilian coast, and the region has been the target of various forms of transformations, mainly as a consequence of social, economic, political, cultural and environmental changes resulting from the development agenda. Notably, on the northeastern coast, vaunted to the four corners as the “Brazilian Cancun” (Spinelli, 2007), the strength of environmental activism as an instrument of development becomes even greater, especially of the extraordinary natural potential, geographical location and climatic conditions.

Such characteristics are linked to the growing effort for the recognition of territories through advances related to the development of environmental policies. After several years of intense discussions on the structuring of the marine and terrestrial protected areas, in July 2000, Federal Law No. 9.985 was enacted, establishing the National System of Conservation Units (SNUC), in which 12 categories of ecological and environmental management are in effect, distributed into two large groups, namely: Fully Protected and Sustainable Use, with specific objectives and norms to be followed in the creation and management of the Conservation Units (UCs).

Within the Northeast Brazilian territory, it is located exclusively in areas under the Federal domain and Permanent Preservation Area - APP (Law No. 12.651/2012), represented by the mangrove forest belt, it is part of an Environmental Protection Area - APA and its margins colonised by mangroves (Paiva, 2018).

Since it is a Conservation Unit of sustainable use, where the sustainable exploration of natural resources is allowed, the APAs are marked by intense actions in which they use their resources for subsistence, commercialisation and activities catalogued by institutions and projects, such as artisanal fishing, which extracts fish products from the marine and mangrove ecosystems, and tourist activities widely carried out, especially during the summer, related to the vast area of reef environments found in these UCs of the northeastern coast.

The diversification of activities performed in these territories is followed by the negative impacts caused by human actions and, with them, the improper disposal of waste; however, there is still a low number of studies on the effects of plastic waste on the Brazilian coast, especially in the northeastern region of the country, even though it is a region of great environmental, social and economic relevance surrounded by diverse marine habitats that include, sandy beaches, mangroves, estuaries, rocky coasts, coral reefs, oceanic islands and atolls, and several traditional and fishing people who live directly from the sea (Viana et al., 2021).

1.3 GENERAL OBJECTIVE

Therefore, this guideline document acts directly following international demands, contributing to the public knowledge of plastic pollution in the Brazilian Northeast, seeking the engagement of various stakeholders, i.e., representatives of pub-

lic and private sectors, academia and the third sector, in the theme to implement actions and public policy appropriate to the reality and problems at local and regional level on the Northeastern coast.

2. DIAGNOSIS OF PLASTIC POLLUTION IN THE NORTHEAST

The review of studies, in English and Portuguese, was carried out through a systematic search on the Google Scholar platform using the following keywords: "Plastic Pollution" and "Northeast" and "Brazil" and "Biota", "Plastic Pollution" and "Northeast" and "Brazilian coast", "Plastic Pollution" and "Northeast", and "Ingestion" and "Plastic" and "Northeast". Several documents such as articles, abstracts, dissertations, and thesis were retrieved and totalled 133

bibliographic references in different areas of knowledge. In this diagnosis, only peer-reviewed scientific articles in English or Portuguese focusing on the marine biota of the Northeast coast will be presented.

From 2004 to 2022, 35 papers were published reporting the ingestion or entanglement of plastics in wild animals inhabiting the Northeastern region of Brazil (Figure 2).

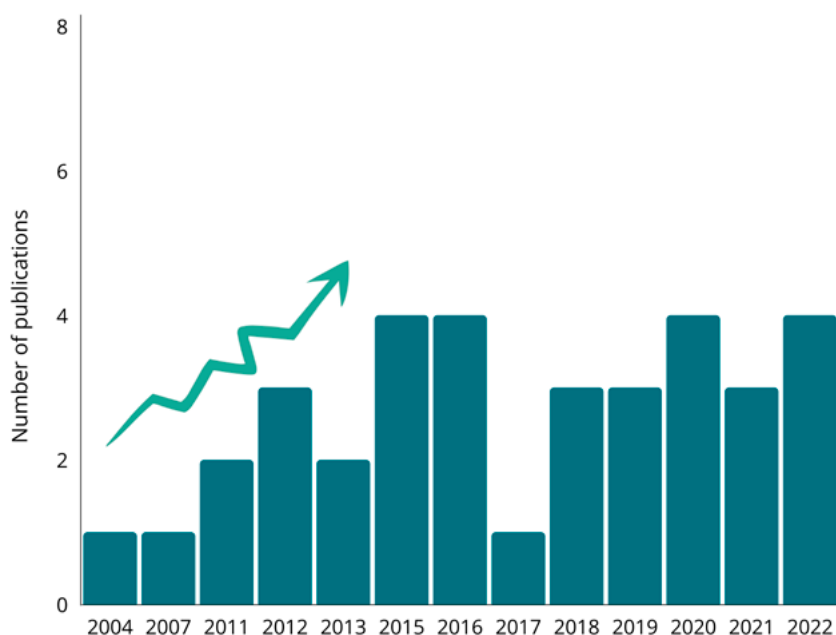


Figure 2 Number of publications reviewed about the interaction of plastics with free-living animals in the northeast region of Brazil during the years 2004 to 2022. N=35.

The distribution of the studies was basically between estuarine and coastal areas, with some studies, mainly with reptiles and seabirds data, that were collected in oceanic island areas, and only one study was done in a continental area, with freshwater fishes (Figure 3). In the majority of the studies, the identification of the plastic particles was performed by visual analysis or was not detailed, and in only 11 studies were established quality assurance and quality control measures (QA/QC) in sample extraction. These security procedures are essential for validating the information and the reliability of the data

obtained, avoiding the risks of cross-contamination or errors in the identification of the samples, and so that the methods used can be replicated in other research. Of these studies, only four determined the particles' polymeric characterisation using spectroscopy methodologies such as FTIR (Fourier-transform infrared spectroscopy), micro-Raman, and LDIR (Laser Direct Infrared). Polymeric identification is important because it allows a better understanding of the origin of plastics and their possible sources in the environment, besides indicating the most abundant polymers that may threaten organisms.

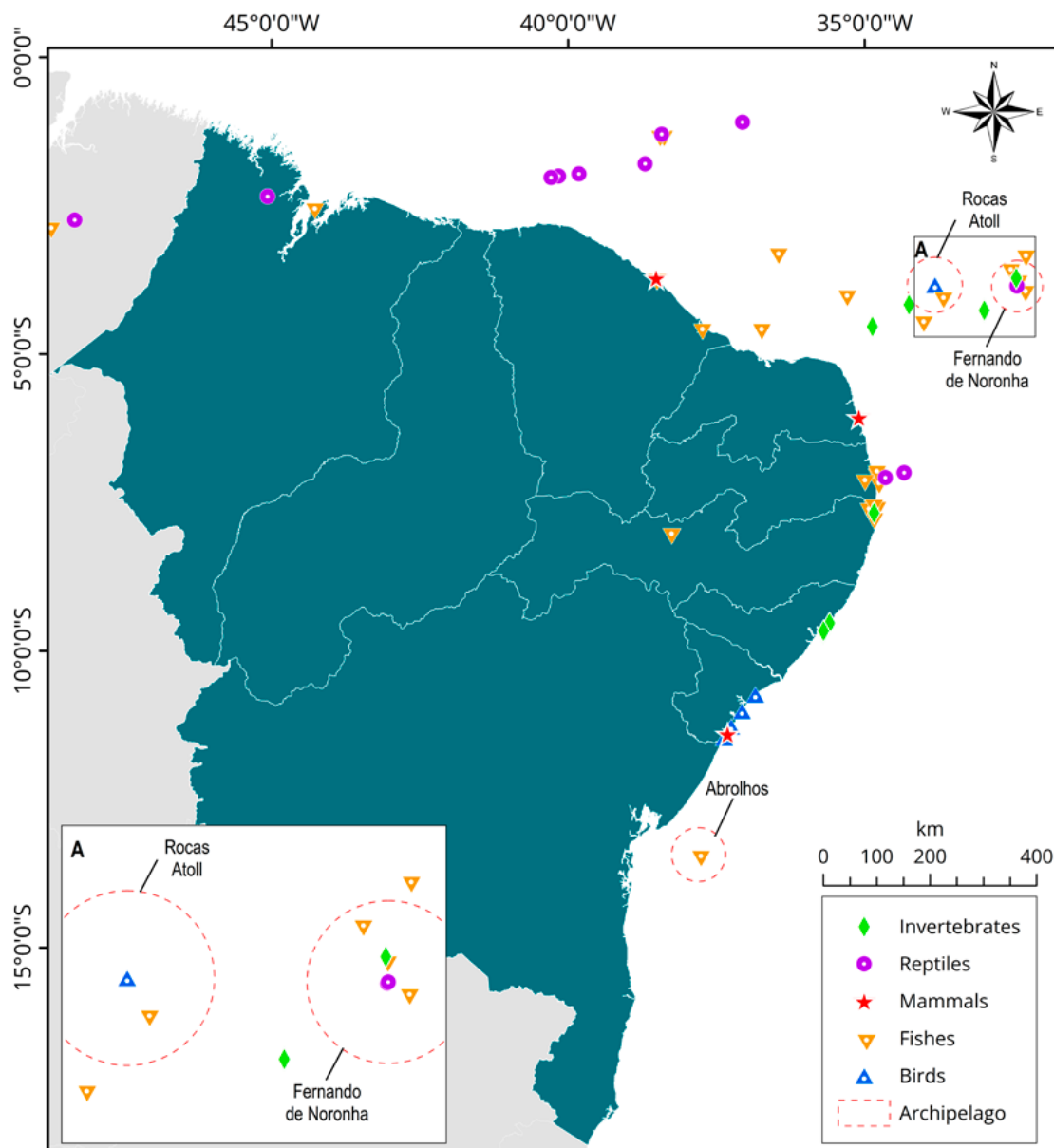


Figure 3: Map of occurrence of biota studies associated with plastic pollution (ingestion or entanglement) in Northeast Brazil.

Of the published and analysed studies for the northeastern region of Brazil, only two reported impacts on the group of seabirds, but only one study detailed information on the species examined and reported plastic ingestion by the masked booby (*Sula dactylatra* Lesson, 1831) (Figure 4). Three studies reported plastic interaction in three mammal species (3.9%), the manatee (*T. manatus manatus*), the Guiana dolphin (*Sotalia guianensis* Van Bénédén, 1864) and the rough-toothed dolphin (*Steno bredanensis* G. Cuvier in Lesson, 1878). All studies with marine mammals made visual analyses from the necropsy of the animals, and in total, only six individuals were analysed. The low number of studies on the interaction of plastic pollution with marine mammals is due to the difficulty in working with this group because they are large animals, and the samples are obtained through the collection of stranded

material on beaches where the animal is found already dead and decomposing.

Six studies reported the interaction of plastic with reptiles, where three species were analysed (3.9%), the green turtle (*Chelonia mydas* Linnaeus, 1758), the hawksbill turtle (*Eretmochelys imbricata* Linnaeus, 1766) and the olive ridley turtle (*Lepidochelys olivacea* Eschschscholtz, 1829). The biological group of invertebrates was represented by four studies, where five species (6.5%) were analysed; among these, the crabs *Eriphia gonagra* Fabricius, 1781 and *Pachygrapsus transversus* Gibbes, 1850, the oceanic cephalopods, mid-water squid (*Abralia veranyi* Rüppell, 1844) and the vampire squid (*Vampyroteuthis infernalis* Chun, 1903) and a bivalve, popularly known as shellfish (*Anomalocardia flexuosa* Linnaeus, 1767).

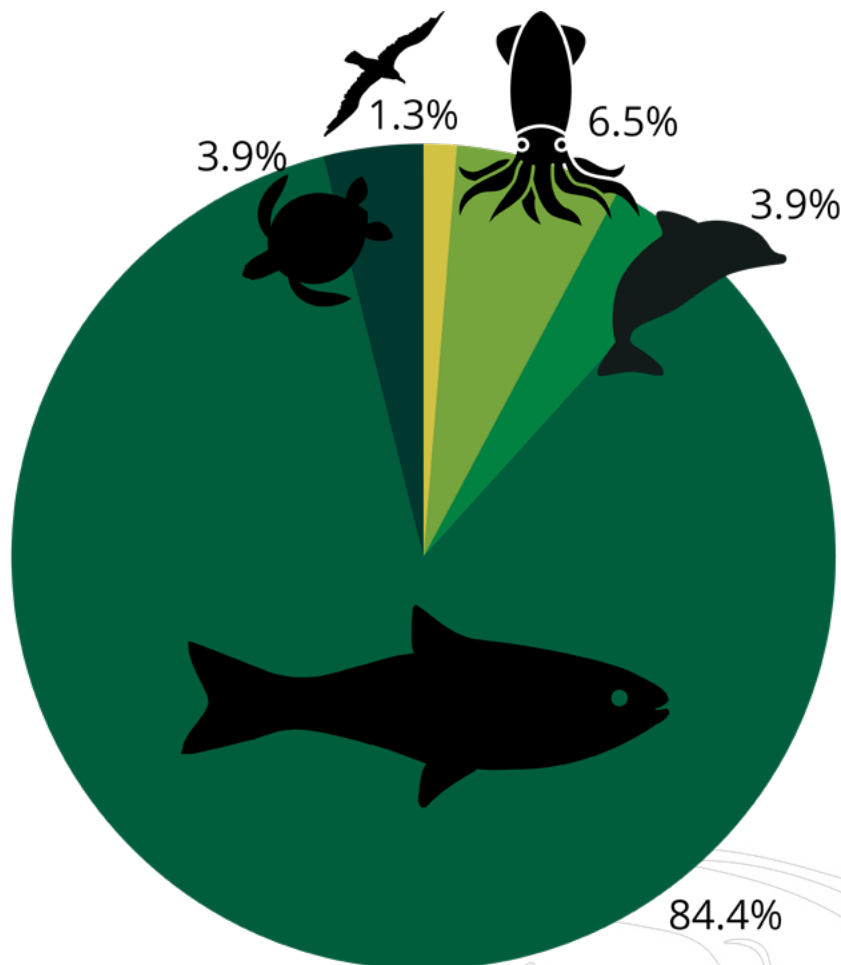


Figure 4: Percentage of biological groups reported in studies on plastic pollution in northeastern Brazil.

The fish group was the most studied for the region, where around 65 species of estuarine, coastal and oceanic fishes (84.4%), with a sample number of more than 6 thousand individuals, were analysed. The large number of data obtained for this group is due to the facility in sampling, compared to other groups like mammals, for example, since they can be obtained from artisanal fisheries or through field collection, usually near the cities in rivers and estuaries. Despite this, the lack of standardisation of information (concerning the unit of measurement, for example, the number of particles per individual) and detailing of the procedures used to extract particles is a severe shortcoming observed in this group for the Northeastern region of Brazil. Where only two studies used digestion protocols for microplastic extraction, and only ten studies detailed the use of QA/QC procedures. Furthermore, confirmation (polymer analysis) and categorisation of the types of plastics (microplastics and/or macroplastics, shapes and colour)

found are necessary for robust analysis and global data comparison.

From the analysed species with reports of ingestion and interaction with plastic in northeastern Brazil, 63 were evaluated by the International Union for Conservation of Nature and Natural Resources (IUCN) as to their risk of extinction and are on the Red List of Threatened Species. One species is classified as "Critically Endangered", the hawksbill turtle (*E. imbricata*), and three species are classified as "Endangered", namely: the whale shark (*Rhincodon typus* Smith, 1828), the green turtle (*C. mydas*) and the manatee (*T. manatus manatus*). Besides these, four species are classified as "Vulnerable", four as "Near Threatened", two as "Data Deficient", and 49 are listed as "Least Concern". This information is essential for better monitoring of the fauna and enabling mitigation measures for anthropic impacts, such as an action plan, and thus contribute to species conservation.

3. WHAT IS THE "SENTINELS OF THE SEAS" PROJECT?

Marine animals have been used as sentinels for several years, as they provide data and warnings about the health of the coastal and marine ecosystem, enabling better assessment and management of the sources and effects of plastic waste. So, the Sentinels of the Seas project, funded by the National Geographic Society, was born. The initiative's main objective was to assess plastic waste in endangered coastal marine mammals. In the first stage, the stomachs of Guiana dolphins (*S. guianensis*) from the coast of Ceará state were analysed to verify the presence of plastic items. Therefore, 325 plastic particles were identified in 95% of the individuals (n = 40 individuals), main-

ly microplastics (319 particles <5 mm). The fragment was the main type of plastic particle identified with 56.1% of the total, while other types identified represented less than 20% per category (Filaments = 15.7%; Foam = 10%; and Film = 9.4%). Regarding colour, white was the most commonly identified in stomach contents (41.1%), followed by black (38.5%), blue (12.8%), green (4.1%), and red (3.4%). Therefore, these data emphasise the importance of marine mammals as sentinels of the sea and coastal environment health and warn about the significance of plastic pollution in the environment affecting at individual and ecosystem levels.

In this regard, encouraging discussion and cooperation between different stakeholders is essential to understand the problem's causes and effects and corroborate the stakeholders' network to mitigate, control and monitor plastic pollution. Thus, this project promoted the 1st and 2nd Sentinels of the Seas Workshop. The first workshop was held in May 2022 to encourage the discussion and dissemination of the impacts of plastic pollution on the environment and marine fauna, as well as the challenges of implementing plastic waste management policies. The event involved the participation of Brazilian researchers specialising in the subject and an audience of approximately 200 people. The second workshop aimed to identify the causes, effects, and solutions at a regional level of the problem of plastic waste on the Northeastern Brazilian coast. In total, 16 people working in state environmental secretariats, universities and non-governmental organisations in Northeast Brazil came together in the second phase.

From the results obtained at the 2nd Sentinels of the Seas Workshop, it is expected that:

- This document will guide future actions, such as an action plan and monitoring,

to reduce plastic waste at its origin, and mitigate the effects on the marine biota of the Northeast;

- Provide relevant data and results to different stakeholders, especially government authorities, for the creation of laws, guidelines and public policy to tackle plastic pollution in the Northeastern states;
- Encourage the construction of a collaborative space and benefit the formation of a network between various stakeholders in fauna conservation, environmental management and/or plastic pollution on the impacts resulting from plastic waste in the marine biota of the northeastern coast;
- To strengthen and develop at local and regional levels actions for preventing and reducing plastic pollution aligned with target 14.1 of the Ocean Decade.
- Therefore, with the commitment of representatives of the State, researchers and NGOs, we hope that the objectives listed above are achieved through this document, which is of strategic importance due to its collaborative construction in the fight against plastic pollution in the Northeast.

3.1 IDENTIFICATION OF PARTICIPANTS IN THE II WORKSHOP SENTINELS OF THE SEAS

The 2nd Workshop Sentinels of the Seas took place remotely through the Zoom platform on the 7th and 17th of November 2022. Based on the main objective of the workshop to identify the causes, effects, and solutions to the plastic problem in the Northeast, the main prerequisite

for participation in the workshop was to work in the environmental area in the public sector, private sector or third sector, focusing on solid waste and/or plastic pollution. The survey of participants was done through a previous list provided by Aquasis and research in institutional web-

sites (e.g., Lattes platform and environment secretariats of state governments) that resulted in a list of approximately 60 people.

Thus, invitation letters were sent out by e-mail presenting the Sentinels of the Seas initiative and asking those interested in completing a form of intent to participate. In total, 40 people representing 21 different institutions filled in the form. Then, a preliminary analysis of the stakeholders was carried out through qualitative data on professional training and area of activity to modulate the intervention and preparation of the workshop

support materials, aiming to contribute to a more efficient approach and provide a mutual dialogue between the participants. After analysis, the dates for holding the workshops of the 2nd Workshop Sentinels of the Seas were indicated according to the preference of the most participants for better adhesion to the event. The introduction of the participants was done by e-mail or message application to share information, guides for the use of the platforms used (e.g., Zoom and Mural) and a participant's guide with the objective of the workshop, proposed activity and a brief contextualisation with data and news about plastic pollution.

3.2 WORKSHOP IMPLEMENTATION PROCESS

Qualified specialists from different sectors attended the workshops of the 2nd Sentinels of the Seas Workshop (e.g., government, third sector and university) with a background in plastic waste concerning waste management, social engagement, marine fauna rescue and plastic pollution research.

The first workshop was referenced in the "Problem Tree" methodology, which is used in various methodological approaches to planning based on the collective construction through a cause-and-effect diagram referring to a macro problem (Coral et al., 2009). The macro problem was discussed, among a group of 13 people, through the following guiding question: "What impacts of plastic waste have you observed in the marine biota of the northeast coast? In the second workshop, "Solution Seas", the debate held by a group of 9 people discussed the construction of solutions and the indication of other stakeholders with an active role in the causes and effects presented and argued in workshop 01 (Figure 5).

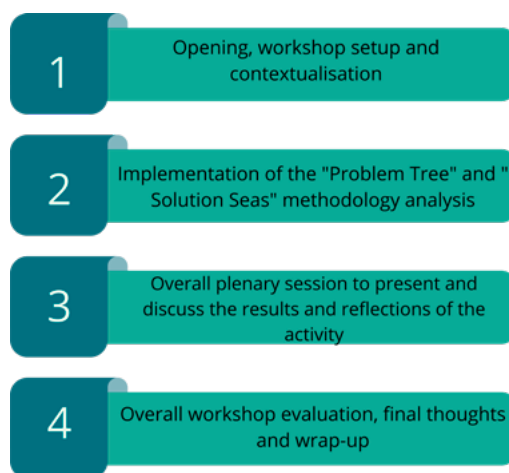


Figure 5: Stages of development of the II Workshop Sentinels of the Seas in workshops 01 and 02 held on 07 and 17 November 2022.

In general, the debates took place within smaller groups of 3 to 4 people to promote a better exchange of experiences and knowledge among the participants. Then, each group's discussion was presented in a general plenary session, where each group and participant expressed and argued their opinions about the problem, improving the collaborative process and the knowledge of different contexts in the Northeastern states among the group.

4. CAUSES, EFFECTS, SOLUTIONS AND STAKEHOLDERS INVOLVED IN TACKLING PLASTIC POLLUTION IN THE NORTHEAST

Thus, the need to face the problem at a regional level and the lack of knowledge and scientific studies in the Northeast region highlights the importance of integrating different stakeholders that are involved in management, awareness, and the effects of solid waste, including plastics, to create a basis for future actions on the Northeastern coast. Therefore, the II Workshop Sentinels of the Seas was constituted as a participative and collaborative space where it was possible to know, through the expertise of each participant, what are the causes and effects of plastic waste in marine biota and reflect on solutions and stakeholders that already act and that can aggregate in more effective actions to combat plastic pollution (Figure 6).

Therefore, the results of the 2nd Sentinels of the Seas Workshop are presented here and categorised into a) causes and effects, b) solutions and c) stakeholders.

The participants of workshop 01 argued about different causes of plastic pollution in the Northeast; some reasons were considered to be direct since the consequences are immediate or short-term action; for example, one can mention that the lack of solid waste collection points, including plastics, implies the irregular disposal of plastics on the beach, seashore and others. In contrast, the indirect causes arise from the lack or absence of measures and actions of the causer, usually at higher organisational levels, such as the absence of Zero Plastics programs and the lack of adequate communication to different sectors of society about plastic pollution.

The causes cited by the participants were grouped into six main categories: Public Policy, Infrastructure, Management, Science, Education and Natural Causes (Figure 7).

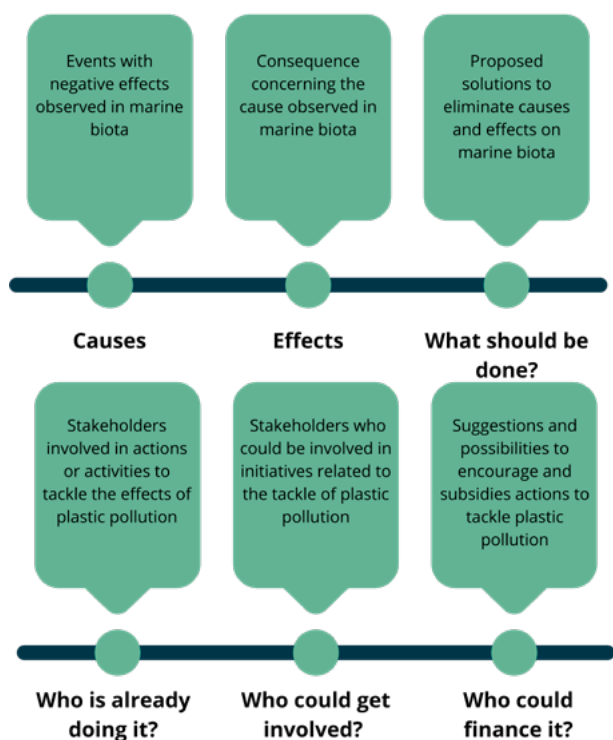


Figure 6: Overview of the results obtained in the 2nd Sentinels of the Seas Workshop.



Category	Causes	Effects	What should be done?	Who is already doing it?	Who could get involved?	Who could finance it?
PUBLIC POLICY	<ul style="list-style-type: none"> Absence of Zero Plastic programs; Lack of regulation in shops, resorts and other polluting sources in the coastal zone. 	<ul style="list-style-type: none"> Amputation of limbs and entanglement (animals get trapped in nets); Ingestion of fishing gear; Ingestion of plastic litter; Death; Ghost fishing. Facilitates the introduction of invasive species into the region; Disease susceptibility; Malnutrition; Gastrointestinal disorder; Higher demand of animals for the Rehabilitation Centres. Increase in the number of stranded animals with wastes; 	<ul style="list-style-type: none"> Proper sewage treatment, filtering of plastic materials, barriers, boat collectors; Ban single-use plastic (disposable cups and plates, straws); Incentive to create cooperatives; Subsidies for artisanal fishermen to collect gear at sea (e.g., discount on oil); Incentives in sustainable businesses to reuse plastic. 	<ul style="list-style-type: none"> National Secretariat of Sanitation Federal University of Alagoas - Laboratório de Ictiologia e Conservação (LIC) Federal University of Alagoas - Laboratório de Biologia Marinha e Conservação Federal Rural University of Pernambuco - Departamento de Pesca e Aquicultura, Laboratório Bioimpact Federal University of Pernambuco - Departamento de Química Federal Rural University of Pernambuco, UFRPE - Departamento de Biologia 	<ul style="list-style-type: none"> Secretariat of Fisheries and Ministry of Environment; Residents' Association; Noronha Zero Waste; Verde Luz Institute (CE); Environment Departments at municipal and state level; <p>Various departments and sectors of:</p> <ul style="list-style-type: none"> Federal University of Alagoas; Federal University of Bahia; Federal University of Sul da Bahia; Federal University of Paraíba; University of Delta do Parnaíba; Federal University of Piauí; 	<ul style="list-style-type: none"> Government at the federal, State and municipal levels; State and municipal environmental departments; Tax incentives; Technology companies; Industrial Fishing Entrepreneurs; Ministry of Environment.
INFRASTRUCTURE	<ul style="list-style-type: none"> Disposal of fishing gear; Lack of solid-waste management on the coastal zone. 		<ul style="list-style-type: none"> Expansion of clinical care for marine animals (e.g. creation and maintenance of institutions hosting animals for rehabilitation); Infrastructure for the proper disposal of fishing gear; Retrieval of lost fishing gears (industrial fishing); Technologies for remote tracking of industrial fishing nets. 			
MANAGEMENT	<ul style="list-style-type: none"> Absence of a national plan to tackle plastic pollution; Lack of cooperation between economic sectors on the coast; 		<ul style="list-style-type: none"> Recycling of plastic items; Monitor the disposal of solid waste; Promoting cleanup campaigns in the city, beaches, etc.; 			
MANAGEMENT	<ul style="list-style-type: none"> Lack of selective waste collection and correct disposal of hazardous waste. 	<ul style="list-style-type: none"> Changes in the "natural" behaviour of animals; Potential chemical contamination of the biota; Contamination of the trophic web and favours new diseases, and mutations; Habitat loss; Biodiversity loss; Threat of extinction for species with reduced populations 	<ul style="list-style-type: none"> Dispose of unused equipment and monitor disposal; Creation of rubbish bins and waste drop-off points; Codification of fishing gear and implementation of reverse logistics. 	<ul style="list-style-type: none"> Baleia Jubarte Institute (Bahia) Patrulha Ecológica Mamíferos Aquáticos Foundation SEMA, Superintendência a de gestão de resíduos (Maranhão) Comissão Ilha Ativa (Piauí). Lixo Zero Institute (Rio Grande do Norte) Secretaria de Infraestrutura, dos Recursos Hídricos e do Meio Ambiente (SEIRHMA, Paraíba); Tartarugas do Delta Institute (Piauí); Praias Limpas Biota Institute; Ecoassociados Centro de Estudos e Monitoramento Ambiental (CEMAM, Rio Grande do Norte). 	<ul style="list-style-type: none"> Federal University of Ceará; Federal University of Sergipe; Federal University of Rio Grande do Norte; Rede de Tartarugas Marinhas do Nordeste (RETAMANE); Startups and Greentech; Salve Maracáipe; Xô Plástico; Recolixo (UFPE); Amare Institute (MA); Tamar project; Rebio Atol das Rocas. 	
SCIENCE	<ul style="list-style-type: none"> Lack of data on the impacts on biota; Lack of knowledge about pollutant sources on land and sea; Standardisation of samplings and free access to data; Partners network and monitoring of plastic pollution. 		<ul style="list-style-type: none"> Economic incentives for research on the subject; Environmental monitoring; Baseline and experimental studies on the effects on animal health; Capacity building of the team and contribution of resources for the purchase of materials; Development of technologies for new production materials. 			
EDUCATION	<ul style="list-style-type: none"> Lack of awareness of the effects of plastic pollution; Increase public awareness of plastic pollution; Lack of inclusive and accessible communication at all levels and sectors. 		<ul style="list-style-type: none"> Environmental education on recyclable materials; Access to information; Awareness actions with fishers and communities; Dissemination of data on the economic and social impact of improper disposal. 			
NATURAL CAUSES	<ul style="list-style-type: none"> Plastic items transported via ocean currents; Infrastructure damage from climate. 		<ul style="list-style-type: none"> Use of climate data to forecast rainfall and storms; Action plans for prevention, and clean-up in affected areas. 			

Figure 7: Causes and effects of plastic waste on the marine biota of the Northeastern coastline reported by professionals from different institutions in the Northeast of Brazil. The causes were categorised in Public Policy, Infrastructure, Management, Science, Education and Natural Causes, and the effects were categorised as short-term (light green), medium-term (medium green) and long-term (dark green). Additional data was extracted from Brazil's NE Regional Report of the Ocean Decade.

The causes cited in Public Policy were the “Absence of Zero Plastic programs” and “Lack of regulation in shops, resorts and other polluting sources in the coastal zone”. These causes are also closely related to the causes cited in the categories of Infrastructure and Management since the National Policy covers them on Solid Waste (PNRS, Law No. 12.305).

The PNRS, a law instituted in 2010, brings important instruments for the proper and adequate management of solid waste throughout the country for manufacturers, importers, distributors and sellers. The policy also involves issues on waste management of a business, which should seek to reduce waste generation, increase recycling and reuse, proper disposal of waste generated and propose sustainable consumption practices. Actions directly related to SDGs 11 and 12. All actions and instruments provided for in the PNRS contribute (in)directly to the prevention and mitigation of plastic pollution effects. However, few measures have been taken regarding this policy, directly affecting the quality and environmental health of coastal and marine ecosystems.

In addition to the environmental impacts caused by the poor management of solid waste, including plastics, this leads to economic and social losses. For example, the clean-up of tourist beaches that do not have adequate infrastructure for solid-waste management spends more money on the public coffers of the city and, consequently, may generate less income for being less attractive to tourists and visitors (Bergmann et al., 2015; Leggett, 2014). In Brazil, on the tourist beaches of Natal (RN), more than R\$18,000 reais per day (R\$6,570,000 million/year) were spent to clean 36 tons of waste/day in 2018 according to URBANA (*Companhia de Serviços Urbanos de Natal*). The high costs of equipment, gasoline and labour could be reversed with the improvement of the city’s infrastructure and the increase of sustainable tourism and community in

the region, which would increase income generation in the city.



Figure 8: Urban solid waste at Gaibú rocks, Pernambuco coast. Photo: Raquelina Monteiro, 2019.

The coastal municipalities of the Northeast region need to effect the actions foreseen in the PNRS concerning solid-waste management to avoid the accumulation of plastic and other hazardous waste along the coast (Figure 8). In turn, governments and solid waste and environment departments need to strengthen and consolidate state and municipal waste management plans that include an effective collection and recycling system. In the long term, investing in new packaging that is easy to recycle and replace, when possible, with other materials (e.g., paper) is necessary. In this scenario, reducing plastic consumption and production is an effective measure in the fight against plastic pollution that includes society’s engagement in the short term by reducing the use of disposables, for example.

Regardless of the measures and solutions presented here, this discussion must occur within the government, in municipal and State councils of the Northeastern states. In addition, the logic of the prevalence of economic decisions over environmental decisions in the system of use and disposal of plastic must be stopped. Specific legislations and guidelines for plastics management arise in various parts of the world, and Brazil is no different. Some states and municipalities have created and approved legislation to address the

topic, mainly focusing on the ban on single-use products (Pertussatti, 2020). Most recently, at the national level, the launch of the National Plan to Combat Marine Litter (MMA, 2019) in 2019 brought directions to tackle plastic pollution in the country through the six axes of implementation present in the document, which are: immediate Response, Solid-Waste Management, Research and Technological Innovation, Incentives and Sectoral Agreements, Standardization and Guidelines, and finally Education and Communication. In São Paulo, the PEMALM (São Paulo Strategic Plan for Monitoring and Assessment of Marine Litter) is the first initiative in Brazil at a regional level to combat marine litter pollution. In addition, the initiative is aligned with the goals of the State Plan for Solid Waste (PERS) of São Paulo, contributing to its effective implementation.

In the category Science, the absence of scientific data about the effects on the marine biota of the Northeast, the lack of knowledge of the polluting sources on land and sea, the non-standardisation of sampling, the lack of access to scientific data generated, and the absence of a network of partners for monitoring plastic pollution were some of the causes discussed by the participants. The causes mentioned are constant concerns of the global scientific community since the lack of standardisation of sampling and analysis hinders the comparability between data and, consequently, a more robust analysis of the information produced that could be applied to different sectors, such as environmental agencies, academia, NGOs, among others.

The lack of comparability and accessibility of data delays the development of more refined research and the development of policies and actions aimed at tackling plastic pollution. Universal access to information produced by public and private institutions should be a fundamental right. Currently, some national and in-

ternational initiatives have made access to information on plastic pollution more open and accessible through open-access digital platforms for the provision of data and information, such as the *Global Plastic Ingestion Initiative* – <http://gloveinitiative.shinyapps.io/Glove/> and *Global Partnership on Marine Litter* – www.gp-marinelitter.org.

The Education category dealt with the general unawareness of the effects of plastic pollution, the immediacy of the problem to the population and the lack of inclusive and accessible communication at all levels and sectors of society, government, academia, and the private sector. Educational and innovative tools suitable to each local reality are essential for the development of citizens able to reflect and decide on the future of a more sustainable society. Actions have been carried out in Environmental Education, and in the coastal zone, ocean literacy has been a protagonist in applying innovative methods in formal and non-formal spaces.

The last category, Natural Causes, corresponds to the spread of plastic items by marine currents and other physical factors and the damage and loss of equipment and structure by weather. Often, lightweight plastics are carried by wind and rain into sewers, streams, rivers and ultimately into larger water bodies such as seas and oceans. In addition, disasters such as flooding should also be considered a type of natural cause and source of plastic pollution.

The effects of the causes mentioned by the participants were classified into short, medium and long-term effects. Thus, in the short term, i.e. immediate effect, impacts related to plastic ingestion, amputation of limbs and entanglement of animals, bio-invasion and ghost fishing were cited. In the medium term, vulnerability to disease development, malnutrition and other health disorders was related to in-

creased demand for animals in rehabilitation. Long-term effects are the result of the unfolding of short- to medium-term effects that, when accumulated, can alter animal behaviour, e.g. exchange of nesting areas, ingestion of plastic and other associated toxic substances that have the potential for chemical contamination at the individual and ecosystem level, including favouring the development of diseases and mutations.

The presence of plastic waste in the environment also favours the loss of habitat quality, driving away resident and migratory species, being an aggravating factor when the species affected are endangered animals or endemic species. In general, all the effects mentioned by the group favour the loss of biodiversity, damaging the balance of the coastal and marine ecosystems and human populations that live directly from the sea, such as traditional populations.

Solutions and stakeholders were presented by the group based on the causes and effects discussed with the aim of resolving the causes to eliminate the deleterious effects on the marine biota of the Northeast.

The solutions were categorised again into Public Policy, Infrastructure, Management, Science, Education and Natural Causes (Figure 7). Thus, in Public Policy, the solutions mentioned were the adequate treatment of sewage and techniques for preventing plastic from achieving and flows in rivers and streams, specific guidelines for the management of plastic pollution, such as the ban on single-use plastics, tax incentives for sustainable businesses and subsidies for artisanal fishermen for the collection of fishing gear at sea, when it came to ghost fishing. Likewise, in the Infrastructure and Management categories, solutions presented contemplate many actions and instruments already mentioned in the PNRS and the National Plan for Marine Litter. Thus, it can be noticed

that the solutions, in general, are already known by different stakeholders, indicating that the lack of initiatives at a local and regional level in agreement with public authorities is one of the main obstacles to the implementation of practical actions to combat plastic pollution in the Northeast. Therefore, the social mobilisation of scientists, NGOs, and society is essential to transform ideas into realistic and applicable short- and long-term solutions.

The solutions to the problem in the Northeast must be based on Science, and therefore, it is necessary to have incentives for research and infrastructure on the subject, comprehensive monitoring (e.g. action plans at the state/regional level) that considers the pollutant sources, accumulation and dispersion in the coastal and oceanic environment, levels of contamination in sentinel species of environmental and economic relevance, and investments in human resources trained to deal with the subject, for example, public managers, scientists and researchers for the generation of robust data that can be used in decision making.

Investing in communicators and communication teams is a viable alternative for the Education category when it comes to producing materials, including textbooks and other accessible products in the Portuguese language and suitable for different audiences (See an example at <https://oceanliteracy.unesco.org/plastic-pollution-ocean/>). As well as partnerships with schools and teachers, radio and TV programmes, digital influencers and other stakeholders communicating on the topic with quality information can help.

On the other hand, the Natural Causes that promote the dissemination and deposition of plastic waste in the environment should be tackled by solving the problems mentioned above, i.e., an efficient PNRS and plastic waste management prevent the disposal, loss or abandonment of this material.

1. FINAL REMARKS

The Northeast coastline is more than 3 thousand kilometres long, starting from the Parnaíba Delta and extending to the Recôncavo Baiano, with a high diversity of environments of fundamental importance for the balance of biodiversity, such as oceanic islands, mangroves and estuaries, sandbanks, salt marshes, dunes, rocky coasts, lagoons and coastal and deep reefs. Despite its environmental, economic, social and strategic relevance, the Northeastern coast is one of the country's most impacted biogeographic due to the high density of human occupation, inefficient public management and economic activities such as tourism and shipping. However, plastic pollution is an emerging issue that is already seen as a global crisis similar to the climate emergency. The deleterious effects of plastic on biota constitute a significant threat to marine life and the conservation of diverse habitats in the Northeast region. Global data already indicates the ingestion of this material by over 1,500 species (Santos, 2021). On the other hand, it is estimated over 300 000 deaths of marine mammals per year from entanglement in fishing nets, ghost fishing and different types of plastic waste (Read et al., 2006).

In this context, the Northeastern region still lacks scientific studies on the subject; despite this, alarming data on the effects of plastic were identified in 35 articles on the coast. Records of ingestion and entanglement were identified among the more than 70 species analysed for seabirds, mammals, fish, reptiles and invertebrates. Besides the low number of studies, the lack of standardisation between sampling and analysis methods, punctual sampling and the use of different measurement units make it impossible to integrate information for visualisation at spatial and temporal scales that could facilitate the

production of helpful knowledge for public policy, for example.

Quality information is vital to establishing and improving more adequate strategies for conserving and preserving coastal and marine ecosystems, including the Northeast region. The lack of knowledge and access challenges many scientists, public managers, decision-makers, and society. Therefore, the synergy between all the Northeastern states regarding a plastic pollution monitoring program or plan based on sharing resources, projects, methods, human resources, and infrastructure is urgent.

The time for action is now for the environmental restoration of the Northeastern coastline so heavily impacted by human impacts. The collaborative work and involvement of researchers, NGOs and public authorities in the search for a strategic and action plan becomes essential since it will serve as a guide in the planning and execution of activities in different sectors, in particular, environmental secretariats at the state and municipal level, private initiatives on environmental issues, research laboratories on plastic pollution and other sectors. This guideline document is an initiative of intervention in this regard and becomes the first step at the regional level in the construction of a group that engages and mobilises its partners to join forces in the fight against plastic pollution.

Therefore, understanding how plastic pollution affects ecosystems and animals in the Northeast of the country is crucial to establish national, regional and local public policy and contributing to global policies aimed at the sustainable use of ecosystems.



Photo: Aquasis

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