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Project Report

Ocean microplastic pollution and its impact on coastal ecosystems

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ABSTRACT

Plastic pollution profoundly impacts terrestrial and marine biomes globally, affecting marine biodiversity through pervasive distribution mechanisms like ocean currents. Environmental studies are crucial for understanding the significant impact of anthropogenic activities on these critical ecosystems. The central research question addressed by this work is: What is the impact of ocean pollution by microplastics on coastal ecosystems? This inquiry is vital given that oceans cover three-quarters of the globe, regulate climate, support biodiversity, and facilitate global trade.

The evolution of society introduced highly persistent plastic components into biosystems. These non-biodegradable materials persist in various forms (macro-, micro-, and nanoplastics), exposing marine organisms to lethal and sublethal risks via ingestion or contact with contaminated environmental matrices (water and sediment). This project report establishes a baseline study designed to assess the global distribution and concentration levels of microplastics in marine environments and their implications for coastal ecosystems.

The analysis utilizes data sourced exclusively from authoritative, public repositories, specifically the National Centers for Environmental Information (NCEI) Marine Microplastics Portal, a partner of the National Oceanic and Atmospheric Administration (NOAA). This robust dataset, leveraging one of the world's most significant environmental archives, ensures a reliable foundation for analysis. The findings derived from this study contribute valuable insights into regional MP pollution dynamics and offer recommendations for targeted future research efforts.

Keywords: Microplastic, Pollution, Marine Biodiversity, Coastal Ecosystems, Ocean currents.

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Introduction

Currently, plastic pollution of the environment negatively interferes with land, sea, and numerous biomes, which globally affects marine biodiversity through ocean currents and other means. Environmental studies try to keep up with the advances of society as it develops, in order to understand how the activities of human beings impact ecosystems. In this context, what is the impact of ocean pollution by microplastics on coastal ecosystems?

The question is relevant and interesting because the ocean is the most abundant body of saline water on planet Earth and covers approximately 3/4 of the globe (Garrison, 2009). It influences life through temperature regulation, climate, fishing, transportation of food and cargo, and extraction of oil and natural gas.

In addition, the ocean is the majority habitat of Earth's biodiversity. As society has evolved, technologies have been created and improved in order to facilitate the daily life of humans. In this circumstance, the production and dissemination of plastic components were inserted in the biosystems, whose attributes underwent chemical, physical and biological changes.

Despite the various shapes and sizes of plastic waste that is found in the ocean, most of these pollutants appear in solid form. These fragments, composed of non-biodegradable plastic, are classified as macroplastics, microplastics (MP) and nanoplastics (NP) (Pompêo et al., 2022).

Unfortunately, organisms that inhabit marine waters are directly exposed to the presence of microplastics. The ingestion of fragments or contact with leached particles present in the environmental matrices (water and sediment) can have lethal and sublethal implications for biota (Nobre et al., 2022). Furthermore, the set of fragments turns into ghost nets, which capture fish and other animals for years, until the material is completely decomposed.

This project report serves as a baseline study to assess the global levels and distribution of MP in the ocean and how it affects the coastal ecosystems. The findings from this study will contribute to the understanding of MP pollution in different regions and provide valuable insights and recommendations for further research.

Public and official sources of information were used, such as data from National Centers for Environmental Information (NCEI) – Marine Microplastics Portal, that is partner of the National Oceanic and Atmospheric Administration (NOAA). This choice of dataset was based on a safe source. NCEI maintains one of the most significant archives on Earth, with comprehensive oceanic, atmospheric, and geophysical data.

Objectives

The main goal of this research is to analyze the impact of microplastic ocean pollution on global coastal ecosystems, describing the main consequences and suggestions for mitigation.

This objective prompts the following questions:

• To identify and quantify the particles and depth of MP in sampled waters.

• To analyze the correlation between microplastic concentration and the depth of data collection in the ocean.

• To observe relationship between the pollution level on the beach and the seawater

• To investigate the changes in the global distribution of microplastics in the ocean over 10 years.

• To suggest sustainable strategies to mitigate the impact of microplastics in the ocean and on biodiversity.

Literature Review

Plastic polymers have their occurrence described from the entire coastline to the ocean floor, being considered ubiquitous in the sea (Pompêo, et al., 2022). Despite the diverse shapes and sizes of plastic waste found in the ocean, most of these pollutants appear in solid form. These fragments, composed of non-biodegradable plastic, are classified as macroplastics when their dimensions are larger than 5 mm. They are considered microplastics (MP) when the particles are smaller than 5 mm (approximately the size of a sesame seed) and nanoplastics (NP) are fragments with dimensions between 0.001 µm and 0.1 µm (Pompêo et al., 2022).

To illustrate, hundreds of marine mammals and thousands of marine birds die every year after ingesting or becoming trapped in plastic debris. Sea turtles mistake plastic bags for their prey, jellyfish, and die from intestinal obstructions. Seals and sea lions starve to death after becoming entangled in nets or muzzled by six-pack rings. The same types of rings strangle fish and marine birds. Thousands of Laysan albatross chicks die every year when their parents feed them pieces of plastic instead of food (Garrison, 2009).

The impact of microplastic (MP) pollution on oceans and biomes is vast and growing. Coastal ecosystems, such as mangroves, reefs, and estuaries, act as natural sinks for MP, where the impacts are most acute (Pompêo, et al., 2022).

Furthermore, health damage through the ingestion of MP by various organisms, from zooplankton to fish and shellfish, can lead to gastrointestinal blockages, internal damage, and starvation due to false satiety (Pompêo, et al., 2022). After ingestion, these chemicals and the plastic additives themselves can still be dispersed within the organism.

The lack of field research on long-term subclinical effects is critical, requiring investigations into impacts on wildlife reproduction and growth. Although biomagnification (the increase in concentration of chemicals in the food chain) is a subject of debate in the literature (Silva, 2019), science continues to struggle to understand the full magnitude of the ecological threat and the real risks to long-term human health.

Methodology

This project report serves as a baseline study to evaluate the global levels and distribution of microplastics (MP) in the ocean, as well as their impacts on coastal ecosystems. The results of this research will contribute to the understanding of MP pollution in different regions, providing valuable insights and recommendations for future studies.

Public and official information sources were used, including data from the National Centers for Environmental Information (NCEI) – Marine Microplastics Portal, which is a partner of the National Oceanic and Atmospheric Administration (NOAA). The choice of this dataset was based on the source's reliability, given that the NCEI maintains one of the most significant archives on Earth, with comprehensive oceanic, atmospheric, and geophysical data, in addition to books, dissertations, and master's theses.

It is emphasized that all bibliographic references cited and used for the construction of this study are available for consultation.

The research methodology adopted in this project is classified as secondary data analysis, as it used datasets previously collected and archived by the National Centers for Environmental Information (NCEI) – NOAA. The study is simultaneously descriptive, characterizing the global distribution of microplastics, and analytical, investigating the correlation between the concentration of pollutants and variables such as collection depth or coastal zone pollution parameters.

The target audience for this project is the student and teaching community of the Atlantic Technical University, in order to enrich and strengthen awareness regarding environmental issues.

Methodology and Statistical Techniques

The data analysis, secondary in nature, descriptive, and analytical, utilized a combination of statistical techniques to characterize microplastic (MP) pollution and investigate relationships between variables.

Descriptive Statistics and Data Characterization outlined the main characteristics of the dataset. Descriptive Statistics were used to organize, summarize, and describe the distribution of microplastics in the ocean.

Mean and Median were used to determine the average level of MP pollution (pieces/m^3) in different coastal zones, while the median was used to provide a robust measure of

central tendency, minimizing the influence of extreme values (outliers) often found in pollution data.
Frequency Distribution and Counting was employed to quantify the number of samples or MPs per category.

Analytical Analysis and Modeling

To test hypotheses and understand the relationships between study variables (such as depth and MP concentration), the following techniques were applied:

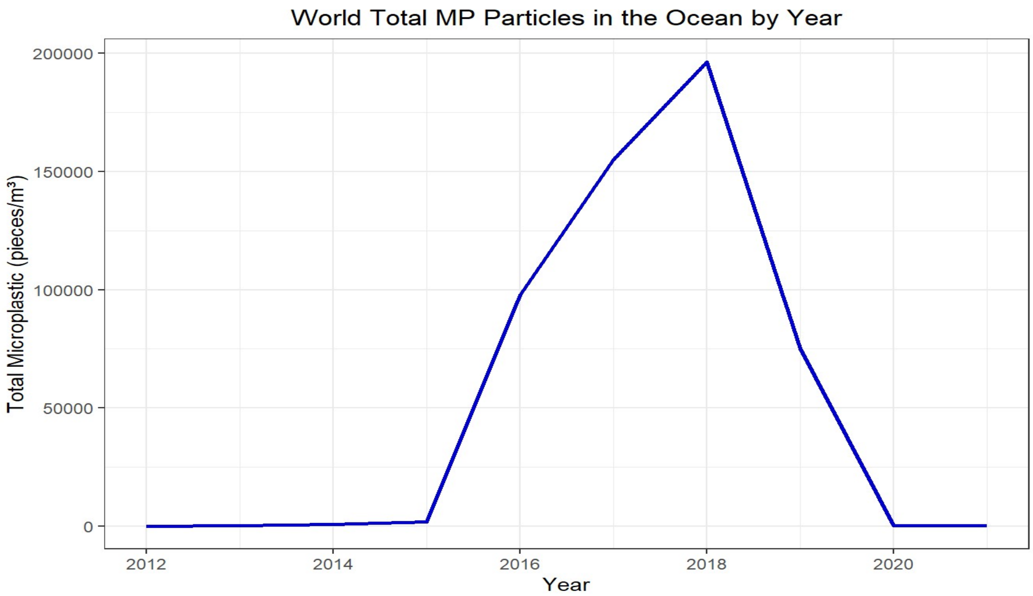
- Correlation Between Numeric Variables: The correlation coefficient (Pearson) was calculated to measure the strength and direction of the association between continuous variables, such as collection depth and MP concentration.
- Heatmap: A graphical visualization used to visually present the correlation matrix. The heatmap allowed for the quick identification of which pairs of numerical variables exhibited the strongest relationships.
- Linear Regression: A statistical modeling technique employed to establish and quantify the relationship between a dependent variable (MP concentration) and one or more independent variables (e.g., depth, latitude).
- Linear Regression Model: The mathematical model resulting from the regression analysis was used to predict how MP concentration might change as a function of the independent variables, providing a basis for inference about the observed data.

Data Collection

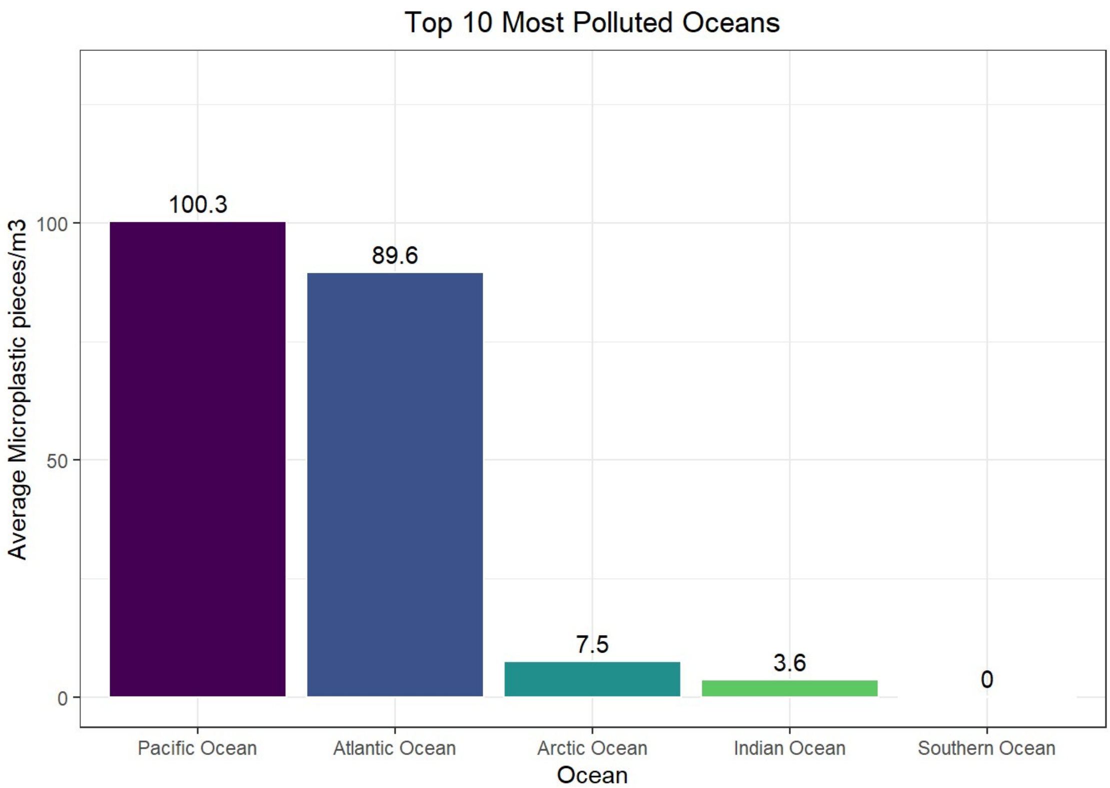
First, the dataset provided by the National Centers for Environmental Information (NCEI) was collected. Upon collecting the information, it was noted that the dataset is composed of 36 variables (Microplastics measurement, Ocean, Water Sample Depth (m), among others) and the Marine Microplastic Concentration data spans the period from January 2012 to December 2021, providing a robust interval for analysis.

Analysis and Results

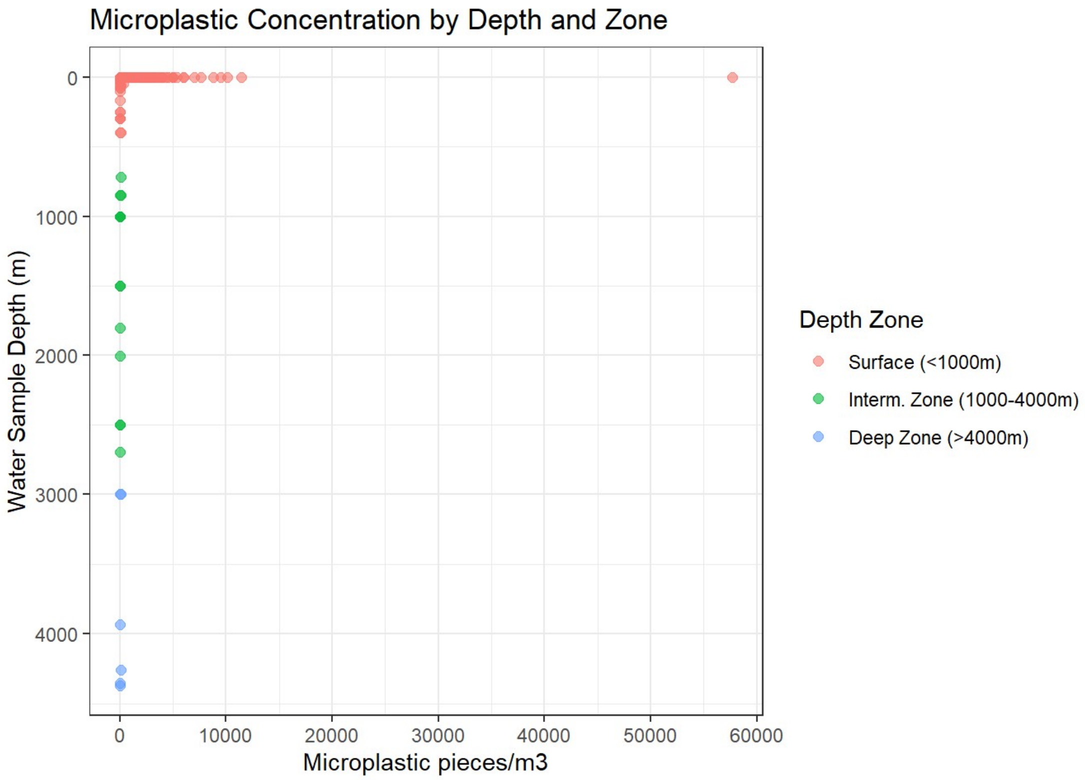
Line Plot - Compute of the World Total Microplastic Particles in the Ocean by Year summed over all microplastics particles and its plot.



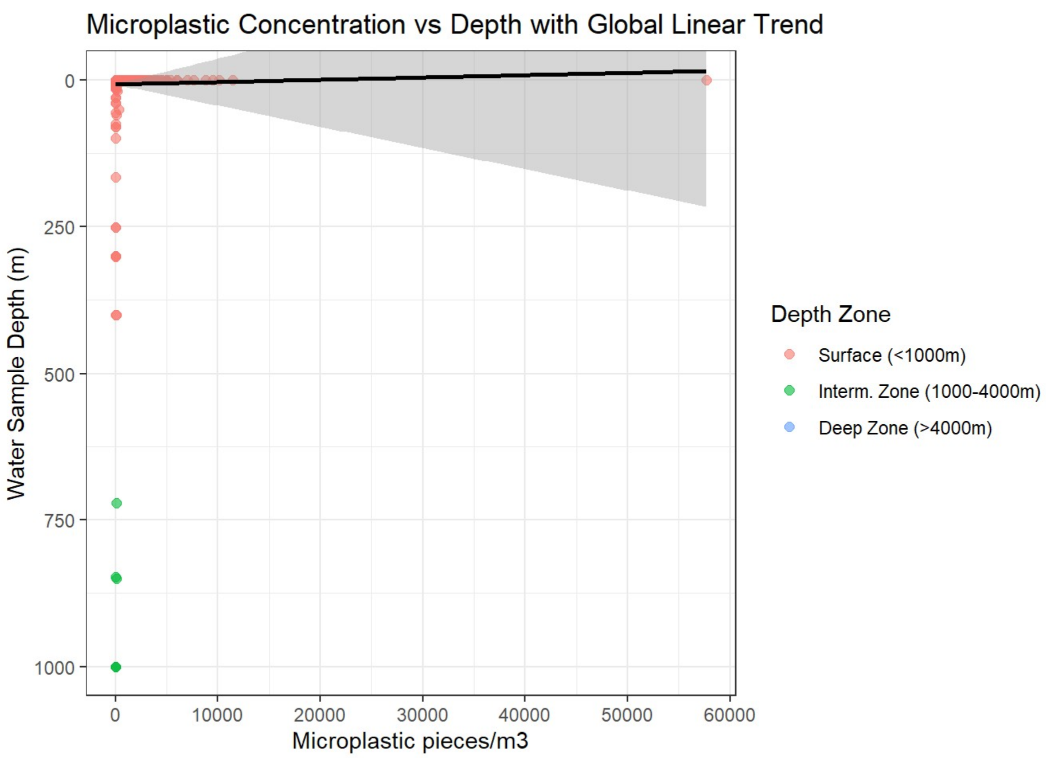
Vertical Bar Plot - Top 10 Most Polluted Oceans



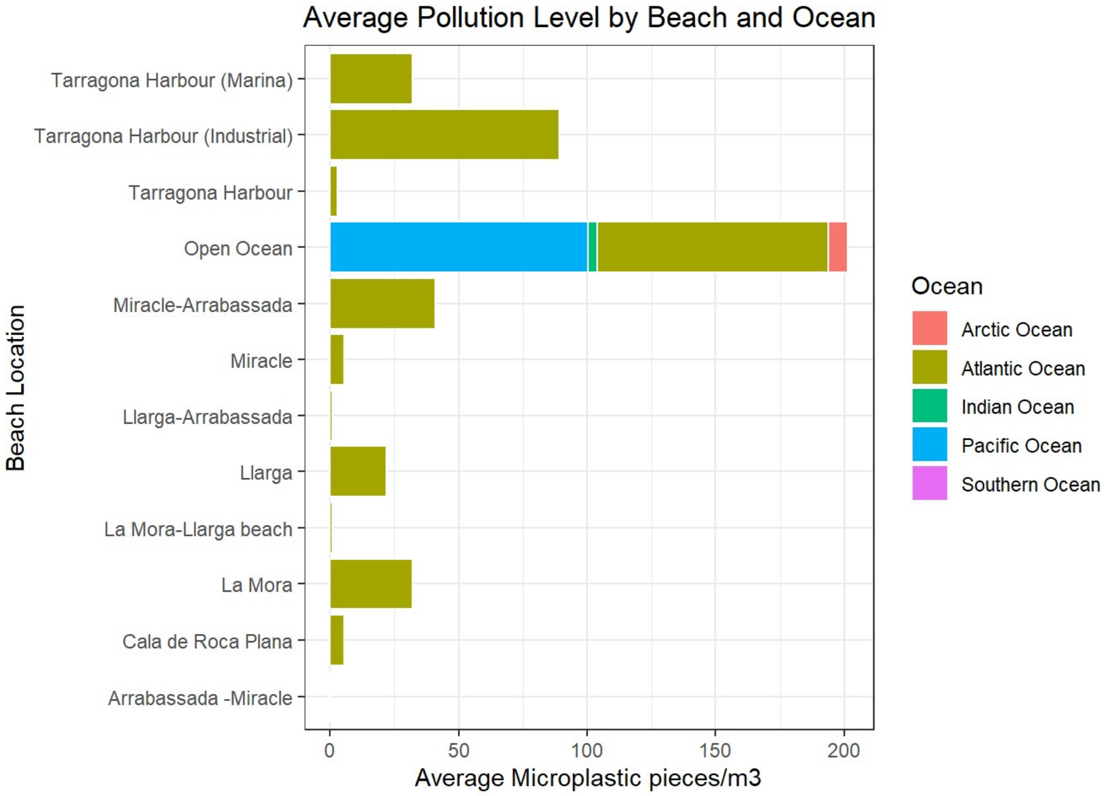
Scatter Plot - Visualize the relationship between microplastic concentration at different depths in the ocean. Each point on the graph represents a single observation or data sample.



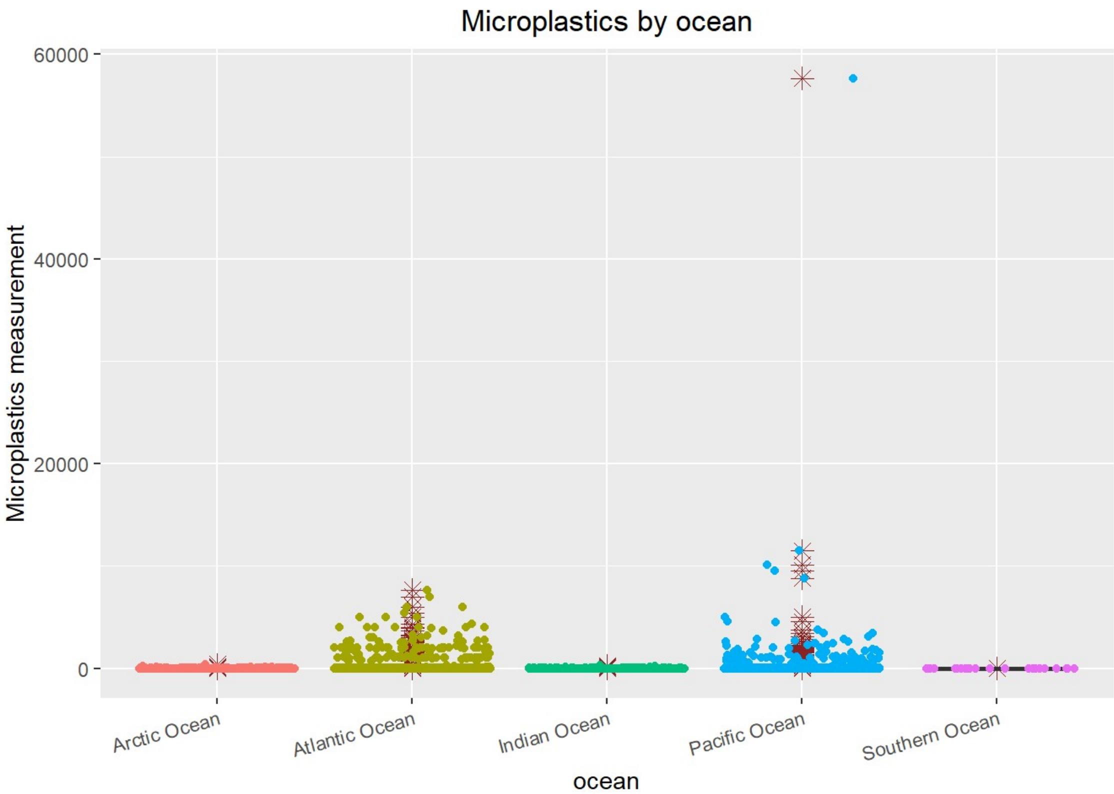
Regression trend line x Scatter plot



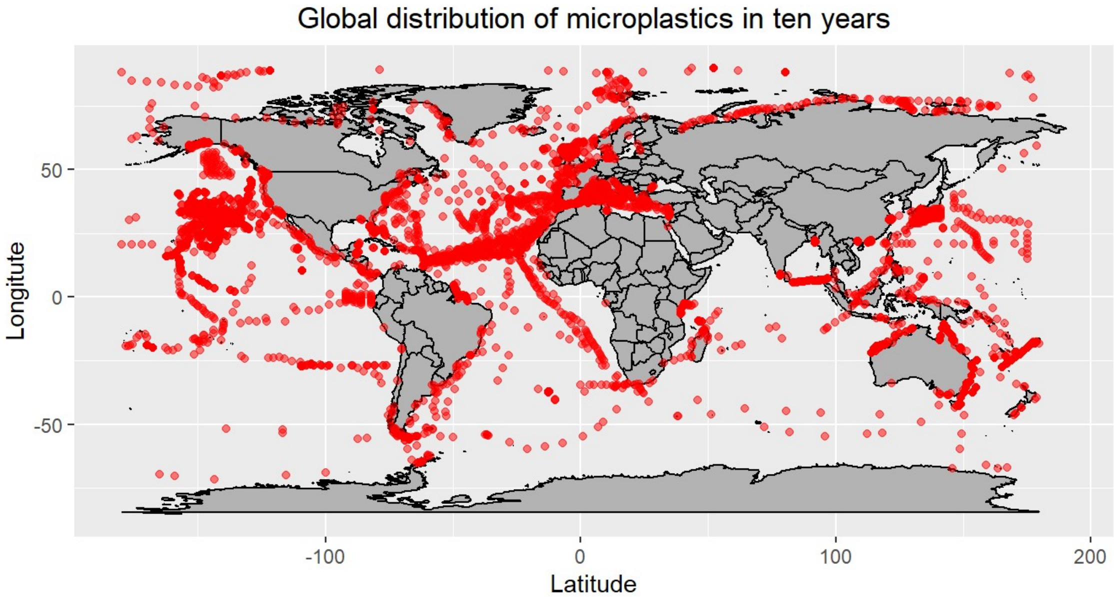
Horizontal Bar Plot - Average Pollution Level by Beach and Ocean



Box Plot - Distribution of Microplastic Concentration by Ocean



Worldmap Static Plot - Visual distribution of Microplastics around the World



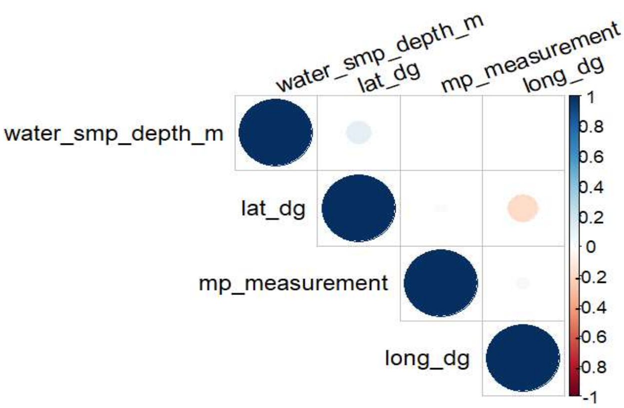
Linear Regression Model - Statistical model that attempts to predict microplastic concentration

```
dm_model <- datamar %>%
        select(mp_measurement, water_smp_depth_m, lat_dg, long_dg) %>%
        na.omit()

model_plastic <- lm(mp_measurement ~ water_smp_depth_m + lat_dg + long_dg, data = dm_model)

summary(model_plastic)
```

Heatmap - Correlation Between Numeric Variables



Discussion

An exploratory analysis of marine microplastic data confirms that pollution is a global phenomenon, concentrated mostly on the ocean surface and with varying intensities across different geographical regions. The results indicate clear associations, such as the inverse relationship between depth and concentration.

Vertical Distribution (Depth)

The visualization of MP concentration by depth (Scatter Plot and Linear Regression Model) indicates a clear vertical stratification and a higher abundance of particles in the surface zone (inverted Y-axis, near 0m). The regression trend suggests that, globally, concentrations decrease as the depth of the water column increases. This is crucial for understanding the transport and fate of MPs in the ocean, suggesting buoyancy as a key factor, although it does not rule out the significant presence of denser plastics in deeper zones.

Geographic Variation (Maps and Bars)

The bar graphs and the static and animated maps demonstrate that pollution is not uniform. "Hotspots" of contamination are identified in specific oceans and beaches, likely associated with oceanic gyres (circular currents that accumulate debris) and densely populated areas with inefficient waste management. The visual distribution in the animated map reinforces the dynamic nature of pollution and the dispersion of sources over time.

Association and Causality

Although the visualizations and regression suggest strong associations (e.g., between geographical location and pollution level), it is vital to interpret these results as correlations, and not as direct cause-and-effect relationships. Factors such as ocean currents, coastal population density, and the nature of the polymers (plastic density) are confounding variables that influence these patterns.

Conclusion and Recommendations

The central conclusion of the study is that microplastic (MP) pollution is a complex and global environmental challenge with clear distribution patterns, requiring urgent and integrated mitigation strategies. The proposed objectives were achieved through the analysis of NCEI data, revealing the following key points:

Identification and Quantification: The study identified and quantified MP particles, confirming their presence at various depths of the sampled water column, though predominantly on the surface.

Relationship with Depth: The correlation and regression analysis demonstrated a clear inverse relationship between microplastic concentration and collection depth, suggesting that the buoyancy of most polymers retains them in the surface layers.

Beach/Sea Relationship: The visualizations indicated an association between the pollution levels observed on beaches and in the adjacent seawater, suggesting that coastal pollution sources are a significant contributing factor.

Global Distribution Over Time: The temporal and spatial analysis over a decade demonstrated that the distribution of MP is dynamic, with the formation of "hotspots" in oceanic gyres and an apparent increase in overall recorded concentrations.

Furthermore, to mitigate the impact of microplastics on the ocean and biodiversity, it is imperative to go beyond ocean cleanup and focus on prevention and the sustainable management of the plastic life cycle. A fundamental strategy involves the implementation of robust public policies: The international community is negotiating a legally binding global treaty (Global Plastics Treaty) to combat plastic pollution. This agreement aims to address the problem across its entire value chain, from production and product design to waste management, promoting a circular economy.

In conclusion, the analyzed data provide visual and statistical evidence of the problem's urgency. The solution lies not only in data analysis but in coordinated global action and the implementation of effective mitigation strategies, such as those proposed by the United Nations Environment Programme and the World Resources Institute (WRI).

Based on the results that point to pollution hotspots and the influence of coastal sources, it is recommended that the rulers use this data to influence local solid waste management policies, promoting the implementation of Plastic-Free Zones on tourist beaches and encouraging the circular economy at a community level.

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