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Assessment of Macro Waste Density and Composition on Residential Coastal Zones in Surigao City, Philippines

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***Abstract*—** This study aimed to assess the macro waste density and composition on the residential coastal zones in Surigao City, Philippines. This study employed descriptive quantitative research design using NOAA Marine Debris Program. Researchers collected macro-waste data from three sampling sites measuring a sample area of 225 m2. The researchers followed standard operating procedures to gather data correctly, weigh the macro waste to quantify the waste problem, recording the weights for subsequent computations. In the final phases, researchers utilize the recorded data to compute metrics like macro waste density, composition and the CCI to assess the macro waste problem existing the sampling sites. Results revealed that plastic bottles are the most commonly collected and abundant type of macro waste in the selected coastal residential areas, particularly San Juan, Dolong, and Sabang. In San-Juan, researchers collected 788 macro wastes weighing 4987.9g, with a density of 3.50, Tondo with 830 macro wastes weighing 4339.2g with a density of 3.69 were collected, and Sabang amassed 955 macro wastes weighing 3981.35g with a density of 4.24. Moreover, the majority of the macro waste composition was plastic bottles for all 3 sampling sites with 33% macro waste composition. Lastly, the Clean Coastal Index (CCI) of the 3 sampling sites have CCIs exceeding >20, thus classified as Extremely Dirty. Thus, it is concluded that plastic bottles have the highest dominance among other macro wastes found along coastal zones in Surigao City and all sampling sites share a common challenge of plastic bottle dominance in their macro waste density and composition with the classification of all sites as "Extremely Dirty" according to the Clean Coastal Index underscores the urgency of implementing comprehensive waste management strategies. Hence, it is recommended to conduct regular clean-up drives and promoting proper waste recycling practices in residential coastal zones of Surigao City as well as selling the artworks created from recycled waste to ensure the sustainability and consistency of our program aimed at maintaining the cleanliness of the coastal area.

***Keywords*—** Assessment, clean coast index, macro waste density, macro waste composition, residential coastal zones.

I. INTRODUCTION

The Philippines faces significant challenges in providing enough housing for its population, leading many individuals and families to seek shelter in coastal areas. Presently, housing problems persist across the country, with limited access to affordable and suitable living spaces. As a result, coastal regions often become densely populated due to their accessibility and close to resources. According to recent statistics, approximately 65% of the Philippine population resides in coastal communities, highlighting the magnitude of this issue (Philippine Statistics Authority, 2020). In Surigao City, many people live in coastal areas because there aren't enough affordable houses. This leads to overcrowding and lots of waste, especially big garbage, gathering there. This is bad for people's health and the ocean. Therefore, the purpose of this study is to assess the macro waste composition and density in Surigao City's residential coastal zones. The researchers adopted a targeted solutions and improve waste management techniques to improve overall living conditions in these vulnerable coastal communities by analyzing the amount and kind of garbage accumulation.

Harrison et al. (2023), stated that macro waste pollution endangers marine life, hinders tourism, and places a heavy financial and health burden on coastal populations. Macro waste, like as plastic bottles and bags, harms marine life by wrapping it in its nets or swallowing it, which can lead to illness or death. It damages local businesses by discouraging tourists from visiting unclean beaches. In addition, it puts the health of those who reside along the coast at risk due to increased garbage cleanup costs and the potential for illness from contaminated water. Also, according to Villanoy & Yap (2020), it is necessary to have a thorough comprehension of the type and magnitude of

plastic pollution present on the residential coastal zones in order to devise and execute effective mitigation programs that would. This study explores an in-depth analysis of the amount and content of macro waste on city-bound coastal residential zones. Through the process of measuring and describing the plastic waste that is found, the researchers will extract important information on the origins, distribution, and possible effects of this pollution. This kind of information is essential for developing focused interventions, increasing public awareness, and influencing governmental decisions in order to address the problem of plastic pollution that Surigao City faces.

On the other hand, several researches have been published about plastic pollution in marine environment. One notable study about this was conducted by Inocente and Bacosa (2022). They studied the presence of macro plastic pollution on selected tourism beaches in Barobo, Surigao del Sur, Philippines and it was found out that found that all four selected tourism sites in Barobo, Surigao del Sur, Philippines (Cabgan Island, Turtle Island, Dapdap Beach, Panaraga Beach) are contaminated with macro plastic litters. Specifically, beaches located on the islands were found to have three times more plastic items, with an average of 0.41 items per square meter, compared to mainland beaches which averaged 0.15 items per square meter. The study of Inocente and Bacasa (2022) focused on tourism beaches in which they examined the amount of plastic litter and cleanliness standards in popular tourist destinations, while our study focuses on residential coastal areas in Surigao City alone. In this study, the researchers aimed to assess the density and composition of macro waste, specifically in residential coastal zones. This study investigated how much waste is present in these areas and what types of waste materials are most common.

This research carefully gathered and sorted all visible large waste bigger than 5 mm along set paths at specific spots using well-known methods for studying large waste, customized for Surigao City's coastal areas where people live. This carefully noted and studied the amount of waste per area and the different types and sources of plastic garbage. Through this thorough investigation, this aimed to show how much big waste really affects Surigao City's coastal areas where people live. By giving stakeholders this information, this study to helped the residents make smart choices, promote eco-friendly actions, and ultimately make these coastal areas cleaner and healthier for both nature and the people living there.

II. STATEMENT OF THE PROBLEM

This study aims to assess the macro-waste density and composition on public beaches in Surigao City. Specifically, this study sought to answer the following specific questions:

1. What type of macro-waste is abundant and mainly found on the selected coastal areas in Surigao City?

2. What is the macro waste density, macro waste composition, and clean coastal index on the residential coastal areas in Surigao City?

3. Based on the findings, what strategies and mitigation program are applicable or suitable to assess the pollution made by macro-waste on the selected coastal areas?

III. METHOD

A. Research Design

This study utilized a quantitative descriptive research design. According to Aggarwal and Ranganathan (2019), the descriptive design is the most basic type of observational study design as it enables the researcher to investigate and characterize the distribution of one or more variables without respect for causal or other hypotheses. Hence, this research design is appropriate on this study because its method can efficiently collect a vast range of information across variables that involves investigation and observation for the researchers to assess the macro-waste density, composition, and Clean Coastal Index on Residential Coastal Zones in Surigao City.

Moreover, the sampling design that this study utilized was based on the NOAA Marine Debris Program (MDP) which developed standardized, statistically valid methodologies for conducting rapid assessments of the debris material type and quantity present in a monitored location.

B. Research Environment

This study was conducted at 3 sampling sites in Surigao City namely: San Juan, Dolong, and Sabang. These sampling sites were considered in the study as it has the coastal areas in Surigao City with families residing on it. Moreover, San Juan is a coastal barangay located in Surigao City, situated in the northeastern part of Mindanao, Philippines. Its population as determined by the 2020 Census was 16,565. This represented 9.68% of the total population of Surigao City. In San Juan, there is a mix of families residing in both land-based communities and coastal areas and a significant portion

of the population living along the coastline, relying on fishing and coastal activities for their livelihoods.

On the other hand, Dolong is a barangay located within Surigao City, situated along the coast of Mindanao, Philippines. It is characterized by highly dense population or squatters living in both land and coastal zones. The area is also known for its diverse marine life, making it a popular fishing spot for fisherfolks. Dolong is home to a diverse population, including families, individuals, and communities engaged in various livelihood activities such as fishing with an overall population of 15,383. Dolong has both land-based and coastal communities, with families residing in traditional houses and small villages scattered across the barangay.

Lastly, Sabang is a barangay located in Surigao City, situated on the northeastern coast of Mindanao, Philippines. It is renowned for its natural beauty, including pristine beaches, coral reefs, and scenic landscapes. The area is surrounded by lush vegetation, coconut palm trees, and turquoise waters, making it an idyllic destination for beach lovers and nature enthusiasts. Sabang is a barangay in Surigao City, in the province of Surigao del Norte. Its population as determined by the 2020 Census was 6,114. This represented 3.57% of the total population of Surigao City. Similar to other coastal barangays in Surigao City, Sabang has both land-based and coastal communities, with families residing in traditional houses and villages. The number of families living in coastal areas is significant, as fishing and coastal activities play a vital role in the local economy and way of life.

On the other hand, Table 1 below showed the coordinates of the sampling sites in their corresponding latitudes and longitudes.

Table 1. *GPS Coordinates of the Sampling Sites*

Sampling Area	Latitude	Longitude
San Juan	9° 47' North	125° 29' East
Tondo	9° 47' North	125° 29' East
Sabang	9° 48' North	125° 28' East

C. Data Gathering Procedure

The researchers collected macro waste on three locations: Sabang, Dulong, San Juan, Surigao City. The study was conducted for 4 weeks with 2 selected days; weekdays and weekdays. Weekdays consists of March 6, 13, 20, 27, and weekends consisting March 9, 16, 23, 30. Lastly it was conducted during 12 noon where the tide was low enough for the area to be 225m².

Phase 1. During this step, supplies such gloves, yarns, weighing scales, notebooks, and ballpoint pens are prepared. The gloves act as safety gear when handling polluted trash. The area where the experiment will be conducted by the researchers is marked with yarn. The weighing scale, which measures the mass or weight of the macro-waste, comes next. Lastly, data is listed or encoded using notebooks and pens.

Phase 2. Measuring the sample area comes next. The researchers measured a 15 by 15 square with an area of 225m2 using measuring tape. The researchers indicated the sample area's boundary with threads following the measurement. The researchers gathered a variety of macro trash items, such as plastic bottles and shoes, over the course of four weeks. Because the sample area is also impacted by sea level rise, the researchers selected low tide to collect more accurate data.

Phase 3. Here, the researchers gather the macro trash and weigh them. Macro wastes should be weighed in order to facilitate data processing for subsequent computations. It is simple to employ the macro wastes in formulations since they are weighed and stated in grams, which gives a quantified measurement of the waste problem.

Phase 4. The weight is recorded by the researchers for use in the study's subsequent computations in the fourth phase. like the Macro Waste Density and the CCI (Clean Coastal Index). Four researchers are involved in gathering the data. After four weeks of two-day workweeks and weekends, the researchers obtained some astounding results. which will thereafter be utilized to obtain the outcome.

Phase 5. The disposal of macro waste is the final stage of this investigation, ensuring that waste is properly handled and placed in the appropriate categories. Each group of researchers was tasked with separating various forms of macro waste, including recyclable materials such as plastics, personal hygiene items like pantyliners

and diapers, medical garbage including face masks and syringes, and metal objects like cans and nails, ensuring that each type is disposed of correctly.

D. Data Analysis

Macro Waste Density

Macro waste density measures the quantity of large, visible waste per unit area, often studied in environmental contexts like coastlines. Putuhena et al. (2020) observed macro waste density in Ambon Bay waters, ranging from 1.32 to 8.84 pieces per square meter, with broken glass and ceramic shards being prevalent. This metric aids in understanding the area of human-generated debris in ecosystems.

$$\textbf{Density analysis} = \frac{number\ of\ macro\ waste}{total\ area\ sampled\ (m^2)}$$

The formula in the image defines the density of plastic litter. It states that the density, which is the number of plastic litter items per unit area, is equal to the total area sampled divided by the number of plastic litter items. Density is represented by the text "Plastic litter density" on the left side of the formula. It represents the number of plastic litter items per unit area (typically measured in square meters, denoted by m²). Total area sampled (m²) is represented by the text on the right side of the formula. This is the total area of the environment that was sampled for plastic litter.

Macro Waste Composition

Classification of various kinds of large-scale residential waste found in coastal zones. According to Brahme et al. (2023), waste composition is the classification of several types of components in MSW. It is typically computed using a conventional waste audit.

The waste audit collects garbage samples from generators or ultimate disposal sites, which are then classified into preset categories and weighted. It implies that waste composition categorizes various kinds of composition in MSW, which includes residential waste found in coastal zones or areas, and it commonly uses an analysis method called waste audit. Pacilan & Bacosa, (2022), defined the composition of Macro Waste mathematically as:

$$\text{Composition analysis} = \frac{number\ of\ items\ in\ a\ category}{total\ number\ of\ items\ in\ all\ categories} \text{x}100$$

The composition of macro waste found in coastal zones was acquired using the formula or equation indicated above. The researchers counted the numbers of each kind of macro waste they found in the opted residential coastal zones, then divided it by the total number of all kinds of macro waste and multiplied it by 100. Furthermore, the formula computes the overall composition of macro waste found in coastal areas.

Clean Coastal Index

The Clean-coast index (CCI) is proposed as the optimal tool for evaluating coastal cleanliness, using plastic debris as a standard measure.

This mathematical approach helps prevent authority bias (Alkalay et al., 2007). By applying the CCI, the total amount of plastic debris collected in the study is determined, providing an objective measure of coastal cleanliness for each location.

$$\text{CCI} = \frac{total\ items\ of\ macrowaste}{total\ area\ sampled\ (m^2)} \text{ x } K$$

Where CCI is the number of litter items per m2; the total area of the sampling unit is generated by multiplying the sampling unit's length by the width; and K is a constant that equals to 20. Qualitatively, a CCI value may categorize beach cleanliness as 0–2 indicating very clean, 2–5 indicating clean beach, 5– 10 indicating moderately clean, 10–20 indicating dirty, and >20 indicating extremely dirty beaches (Vlachogianni et al., 2018).

Macro Waste Litter Category

Litters were classified into these categories: (a) food packaging, (b) disposable utensils (c) food containers (d) cloth, (e) napkin and diapers, (f) ropes, (g) cigarette, (h) plastic fragments, (i) plastic bags, i) styrofoam, (k) medical waste, (l) sack, and (m) nylon fishing line, (n) footwear, (o) plastic bottle, (p) plastic caps, (q) fishing nets, (r) other bottle containers, (s) disposable lighters, (t) plastic cups (u) straws, (v) toiletries, (w) rubbers, (x) tetra packs, (y) metals, (z) glass, (aa) aluminum, (ab) electronics. The total litter count was then tallied to calculate for the clean coast index (CCI) (Alkalay et al., 2007).

IV. RESULTS AND DISCUSSION

Types of Macro Waste Abundant on the selected Coastal Areas

The figure below showed the abundant and most found macro waste on the 3 sampling areas of coastal zones in Surigao City, Philippines.

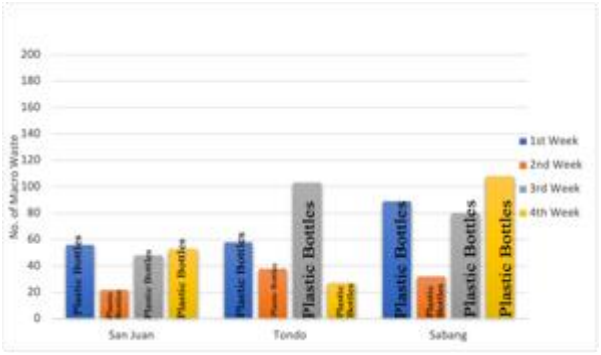

Figure 1. *Types of Macro Waste Abundant on the selected Coastal Areas*

Plastic bottles are the most commonly collected and abundant type of macro waste in the selected coastal residential areas, particularly San Juan, Dolong, and Sabang. People throw plastic bottles and other trash onto beaches or into rivers, which then carry them into the sea. Strong winds and storms also blow litter from streets and landfills into rivers, and eventually into the ocean (Eriksen et al., 2014). Plastic bottles are a big part of this problem because they're everywhere, used for drinks like water and soda. When people don't recycle them properly, they end up in the ocean, where they float on the surface or sink to the ocean. This creates a big mess for marine animals and the environment. So, plastic bottles are a major contributor in the pollution of coastal areas, and it's important for us to find better ways to deal with them to keep our oceans clean. After a month of collecting, 666 plastic bottles were gathered from all sites, twice per week. 179 were collected from San Juan, 226 from Dolong, and 309 from Sabang. Based to the full overview of everyday collection in Figure 2, the most waste was collected during the first week of collection at Sabang, totaling 108 pieces of plastic bottles. While the lowest amount of plastic collected was 22 pieces during the second week of collection in San Juan.

Macro Waste Density on the Selected Coastal Areas

The table below showed the study's locations and macro waste densities gathered from the coastal areas of San-Juan, Tondo, and Sabang. SD Signifies the standard deviation of 4 weeks' accumulation.

Table 2. *Overall Macro Waste Density of Sampling Sites*

Sampling Site	Latitude	Longitude	Mass of Macro waste (g/site)	Total Macro Waste Count	Mean Area sampled (m2)	Mean Density (per m2 ± SD)
San-Juan	9.7904	125.4839	4987.9	788	225	3.50
Tondo	9.7914	125.4911	4339.2	830	225	3.69
Sabang	9.7979	125.4720	3981.3	955	225	4.24

San-Juan's Residential Coastal Area is a home for many fishermen. The population of the area and the fact that people there make a living through fishing contributed to the accumulation of macro wastes. The researchers in San-Juan collected a total of 788 macro wastes that weighs (4987.9g) with a density of (3.50) within a 15 by 15 area in 4 weeks. Among the other sample areas, San-Juan has the lowest dominance of macro waste and also has the lowest macro waste density. San-Juan got the lowest macro waste among the other sample areas as some of the residents' disposal of garbage there are more moderate compared to the other sample areas. Moreover, According to Thushari & Senevirathna (2020), Offshore activities such as commercial fishing, navigation, waste disposal, and shellfish/fish culture are major contributors to plastic waste accumulation in marine and coastal areas. It suggests that the major contributors of macro wastes collection in coastal areas are offshore activities that involves operations beyond coastal or marine environment.

The proximity of Tondo in a lot of fishermen just like as in San-Juan Residential Coastal Area, contributed to the overall macro waste collections found in the area and also due to the fact that it is a highly populated, urbanized, and industrialized area. The researchers in this site accumulated a total of 830 macro wastes that weighs (4339.2g) with a density of (3.69) within a 15 by 15 area in 4 weeks. Tondo macro waste density is moderate compared to the other sample areas due to the lack of waste management, financial, and community participation in the area and the residents there often dispose garbage improperly. According to Abubakar et al. (2022), unsustainable solid waste management practices, worsened by rising urbanization and financial and institutional limits, significantly influence public health and environmental sustainability. This implies

that improper solid waste management deteriorated by rapid urbanization and also due to financial and institutional limitations.

Lastly, Sabang's Residential Coastal area is near the beaches which a lot of people used to hang out or unwind and even celebrates occasions such as birthdays there. Additionally, Sabang has also a lot of fishermen and as populated as the other sample areas, which also attracted and contributed a great number of macro wastes. Within the 15 by 15 area in 4 weeks of accumulation, the researchers gathered a total of 955 macro wastes that weighs (3981.35g) with a density of (4.24). Sabang has the highest density among the other sample areas because it is near to a lot of beach resorts which is prone to tourists and also due to improper waste management and rapid urbanization. Moreover, similar study to the study of Mance et al. (2020), stated that tourism is a key source of environmental strain on Croatia's coastal areas, and the significance and effects of tourism and tourist behavior on the environment should not be overlooked. Urbanization, driven by increased tourism, poses a risk to coastal ecosystems. Which suggests that urbanization and tourism is a major driver of environmental strain and poses a risk to coastal areas.

Types of Macro Waste found on the Overall Sample Coastal Areas

In this figure the researchers discussed about the overall macro waste found on 3 areas: Sabang, Dulong and San Juan. Over on the 4 weeks drive the researchers collected abundant of macro waste.

The figure below identified the most and least abundant on the macro waste count on the overall sample coast areas. The highest percentage was plastic bottle having 33% of the total count. There is a considerable amount of litter in the water, with plastic bottle making up the majority. More specifically, eighty percent of marine waste is made up of plastic waste. According to Pacilan and Bacosa (2022) it was found that the most prevalent plastic waste in any nation with high levels of poverty, like the Philippines, is plastic bottle which were locally available and can easily be purchased. Just like their study in Lanao Del Sur it was found that plastic waste with consumable attribute is the most contributor of waste in the said area.

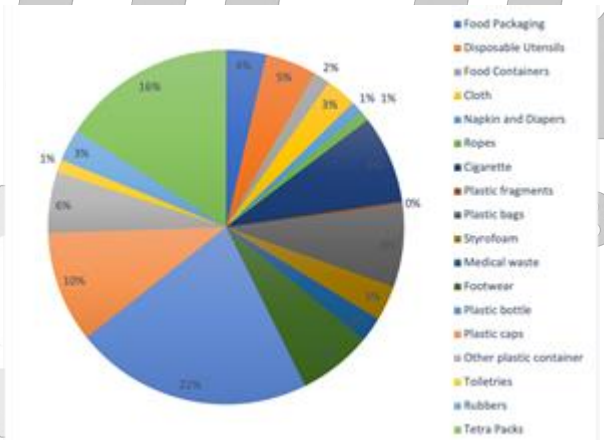

Figure 2. *Types of Macro Waste on all 3 Sample Areas*

In addition, when plastics are heavily utilized to support human activity, such as in drinking water bottles, the amount of plastic waste produced will progressively grow and contribute to global pollution. (Maulidati, 2021). Between 4.8 and 12.7 million metric tons of plastic debris were dumped into the ocean by coastal nations, according to Jambeck et al. (2015). This demonstrates how much plastic is finding its way into marine settings, endangering both the health of our seas and the wildlife that lives there and all around the ocean's surface and are increasingly prevalent in marine ecological systems such as seen in the coastal areas in Surigao City.

Lastly, the least abundant was food containers, food packaging, disposable utensils, napkin and diapers, plastic bags, nylon, and plastic fragments.

Food containers, food packaging and utensils are part of their everyday life and for consuming.

Napkin and diapers were used for their toiletries. Plastic bag is a versatile item such as storing food or garbage. Nylon is used for fishing and part of their living. And

lastly, plastic fragments from recycled plastic bottles as alternative tools were seen in the coastal regions of Surigao endangering marine life.

Clean Coastal Index (CCI) on Coastal Areas

This table shows the comparison of the cleanliness of coastal residential of three selected areas; San Juan, Tondo, Sabang, Surigao City with other beaches in the Philippines based on clean-coastal index (CCI).

Table 3. *Comparative Analysis of Clean Coastal Index (CCI) on Coastal Areas in Surigao City and the Philippines*

Area	CCI	CCI Description	Author
San Juan, Surigao City	>20	Extremely Dirty	This Study
Tondo, Surigao City	>20	Extremely Dirty	This Study
Sabang, Surigao City	>20	Extremely Dirty	This Study
Binduyan, Palawan	>20	Extremely Dirty	Sajorne et al. (2021)
San Miguel, Palawan	>20	Extremely Dirty	Sajorne et al. (2021)
Inagawan, Palawan	16.7	Dirty	Sajorne et al. (2021)
Cabayugan, Palawan	12.08	Dirty	Sajorne et al. (2021)

As shown in the table, it is an information regarding the cleanliness levels of specific locations, measured by a Cleanliness Classification Index (CCI). In the table above, San Juan, Tondo, and Sabang have CCIs exceeding 20, thus classified as "Extremely Dirty." Additionally, findings from a related study by Sajorne et al. (2021) indicate that Binduyan and San Miguel also exhibit a CCI more than 20, having the same CCI Description of "Extremely Dirty." In contrast, Inagawan is labeled as "Dirty" with a CCI of 16.7, while Cabayugan shares the same CCI Description of 12.08. The CCI serves as an indicator of how dirty an area is overall.

According to the data presented in the table, all three listed areas are categorized as extremely dirty, with a CCI surpassing 20. This indicates a notable degree of pollution within those areas. This aligns with findings from a study by Smith et al. (2023), which highlights the widespread pollution problems affecting coastal regions around the world. Coastal locations are especially sensitive to pollution from human activities such as industrialization and tourism, which can be harmful to the environment and public health.

V. CONCLUSION

The study concluded that plastic bottles are the most commonly collected and abundant type of macro waste in the selected coastal residential areas, particularly San Juan, Dolong, and Sabang. Moreover, in San-Juan, researchers collected 788 macro wastes weighing 4987.9g, with a density of 3.50, over four weeks, indicating a relatively low dominance and density of macro waste compared to other sample areas. Similarly, in Tondo, 830 macro wastes weighing 4339.2g with a density of 3.69 were collected. Conversely, Sabang amassed 955 macro wastes weighing 3981.35g with a density of 4.24, reflecting the highest density among sample areas. Moreover, the majority of the macro waste composition was plastic bottles for all 3 sampling sites with 33% macro waste composition. Lastly, the Clean Coastal Index (CCI) of the 3 sampling sites have CCIs exceeding >20, thus classified as Extremely Dirty.

VI. RECOMMENDATIONS

Based on the conclusions, the following recommendations are offered: (1) Department of Environment and Natural Resources (DENR). Implement stricter enforcement of environmental regulations related to waste management and coastal protection and conduct regular monitoring and assessment of coastal areas to identify sources of pollution and track progress in waste management efforts; (2) Bureau of Fisheries and Aquatic Resources (BFAR). Increase efforts to raise awareness among fishermen and coastal communities about the impacts of plastic pollution on marine ecosystems and fisheries and provide support for community-based initiatives aimed at reducing plastic pollution and promoting sustainable fishing practices; (3) City Government of Surigao. Develop and implement comprehensive waste management policies and programs tailored to address the specific challenges of plastic pollution in coastal areas and invest in infrastructure improvements for waste collection, segregation, recycling, and disposal; (4) Residents. Practice proper waste disposal and recycling habits to reduce the amount of plastic waste entering coastal environments and participate in community clean-up activities and support initiatives aimed at protecting and preserving coastal ecosystems;

(5) Future Researchers. Collaborate with local stakeholders to develop and implement research-based solutions to mitigate plastic pollution and safeguard coastal ecosystems.

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