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CHARACTERISATION OF MACRO-PLASTIC WASTE ALONG THE PHILIPPINES' LONGEST COASTAL BOULEVARD: BASIS FOR SOLID WASTE MANAGEMENT AND POLICY FORMULATION

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ABSTRACT. This study focused on the characterisation of macro-plastic waste in terms of types and quantities along the Philippines' longest coastal boulevard, considering density and cleanliness as a basis for solid waste management and policy formulation. Macro-plastic identification and counting were conducted in four (4) municipalities and eight (8) barangays using the standing stock survey method. There were six (6) types of macro-plastic waste, with the highest quantity consisting of beverage (37.2%) and food packaging (30.5%), followed by fishing gear (17.0%), plastic utensils (9.2%), toiletries (4.8%) and household wastes (1.4%). The computed overall density from a total of 3,978 macro-plastic waste items over 12,000 m^2 of beach area sampled was 0.3 (CM), meaning there were 0.3 litter items of plastic per m^2 throughout the whole boulevard. The computed overall beach cleanliness was 6.6, which means that the cleanliness status is moderate. Overall, most macro-plastic waste is generated by locals or visitors. In conclusion, a policy regulating the use, littering, and carrying of plastic along boulevards is recommended to prevent plastic pollution considering the province's growing ecotourism and the future expansion of the coastal boulevard.

Keywords: coastal road; ecotourism; social plastic.

INTRODUCTION

Plastic debris pollution is one of the world's most prevalent pollution problems,

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affecting oceans and inland waterways (Sheavly and Register, 2007). An estimated 10% of plastic waste ends up in the ocean (Thompson, 2006), endangering marine turtles (Abreo *et al.*, 2016) and altering the physical properties of the marine environment (Carson *et al.*, 2011). The Philippines, considered a "sachet economy" (GAIA, 2019), largely contribute to plastic pollution of the marine environment (Jambeck *et al.*, 2015; Lebreton *et al.*, 2018), making them the main global polluters in terms of marine plastic waste (Paler *et al.*, 2022; Van Ryan Kristopher, 2021), with 0.28-0.75 million metric tonnes per year (Jambeck *et al.*, 2015). As a result of mass production, plastics have spread throughout the marine environment and are now particularly common in marine ecosystems (Bonanno, 2022a), significantly threatening environmental and human health as well as the economy (Khadanga *et al.*, 2022). Most of this plastic waste comes from unregulated use, manufacturing and importation, indiscriminately dumped or deposited at dumpsites and landfills (Eisma-Osorio, 2021). Significant quantities of plastic debris originate from various activities such as tourism, fishing and other recreational activities on beaches (Rakib *et al.*, 2022).

The coastal waters alongside Cory Aquino Boulevard, situated in Camarines Norte province, known as the longest coastal road in the Philippines, have also faced threats from plastic pollution. Plastics are widespread and spatially variable on longer beaches (Al Nahian *et al.*, 2022; Rakib *et al.*, 2021, 2023). This boulevard was built under the Tourism Road Infrastructure Program of the Department of Tourism (DOT) and the Department of Public Works and Highways (DPWH), completing 5.017 kilometres out of the 8.657 kilometres, passing through several coastal towns including Mercedes, Daet, Talisay and Vinzons. The boulevard is declared a tourism destination with a wide boardwalk cast from red semi-adobe bricks and built as a viewing deck (OGRP, 2015). Thus, apart from seeing Bagasbas Beach, a famous surfing destination in the Bicol region, travellers also get to see Baybay Beach in Mercedes, San Jose Beach in Talisay and Sabang Beach in Vinzons, making it a perfect destination for picnics, camping, cycling, jogging, fishing, swimming, surfing and other activities.

However, associated with these activities is the increasing garbage waste, particularly plastic materials that are left along the boulevard and eventually washed into the ocean. Most of the waste that could be found was plastic waste, which can be easily observed along its beach areas and intertidal zones, posing a serious threat to marine biodiversity and human health.

Considering the province's growing ecotourism and livelihood opportunities brought by the development of the boulevard and its future expansion, it is imperative to work on the sustainability of the resources. Research should be done specifically on the plastic wastes themselves and the contributing factors to formulate economically and ecologically feasible policies and management plans. This will help decision-makers and planners in local government units, along with the community, to develop policies regarding macro-plastic issues. In response to this crucial need, pioneering work on the status of the Philippines'

longest coastal boulevard is important to protect the province's growing eco-tourism and its natural resources from possible threats of marine plastic pollution.

In particular, a significant amount of pandemic-related plastic was documented along the longest naturally occurring beach in the world, particularly at tourist and recreational beaches (Rakib *et al.*, 2021). These plastics pose a serious threat to marine biodiversity and several international commitments, and declarations emphasise the importance of prioritising marine plastic pollution-fighting actions (Eisma-Osori, 2021).

If waste management does not improve, the total amount of plastic waste entering the ocean is expected to increase by an order of magnitude by 2025 (Jambeck *et al.*, 2015). Evidence suggests that even remote and protected areas are not immune to plastic pollution (Fagiano *et al.*, 2022), and it is essential to identify marine macro-plastics that have washed up on beaches to determine the source of the pollution and develop the best cleanup plans (Giugliano *et al.*, 2022). Additionally, marine plastic research is critical in the Philippines because the country is heavily reliant on the marine environment and the ecosystem services it provides (Abreo, 2018).

However, there are limited studies on macro-plastic waste characterisation conducted in the Philippines, particularly on newly developed coastal roads. Therefore, we conducted macro-plastic waste characterisation along the coastal boulevard to develop both ecologically and economically sound management plans and policy recommendations.

MATERIALS AND METHODS

Description of the study site

The Cory Aquino Boulevard, an 8.7-km-long boulevard in the province of Camarines Norte, in the Bicol region that passes through the municipalities of Daet, Mercedes, Talisay and Vinzons, is regarded as the longest coastal boulevard in the Philippines.

It serves as an access road to various tourist destinations in the province, with popular beaches such as Bagasbas Beach in Daet, Baybay Beach in Mercedes, San Jose Beach in Talisay and Sabang Beach in Vinzons (*Figure 1*).

Sampling site

We characterised macro-plastic wastes along the Cory Aquino Boulevard covering four (4) municipalities and eight (8) barangays. Four sampling stations (municipalities) were assessed, namely Mercedes, Daet, Talisay and Vinzons, covering eight barangays consisting of San Roque and Del Rosario in Mercedes, Bagasbas and Awitan in Daet, San Jose and Del Carmen in Talisay, Calangcawan Sur and Calangcawan Norte in Vinzons (*Figure 2*).

Sampling method

We used the stock inventory method to assess and characterise the macro-plastic waste types and quantity along the beachfront of the boulevard.

We applied a quantitative research and data analysis by obtaining primary data during field sampling to characterise plastic wastes.

A belt transect measuring 50 x 30 m (1,500 m^2) was laid along the beachfront of each barangay to a total of 12,000 m^2 for the four (4) municipalities.

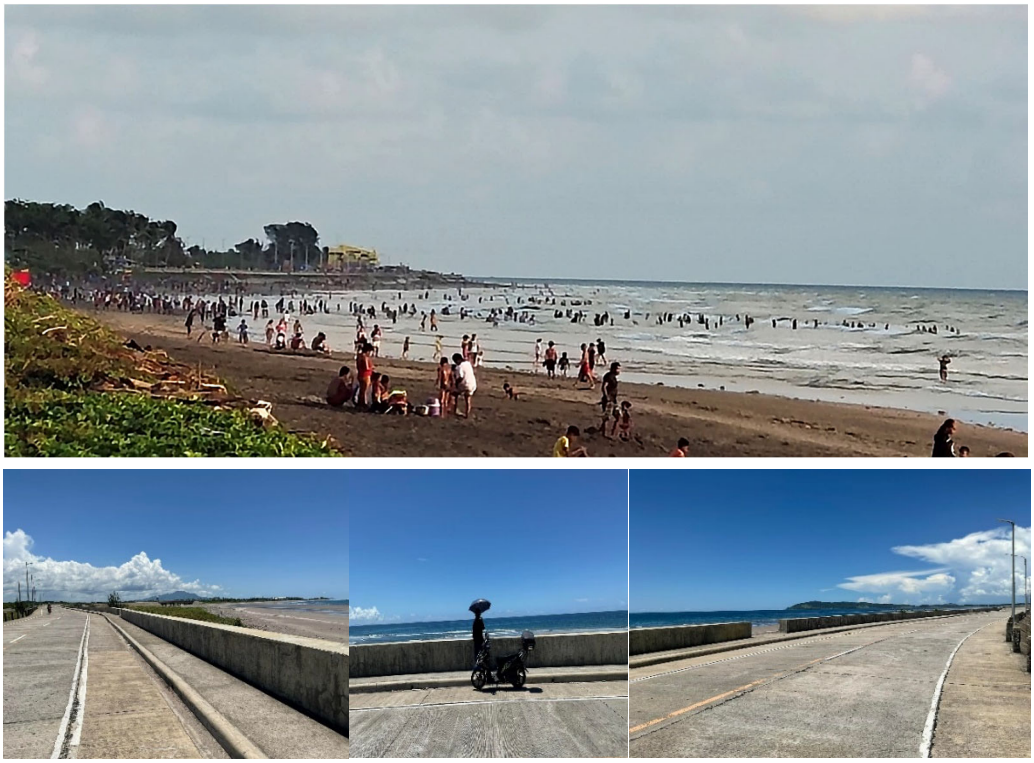

Figure 1 – Actual situation of the beachfront of the boulevard throughout the weekend, showing the massive crowds of people congregating (upper picture). The concrete structure of the coastal boulevard (lower pictures) serves as the road network for the different municipalities

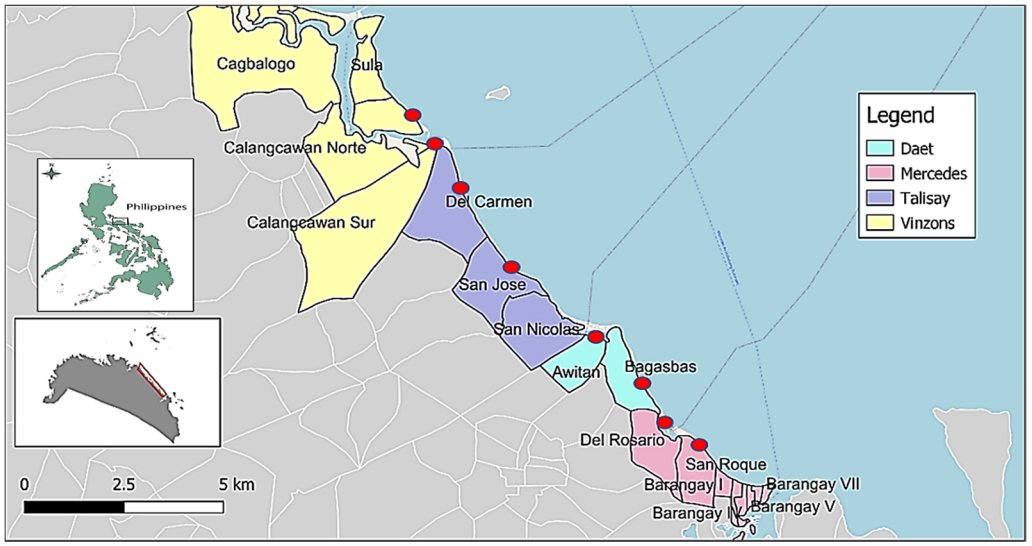

Figure 2 – Location map of Camarines Norte, showing the sampling sites of the study along the coastal boulevard

The laying of the 30-m transects started from the wall of the coastal road perpendicular and reached the shore, whereas the 50-m transect was laid in a parallel position, as shown in *Figure 3*.

Data collection

The stock inventory method was used to record the types and quantity of macro-plastics along the boulevard. During sampling, the types and quantities of plastics were recorded in a prepared inventory form. Sampling was carried out progressively covering all sampling sites for three (3) Saturdays, conducted between 6:00 and 8:00 AM and covering all sampling sites.

The standing stock survey method following Opfer *et al.* (2012) was used in assessing macro-plastic waste in beach areas of the covered sampling sites, where the plastic items within transects at the shoreline site were tallied/counted on-site to determine the total density (# of items per unit area) of plastics present with a size of > 1 cm (Hartmann *et al.*, 2019).

Data analysis

At each transect, the types and quantities of plastic items were recorded to calculate density and cleanliness.

Macro-plastic density

The macro-plastic density was calculated for each municipality and barangay, following Lippiatt *et al.* (2013) (*Equation 1*):

$$CM = n / (w * l) \quad (1)$$

where CM is the density of litter items per m^2; n is the number of litter items recorded; w and l are the width and length of the sampling unit, respectively.

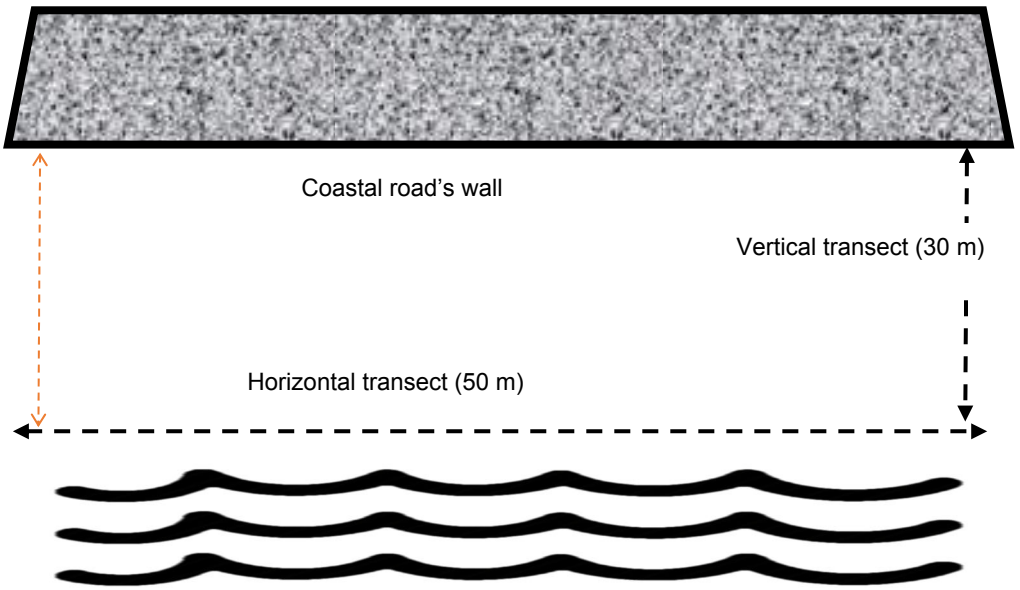

Figure 3 – Sampling design of the study in each station. Broken black lines represent the transect lines, and the orange broken line represents an imaginary line showing the sampling unit area covered during data collection

Beach cleanliness

The beach cleanliness in each barangay was assessed through the Clean Coast Index (CCI) following Alkalay *et al.* (2007) (*Equation 2*):

$$CCI = CM * K \quad (2)$$

where CM is the density of litter items per m^2, and K is a constant that equals 20.

Interpretation

According to the CCI scale developed by Alkalay *et al.* (2007), values from 0–2 indicate very clean beaches, 2–5 indicate clean beaches, 5–10 indicate moderately clean beaches, 10–20 dirty beaches, and > 20 indicates extremely dirty beaches (*Table 1*).

RESULTS

Types and quantity of macro-plastic items

Six types of macro-plastic items were categorised, totalling 3,978 pieces along the boulevard. The highest quantity in terms of frequencies recorded consisted of two types of macro-plastics: beverage packaging with 1,479 pieces (37.2%) and food packaging with 1,215 pieces (30.5%).

This was followed by fishing gear with 675 pieces (17.0%), plastic utensils with 366 pieces (9.2%), toiletries with 189 pieces (4.8%) and household wastes with 54 pieces (1.4%).

The types of beverage macro-plastic wastes primarily included plastic bottles (44.02%), juice pouches (2.43%), Yakult bottles (3.45%), Styrofoam cups (1.42%), plastic cups (29.21%), milk tea cups (6.69%), coke float cups (0.41%) and bottle caps (12.37%). Food packaging macro-plastic items primarily consisted of apple foam (3.21%), cup noodles (0.49%), dessert cups (5.43%), biscuit wrappers (4.94%), candy wrappers (3.46%), junk food wrappers (35.06%), coffee wrappers (0.74%), soy sauce wrappers (0.74%), juice wrappers (0.25%), fast-food plastic bags (3.70%), grocery bags (8.15%), transparent plastic (28.40%), ice plastic (1.23%), food containers (2.72%), jelly ace plastic cups (0.99%) and butter containers (0.49%). Fishing gear macro-plastic waste primarily included fishing nets (10.22%), chicken wire nets (8.00%), Styrofoam floats (48.00%), fishing ropes (24.00%), plastic straw/ties (9.33%) and monofilament nylon (0.44%).

Food utensil macro-plastic waste primarily consisted of plastic utensils (6.56%) and drinking straws (93.44%), whereas toiletry macro-plastic wastes primarily included diapers (22.22%), lotion bottles (15.87%), shampoo sachets (22.22%), face masks (4.76%), perfume containers (1.59%), alcohol containers (3.17%), hair combs (6.35%), toothbrushes (1.59%), toothbrush caps (1.59%), toothpaste containers (7.94%) and soap sachets (12.70%).

Household macro-plastic waste primarily included tarpaulin (11.11%), detergent bottles (38.89%), plastic toys (5.56%), shoe glue containers (5.56%), hard plastic/mega boxes (5.56%), cigarette filters (5.56%), wallpaper foam (5.56%) and Sackolyn (22.22%), as shown in *Figure 4*.

Density of macro-plastic items

Table 2 shows the density of macro-plastic items throughout the whole coastal boulevard as well as per sampling barangay and municipality.

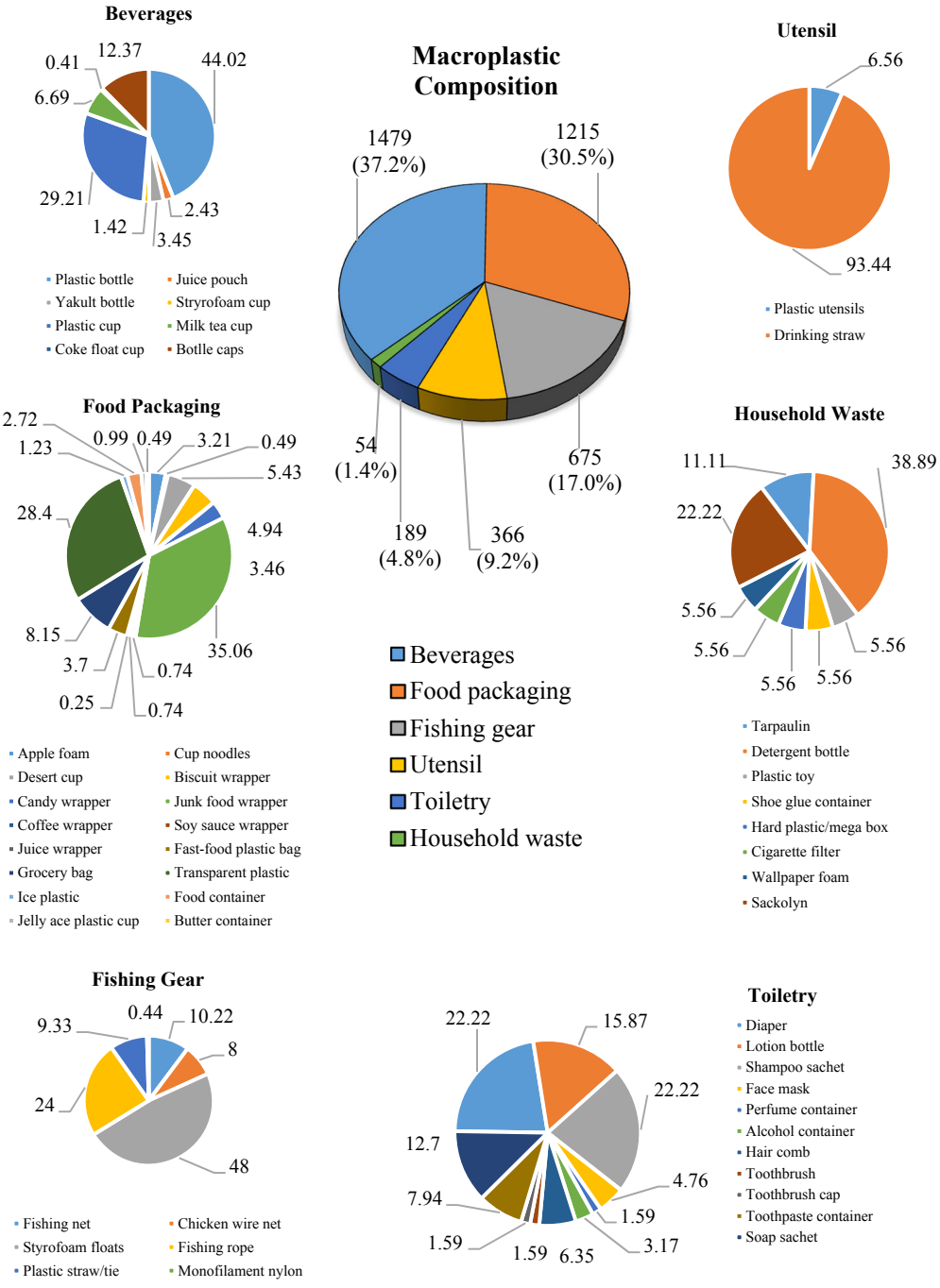

Figure 4 – Types and quantity of macro-plastic items found along the boulevard

The computed overall density from a total of 3,978 itemswastes over the 12,000 m^2 beach area sampled was 0.3 (CM), which means that there were 0.3 litter items of plastics per m^2 throughout the entire boulevard.

The highest density per municipality was recorded in Mercedes (0.84), followed by Talisay (0.78), Daet (0.59) and Vinzons (0.45). Density per barangay was highest in San Jose (0.59) and Del Rosario (0.48), followed by Bagasbas (0.39), San Roque (0.37), Calangcawan (0.24), Mantigbi (0.21), Awitan and Del Carmen (0.19).

Cleanliness status of the Boulevard

The computed overall beach cleanliness from a total of 3,978 macro-plastic items over the 12,000 m^2 land area sampled was 6.6, which means that the boulevard is moderately polluted.

The clean coast index showed that the municipality of Vinzons is clean, with a CCI value of 4.48, whereas Mercedes (8.42), Daet (5.86) and Talisay (7.76) are moderately polluted.

In terms of barangay, the values were as follows: Awitan (3.84), Del Carmen (3.72), Calangcawan Sur (4.24) and Calangcawan Norte (4.72). The barangays of Del Rosario (9.52), San Roque (7.32) and Bagasbas (7.88) are moderately polluted, and San Jose (11.8) is considered dirty (*Table 3*).

DISCUSSION

In general, the majority of macro-plastic items found along the boulevard were associated with food products, accounting for 76.9%, consisting of beverage and food packaging as well as utensils. The plastic waste items, including toiletries, are associated with coastal tourism-related activities as the area is a popular destination for both tourists and residents.

Marine litter visible on beaches is often the product of littering and dumping (Wang *et al.,* 2020), coming from coastal recreational activities (Pham *et al.*, 2014), fishing, recreation, beach visitors, coastal inhabitants and beach vendors (Rakib *et al.*, 2022). According to Khadanga *et al.* (2022), tourism has a greater impact on the beach in terms of pollution when compared with local sources. Additionally, beverage-related items were the most frequent type of plastic litter across all beaches, ranging from 40%–63% of all plastic debris by count (Chitaka and von Blottnitz, 2019). Additionally, Camarines Norte is surrounded by key fishing grounds: Lamon Bay, San Miguel Bay and the Philippine Sea (Biag *et al.*, 2022a), and plastic wastes from fishing gear items ranked 3rd in terms of quantity. Aside from the regular fishing activity, sports fishing is highly popular along the boulevard, and fishing equipment is frequently found on beaches (Thiel *et al.*, 2013; Topçu *et al.*, 2013). The lowest quantity of macro-plastic items was found for household-related plastic waste as this is a coastal road with only a few nearby communities. There are only few houses along the boulevard, and open fields, commercial establishments and street vendors are dominant. In terms of plastic waste composition, plastic bottles, followed by plastic cups, are the most regularly generated types of beverage plastic waste on the boulevard in terms of quantity, which can be attributed to the consumption of various beverages.

Table 1 – Clean coast index (CCI) scale and numeric values

Coast index	Very clean	Clean	Moderate	Dirty	Extremely dirty
Numeric index	0–2	2–5	5–10	10–20	20+

Table 2 – Macro-plastic waste density (CM) per barangay and municipality

Municipality	Mercedes		Daet		Talisay		Vinzons	
Barangay	**DR**	**SR**	**B**	**A**	**DC**	**SJ**	**CS**	**CN**
Total MP items/barangay	714	549	591	288	279	885	318	354
Density (CM)/ barangay	0.48	0.37	0.39	0.19	0.19	0.59	0.21	0.24
Density (CM)/ municipality	0.84		0.59		0.78		0.45	

Note: Barangay, DR - Del Rosario; SR - San Roque; B - Bagasbas; A - Awitan; DC - Del Carmen; SJ - San Jose; CS - Calangcawan Sur; CN - Calangcawan Norte

Table 3 – Beach cleanliness statuses of the barangays and municipalities

Barangay	DR	SR	B	A	DC	SJ	CS	CN
Total	714	549	591	288	279	885	318	354
CCI values/barangay	9.52	7.32	7.88	3.84	3.72	11.8	4.24	4.72
CCI index	M	M	M	C	C	D	C	C
CCI values/municipality	8.42		5.86		7.76		4.48	
CCI index	M		M		M		C	

Note: Barangay, DR - Del Rosario; SR - San Roque; B - Bagasbas; A - Awitan; DC - Del Carmen; SJ - San Jose; CS - Calangcawan Sur; CN - Calangcawan Norte. CCI index, D - Dirty; M - Moderate; C - Clean

The highest quantity of food packaging plastic waste is from junk food wrappers, followed by transparent plastics carried by visitors or purchased from nearby establishments, street vendors or city stores. Juice wrappers used as packaging for juice powders were less frequently found. Drinking straws are the most food-utensil-type plastic items because of the significant presence of liquid drinks served along the boulevard, as opposed to plastic utensils used during meals in dine-in restaurants located along the boulevard. The high number of drinking straws can be explained by the high number of individuals carrying liquid beverages along the boulevard or bought at food outlets. Most of the toiletry plastic waste is from diapers and shampoo sachets, associated with swimming activities, whereas diaper waste comes from babies and pets carried during swimming or family visits. Perfume containers, toothbrushes and toothpaste caps accounted for a lower proportion of toiletry plastic and are associated with water recreational activities. Styrofoam floats are the most common types of floats in fishing nets, hooks and lines, and produce the most plastic waste. Aside from fishing, seaweed farming can be another source of Styrofoam floats as it is popular in the area as shown in studies (Biag *et al.,* 2022b, c).

In contrast, monofilament nylon was found less frequently as it is highly resilient and used mostly in tying; because of its high durability, it hardly is broken or lost during fishing operations. Lastly, household plastic waste mainly comes from detergent bottles, which are used as liquid stain removers during laundry. Plastic toys, shoe glue

containers, hard plastics, cigarette filters and wallpaper foams were found at the lowest quantities.

In terms of quantity, the municipality of Mercedes has the highest density of macro-plastic waste, particularly in the barangay of Del Rosario, followed by Talisay, primarily in the barangay of San Jose. The high density of plastic waste in Mercedes is due to nearby residents along the coastal boulevard. The high density in Talisay, particularly in San Jose, is due to the large number of visitors, nearby street vendors and food establishments, gaining more popularity than other sites along the boulevard. Generally, the macro-plastic waste density in the boulevard was 0.3 litter items of plastic per m^2, with the highest density in the municipalities of Mercedes (0.84), Talisay (0.78), Daet (0.59) and in the barangays of San Jose (0.59), Del Rosario (0.48) and Bagasbas (0.39), indicating that plastic wastes density is higher in areas which are popular tourist destinations and have continuous and well-developed coastal roads with beach spots for swimming, picnics and other recreational activities.

The boulevard's overall beach cleanliness status is 6.6 (moderate). Apart from Vinzons, where the coastal road is discontinuous, the coastal road connecting Mercedes, Daet and Talisay is a developed coastal road and the area most visited, resulting in moderate to dirty conditions. The barangays of Awitan, Del Carmen, Calangcawan Sur and Norte are considered clean, Del Rosario, San Roque and Bagasbas are considered moderately polluted, and San Jose is considered dirty. The moderate to dirty conditions are due to the quantity of people visiting the area, the type of establishments and the activities performed. In particular, San Jose is the place where street sellers are more prevalent than in other barangays, resulting in a higher number of visitors, such as in Bagasbas in Daet. Hayati *et al.* (2020) stated that uncontrollable tourism waste can increase and result in "extremely dirty" areas.

Most of the macro-plastic wastes found in this study are from littering and regarded as “social plastics”. This was also observed for one of the longest beaches in the world due to inadequate solid waste management practices and a lack of environmental awareness among beachgoers (Rakib *et al.*, 2021). Policies, especially in the form of an ordinance prohibiting the use of macro-plastics along the boulevard and littering, are necessary to prevent plastic pollution of the marine environment. The Philippines’ primary law on solid waste management is the Republic Act. No. 9003, otherwise known as the Ecological Solid Waste Management Act, enacted in 2000 (OGRP, 2001). However, despite the presence of such a law, the indiscriminate dumping of plastics continues and adversely affects public health and the environment (Eisma-Osorio, 2021). Effective solid waste management measures in Camarines Norte (Azuelo *et al.*, 2016) are concentrated at the household or establishment level. Although there may be some local legislation or ordinances in place banning single-use plastics, the Philippines have no nationwide ban on single-use plastics (Eisma-Osorio, 2021). To address the issue of plastic waste accumulation in the marine environment, the government should first actively address it by passing laws to regulate its sources

(Venkatramanan *et al.*, 2022) and to be able to develop effective policies that at least lessen the effects (Bonanno *et al.*, 2022b). Therefore, a policy regulating the use of macro-plastic along the boulevard should be institutionalised by the local government units and provinces to protect the marine environment and prevent further health problems and marine plastic pollution.

CONCLUSIONS

The macro-plastic items are mainly derived from hand-carried food by visitors as well as generated waste from food establishments and street vendors. The density of macro-plastics is influenced by the type of area and the activities performed. Areas known as popular tourist destinations and with continuous access to coastal roads, with beach spots for swimming and picnics, tend to have a high density of plastic waste. The cleanliness of the municipalities and corresponding barangays is mostly influenced by the coastal boulevard, which has a high number of visitors, activities, establishments and street vendors. As a result of the existing and future development of the boulevard, the accumulation of macro-plastic waste may grow due to the influx of people in the area. Thus, if macro-plastic waste generation is not managed and controlled, the current moderate pollution status is expected change to a high or extremely high pollution status in the near future. Despite existing initiatives such as weekly beach trash cleanings along the boulevard, macro-plastic waste is still abundant and will continue to increase as the number of people increases and as tourism activities boom. Hence, an ordinance regulating the use, littering and carrying of plastic along Cory Aquino Boulevard and providing penalties for violation thereof is necessary to protect the marine environment, human health, and sustainable economic development.

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