Marine litter pollution along sandy beaches of Can Gio coast, Ho Chi Minh City, Vietnam

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Abstract. Marine debris is a significant threat to the marine environment, human health and the economy in Can Gio island, Vietnam. In this study, we conducted beach litter surveys to quantify and characterize marine litter from six beach transects in this region for the first time using the OSPAR beach litter monitoring guideline. A total of 29,456 items weighting 529,432 g was recorded from 12 surveys in two monitoring campaigns in December 2019 (dry season) and in June 2020 (rainy season). Plastic was the most abundant type of litter in terms of quantity (a total of 26,662 items) and weight (325,606 g), followed by paper and cardboard, cloth, wood, metal, glass and ceramics, rubber and other items. Meanwhile, ropes (less than 1 cm in diameter) and plastic bags accounted for the major parts of sampled plastic items, i.e., 20.18% and 14.46%, respectively. In general, a higher percentage of marine litter, particularly the fishing related items, was found in the rainy season than in the dry season, possibly due to increased fishing and aquaculture activities. In contrast, a reduction pattern of the single use plastics in the rainy season might be due to the decreased tourism activities during the Covid pandemic period. This study not only showed the magnitude of litter pollution, but also provided valuable information that could help decision making to better control and reduce marine litter in the region. In addition, insights from this study indicate that there is an urgent need to design collection, reuse and recycling programs in the area. The collected recyclables, specially plastics, will be a great source of materials for recyclers in a circular economy achieving sustainable development goals.
1. Introduction

Marine debris (or marine litter, ML) is defined as “any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment” [1]. For decades, ML is increasingly accumulated in various marine environment, such as sea surface, sea floor, water column, and beaches [2], [3], [4]. It could take hundreds of years to degrade and remove ML from the natural environment. Most studies have shown that plastics are the most common source of ML, accounting for 75% of global average ML pollutants [2], [5]. Furthermore, plastic issues have currently received increasing attention since they can break down into small pieces and thereafter into microplastics that have potential impacts on marine habitat [6]. Until now, ML are found all over the world, making it a global problem. Education and raising public awareness could be one of the most effective ways to reduce ML; however, monitoring ML in order to improve our knowledge is also of utmost necessity for a more effective pollution control.

Asian countries with long coastline and wide water areas are major waste contributors globally. Vietnam is ranked the fourth most polluting country after China, Indonesia and the Philippines. In 2010, Vietnam produced 1.83 million tons of plastic wastes, of which 0.28 – 0.73 million tons ended up in the ocean [7]. In order to decrease the pollution pressure of marine plastic litter, the Prime Minister has issued a National Action Plan (Resolution 36-NQ/TW dated October 22, 2018) for marine plastic waste management until 2030 with the following key contents: (i) implement effectively Vietnam’s initiatives and commitments to the world to address plastic waste issues, specially ocean plastic wastes, ensure the prevention of plastic waste sources, wastes on land and activities at sea, and target to make Vietnam a pioneer in the region in reducing marine plastic wastes; (ii) contribute to promoting the recovery, recycling, and reuse of plastic wastes in Vietnam, and (iii) raise the awareness, behavior and habits of the community and society of using disposable plastic products and non-biodegradable plastic bags. There are some studies on macroplastic in Saigon river, upstream of Can Gio region [8-10]. However, the scientific data regarding the ML pollution in Vietnam are still scarce, but some investigations carried out by NGO show that marine plastic litters are the most abundant artificial polymer materials along beaches in Vietnam [11], [12].

The composition, quantities and distribution of ML in the coastal regions of Vietnam is still not well defined. The main reasons for this are: i) lack of standard monitoring and assessment methods, ii) no appropriate legal framework to support researchers as well as managers for ML pollution investigations. In order to understand the current state of ML pollution in Vietnamese coastline, a case study was conducted in Can Gio beaches. The objective of this study was to conduct a beach litter survey to quantify the litter in a specific sea area in order to evaluate the potential ML pollution threats to the coastal environment of Vietnam.

2. Study area and methods

2.1. Study area

Can Gio is a one of the five main suburban districts located in southeast of Ho Chi Minh City (HCMC), with more than 20 km of coastline running in the southwest - northeast direction. There are large estuaries at Can Gio such as Long Tau, Cai Mep, Go Gia, Thi Vai, Soai Rap, and Dong Tranh Rivers. Can Gio is the only district of the city which is bordered by the sea, i.e., an island separated from the surrounding with a favorable geographical position. The location of Can Gio District was from 106°46’12” to 107°00’50” East longitude and from 10°22’14” to 10°40’00” North latitude [13], [14]. The North area is separated from Nha Be District by Soai Rap River, the South border on the East Sea, the West border on Soai Rap River, the Northeast is separated from Nhon Trach district, Dong Nai province by Long Tau river, and the Southeast border on Tan Thanh district, Ba Ria-Vung Tau bordered by Thi Vai river.
The climate of Can Gio is typically monsoonal with two distinct seasons [13], [14]. The dry season is from December to April of the next year and the rainy season is from May to November. Can Gio is influenced by two main wind directions and mainly the West - Southwest and North - Northeast monsoons. The west-southwest wind from the Indian Ocean blows in the rainy season, from June to October, with an average speed of 3.6 m/s and the strongest wind in August, with an average speed of 4.5 m/s. The North-Northeast wind blows from the East Sea in the dry season, from November to February, with an average speed of 2.4 m/s. In addition, there is a wind gust, from the south to the southeast, from March to May with an average speed of 3.7 m/s.

2.2. Methods
The study was conducted on six sandy beaches of Can Gio, which are located in recreational and aquaculture areas (bivalve culture) (Figure 1). Specific details of sampling area and characteristics of the six sampling locations are shown in Table 1.

**Table 1.** Beach locations surveyed in Can Gio, including number of surveys conducted and a brief description of the locations.

| Site             | Coded site | Replicas | Description                                      |
|------------------|------------|----------|--------------------------------------------------|
| Can Thanh Town   | VT1        | 2        | Near park area, tourists and local resident use areas |
| Can Thanh Town   | VT2        | 2        | Used to be an aquaculture area                   |
| Can Thanh Town   | VT3        | 2        | Aquaculture area                                |
| Long Hoa Commune | VT4        | 2        | Recreational area                               |
| Long Hoa Commune | VT5        | 2        | Aquaculture area                                |
| Long Hoa Commune | VT6        | 2        | Aquaculture area                                |

![Google Earth Image](image_url)  
**Figure 1.** Study area and locations for beach litter sampling
According to the guidance of OSPAR [15], the selection of coastline sampling locations was based on the following criteria:

- Sand or gravel beaches
- No breakwater or jetty affecting local traffic, accumulating or inhibiting debris deposition
- Minimum length of 100 m parallel to the water (i.e., measured along the water's edge)
- No regular cleaning activities.

These locations were surveyed in typical months of the dry season (28th and 29th of December) in 2019 and the rainy season (6th and 7th of June) in 2020, on these days, it was clear, sunny and windy. Each survey consisted of a transect of 100 m length parallel to seawater line and 25 m width extended from the upper beach limit (bushes or rock). In each transect, all non-natural anthropogenic items larger than 0.5 cm on the surface were collected into bags, kept at ambient temperature and transferred to the lab for further processing. In the lab, each bag was emptied on a clear surface, then all of the items were cleaned from the sand and each item was assigned to a litter category according to OSPAR: (i) Recognizable item: whole items that match the category description and/or fragments that are unmistakably from things that fit the category description; (ii) Other items: items clearly recognizable, but lack of designated litter categories; and (iii) Fragments: unidentified broken items classified by material, plastic and polystyrene fragments were sorted into size categories. In addition, similar items were also grouped into single use plastics (SUP), fishing related items (FR) and plastic/polystyrene pieces (PP) according to Hanke et al. [16]. After sorting, the number and dry weight of items per category were recorded.

2.3. Data analysis

We surveyed parameters including density of items (number of items per m² and weight of items per m²), the Clean Coast Index (CCI) [17] and the percentage of single use plastics (%SUP), fishing related items (%FR) and plastic/polystyrene pieces (%PP) were calculated based on the number of plastic items collected. Item density was calculated as follow:

\[ D = \frac{N}{w \times l} \]  

where D is the density of items, N is the total number/weight of items on surveyed transect, w is the width of the transect (25 m), and l is the length of the transect (100 m). As for beach cleanliness, we applied the CCI ranking using the following equation:

\[ CCI = \frac{TL}{TA} \times K \]  

where TL is the total items counted on a surveyed transect, TA is the total area of a transect, and K is a constant factor which was assigned a value of 20. Beaches were classified from very clean to extremely dirty based on the litter condition on the beach (Table 2).

| Value   | Coast index | Visual assessment                                                   |
|---------|-------------|-------------------------------------------------------------------|
| 0 – 2   | Very clean  | no litter is seen                                                  |
| 2 – 5   | Clean       | no litter is seen over a large area                                 |
| 5 – 10  | Moderate    | a few pieces of litter can be detected                             |
| 10 – 20 | Dirty       | a lot of debris on the shore                                       |
| 20+     | Extremely dirty | most of the beach is covered with plastic debris                  |

Source: [17]

In order to determine whether number of items varied significantly in different (dry and rainy) seasons and locations, one-way ANOVA tests were conducted. Prior to the statistical analyses, log transformation was applied to stabilize the variances. Normal distribution and variance homogeneity were checked before performing one-way ANOVA tests. When differences were detected in ANOVA
tests, post-hoc Tukey’s tests were applied. All statistical data analyses were performed using R Statistical Software (version 3.6.1) (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Marine litter abundance and composition

A total of 29,456 items weighting 529,432 g was collected along six beach transects during the two sampling periods, and were classified into 8 major groups. Litter composition could be found on Supplementary Table S1 and abundance on each beach at Can Gio is shown in Table 3, meanwhile percentage of SUP, FR and plastic/polystyrene pieces (PP) are listed in Table 4. The highest percentage of SUP was found at VT1 in the dry season (85.14%). Highest percentage of PP was also recorded in VT1 but in the rainy season (45.11%), of which plastic/polystyrene pieces of size 2.5 – 50 cm was absolutely predominant. The highest percentage of FR (42.93%) was recorded at VT2 in the rainy season.

Overall, the number of items ranged from 294 to 6,779 items per transect, with a mean of 2,455 ± 1,681 items per transect. In term of the weight, the amount of beach litter varied from 8,294 g to 110,345 g per transect, with a mean of 44,177.67 ± 29,161.44 g per transect (Table 4). The high standard deviation values show that beach litter abundance varied substantially in both space and time at each location. The number of items on the least polluted beaches (294 at VT1 in rainy season) and the most polluted ones (6779 at VT4 in rainy season, Table 3) differed by an order of magnitude. Plastic was the most abundant group of ML found on the beaches, representing 89.92% (ranging from 75.41 to 96.34%) of sampled items. Paper and cardboard were the second abundant group (3.74%), followed by cloth (3.01%), wood (1.57%), metal (0.81%), glass and ceramics (0.45%), rubber (0.40%) and other items (0.02%).
Table 3. Abundance (items per transect) and weight (g per transect) of litter collected from six beaches during two sampling periods (on December 2019 and June 2020)

|                  | VT1 Dry season | VT1 Rainy season | VT2 Dry season | VT2 Rainy season | VT3 Dry season | VT3 Rainy season | VT4 Dry season | VT4 Rainy season | VT5 Dry season | VT5 Rainy season | VT6 Dry season | VT6 Rainy season | Mean | SD |
|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|-------|----|
| Abundance (number of items per transect) |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |       |    |
| Artificial polymer materials | 1193          | 266              | 878            | 3712             | 1135          | 3131             | 1960           | 6021             | 2880           | 2003             | 798            | 2685             | 2221.83 | 1531.43 |
| Rubber           | 5              | 0                | 4              | 1                | 8              | 2                | 17              | 9                | 19             | 24               | 6              | 2                | 8.08   | 7.49 |
| Cloth/textile   | 263            | 3                | 9              | 28               | 34             | 16               | 77              | 169              | 75             | 70               | 21             | 23               | 65.67  | 73.99 |
| Paper/Cardboard | 43             | 11               | 29             | 112              | 39             | 40               | 103             | 443              | 184            | 91               | 41             | 73               | 100.75 | 112.80 |
| Processed/worked wood | 1          | 7                | 15             | 46               | 28             | 45               | 28              | 123              | 47             | 21               | 23             | 57               | 36.75  | 30.73 |
| Metal            | 75             | 4                | 8              | 5                | 6              | 3                | 16              | 6                | 9              | 2                | 5              | 11               | 12.50  | 19.20 |
| Glass/ceramics  | 2              | 3                | 7              | 12               | 3              | 13               | 10              | 8                | 7              | 14               | 2              | 27               | 9.00   | 6.79 |
| Other (unidentified) | 0            | 0                | 0              | 0                | 0              | 0                | 0               | 0                | 0              | 0                | 0              | 0                | 0.42   | 1.38 |
| Total            | 1582           | 294              | 950            | 3916             | 1253           | 3250             | 2216           | 6779             | 3221           | 2225             | 896            | 2878             | 2455.00 | 1681.06 |
| % Plastics       | 75.41          | 90.48            | 92.42          | 94.79            | 90.58          | 96.34            | 88.45          | 88.82            | 89.41          | 90.02            | 89.06          | 93.29            | 89.92  |     |

| Weight (g per transect) |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |       |    |
| Artificial polymer materials | 10650         | 6994             | 13502          | 37270            | 15034          | 34580            | 27287          | 56000            | 30499          | 3677.5           | 8650           | 48365           | 27133.83 | 16230.50 |
| Rubber             | 600            | 680              | 300            | 1110             | 50             | 1055             | 3150           | 4102             | 4825           | 1650             | 300            | 1485.17         | 1641.32 |      |
| Cloth/textile     | 6352           | 10               | 375            | 1475             | 1505           | 1950             | 5650           | 11310            | 4750           | 10995            | 1655           | 4650            | 4156.42 | 3718.78 |
| Paper/Cardboard   | 1370           | 55               | 150            | 1300             | 155            | 575              | 360            | 6560             | 675            | 1520             | 300            | 1250            | 1189.17 | 1772.50 |
| Processed/worked wood | 300          | 1000             | 1112           | 6055             | 3905           | 13375            | 3655           | 31350            | 8430           | 4200             | 3500           | 15670           | 7714.33 | 8852.43 |
| Metal             | 3380           | 35               | 475            | 200              | 755            | 300              | 850            | 625              | 125            | 125              | 150            | 700             | 643.33  | 906.62 |
| Glass/ceramics    | 1850           | 200              | 1360           | 1450             | 125            | 3500             | 655            | 1350             | 1550           | 2550             | 250            | 3825            | 1555.42 | 1224.67 |
| Other             | 0              | 0                | 0              | 0                | 0              | 0                | 0              | 0                | 0              | 0                | 0              | 0                | 0.00   | 1039.23 |
| Total             | 24502          | 8294             | 17654          | 48050            | 22589          | 54330            | 43112          | 110345           | 50151          | 60990            | 16155          | 74760           | 44177.67 | 29161.44 |

Note: SD is the standard deviation (n = 12)
3.2. Comparisons of ML compositions, quantities and distribution among locations

A distinctive variation pattern in the ML quantity was found among sites and seasons (Table 3, Table 4). The highest amount of ML was observed at the VT4 location whereas the lowest was observed at the VT1 during the rainy season (Table 3). The mean ML count density was twice higher during the rainy season than during the dry season. Particularly, the litter count density fluctuated in the range from 0.36 to 1.29 items/m² (mean of 0.67 items/m²) and from 0.12 to 2.71 items/m² (mean of 1.29 items/m²) in the dry and rainy seasons, respectively. Beach litter by weight was 11.56 g/m² in the dry season, ranging from 6.18 g/m² in the VT6 to 20.06 g/m² in the VT5, and 23.73 g/m² in the rainy season, ranging from 3.32 g/m² in the VT1 to 44.14 g/m² in the VT4 (Table 4). Except for the VT1 location, an increasing pattern was observed in most of other sampling sites in both beach litter count density and beach litter by weight in the rainy season. However, in the VT5 location, there was a decrease in the count density but an increase in weight of ML during the rainy season, which was due to the increase in size of litter that also lead to the increase in the overall weight. The other four areas reported an increase in both of the count density and weight in the rainy season compared to the dry season. According to the CCI, only the VT1 in rainy season was found to be clean, meanwhile VT2 and VT6 in the dry season were defined to be moderately dirty, and the remaining locations were classified either dirty or extremely dirty in both seasons (Table 4). Regarding the SUP quantities, the highest percentage was recorded at the VT1 in the dry season (85.14%). This location is closed to a park, with a lot of recreational activities from the local community and tourists, and it is also close to the river mouth, which creates a close pathway of pollution transports of inland wastes. Most of the SUP was plastic bags and crisps packets/sweets wrappers. In general, except VT4 and VT6, SUP decreased in the remaining locations in the rainy season compared to the dry season, which may be due to the decreased number of tourists visiting Can Gio during the Covid-19 pandemic period. The highest percentage of FR items (42.93%) was recorded at the VT2 in the rainy season and most of items were strings and cords with a diameter of less than 1 cm that were buried in the sand and were deteriorating. The highest percentage of PP was found at the VT1 (45.11%) in the rainy season, where the abundant pieces of sizes 2.5–50 cm accounted for the majority and were originating from Styrofoam food containers. Overall, the SUP decreasing trend in the rainy season could be attributed to fewer tourists due to the Covid-19 epidemic. However, the pattern of FR wastes tends to be the opposite, i.e., increasing in the rainy season, possibly due to increased fishing and aquaculture activities during the previous months of dry season.

There was no significant difference in the collected data during the dry season between locations (ANOVA, F_{5,276} = 1.38, p = 0.23). However, in the rainy season, there was a significant difference in sampled items (ANOVA, F_{5,250} = 6.06, p < 0.05), and ML densities varied significantly among the
location VT1 with the rest five locations (post-hoc Tukey’s test, $p < 0.05$). Particularly, there was no significant difference between the results during both the dry and the rainy seasons in some locations, including VT3 (ANOVA, $F_{1,84} = 1.71$, $p = 0.19$), VT5 (ANOVA, $F_{1} = 0.03$, $p = 0.85$), and VT6 (ANOVA, $F_{1,80} = 2.30$, $p = 0.13$); however, significant differences in collected ML items were found at locations VT1 (ANOVA, $F_{1,75} = 4.95$, $p = 0.03$), VT2 (ANOVA, $F_{1,92} = 4.55$, $p = 0.04$) and VT4 (ANOVA, $F_{1,102} = 7.51$, $p = 0.01$) between the two seasons. High abundance of ML was observed in all sites for both seasons, except VT1 in the rainy season. At the VT1, the amount of litter in rainy season decreased sharply despite the fact that it is located in a close proximity to the river mouths, and rivers are considered as land-based transports of plastic litter. One explanation to this might be due to the fact that this location is close to a park and most of litter sources came from recreation activities; however, due to Covid-19, the park was closed until the time of the survey and such kind of litters were greatly reduced. There is an increase in litter during the rainy season in most of the locations, most likely due to an increase in precipitation and/or wind leading to increase number of items linked to increased discharge rate from rivers and also increase in fish and aquaculture activities in these locations.

3.3. Top ten ML items

The top ten items for Can Gio beaches are shown in Table 5, all of them are plastics and accounted for 77.9% of found items. The top item, string and cord (diameter less than 1 cm), was mainly small pieces rather than whole items, they were found mostly in sand under a deteriorated state and accounts for 1/5 of the total number of collected items. Seven items out of the top ten in Can Gio beaches are single-use plastics.

| Rank | Item                                                | Percentage |
|------|-----------------------------------------------------|------------|
| 1    | String and cord (diameter less than 1 cm)          | 20.18      |
| 2    | Shopping Bags incl. pieces                         | 14.46      |
| 3    | Plastic/polystyrene pieces 2.5 cm < 50 cm         | 11.76      |
| 4    | Crisps packets/sweets wrappers                     | 10.55      |
| 5    | Cups and cup lids                                 | 4.70       |
| 6    | Small plastic bags, e.g. freezer bags incl. pieces | 4.51       |
| 7    | Cutlery and trays                                 | 3.59       |
| 8    | Plastic caps/lids drinks                          | 3.22       |
| 9    | Straws and stirrers                               | 2.51       |
| 10   | Other plastic/polystyrene items (identifiable)    | 2.42       |
|      | Total percentage                                   | 77.9       |

4. Discussion

The results obtained from this study showed that plastic varied between 75.41% - 96.34% by count, which was higher than the global average (75%) [2], [5] and 43.46% - 84.32% by weight. These results are in line with the findings obtained from other surveys around the world [18], [19], [20]. The presence of plastics could have great potential impacts on ecosystems since they are persistent in the environment and could break into smaller pieces (microplastics), causing far greater harm than the debris itself. This means plastics could be transported to further distance and more into the food chain; in addition, additives compounds, plasticizers and adsorbing-desorbing hazardous chemicals could leach out and be absorbed by victim animals [21], [22], [23]. Therefore, an urgent preventive measure is needed to reduce plastics in the environment.

The present findings also showed that there was an increasing trend in the amount of ML in the rainy season compared to the dry season, which could be due to the weather and/or climate conditions [24]. During the rainy season, high intensity of wind and rain causes flooding in urban areas, which washes down more plastic litters and other debris into rivers [25], [26]. There are evidences that rivers transport waste from land to the ocean [27], [28], [29] and Can Gio is located close to river mouths;
therefore, the amount of litters increased in the rainy season is justifiable. In addition, high cloud coverage and cooler ambient temperature in Can Gio lead to slow degradation of ML. On the other hand, during the time between February and April, there was Covid epidemic that resulted in the low frequency of human appearance (waste pickers, beach clean-up activities, etc.) on beaches, which might also explain the high number of litters during this period.

ML results also suggested that both land-based activities and sea-based activities are major contributors since one-fifth of collected litters were string and cord, mainly from aquaculture and fishing activities in the area; unlike some studies which showed that land-based activities and foreign litters were major contributors [30], [31], [32], [33], [34]. In this study, most of remaining litters were domestic products or routinely found items in shops.

ML in Can Gio beaches were derived from various sources and a majority of them were SUP (plastic bag, crisp/sweet packets, disposable cutlery, etc.). For example, string and cord were extensively used by local fishermen and seafood farmers; plastic bags could come from daily use or were discarded directly on the beaches by visitors. Food-related SUPs (cups, crisp/sweet packets, disposable cutlery, straw) mostly came from beach visitors. Plastic/polystyrene pieces found on beaches were primarily originated from Styrofoam food containers, which are used extensively in inland and beach visitors, and part of them were from blocks of Styrofoam foam which are used by local fishermen as float for their nets.

ML abundance was compared with previous studies from Small Island Developing States and other islands in Pacific region (Table 6). ML was calculated as number of items per square meter of studied areas. Although ML value was higher in Can Gio, it was not substantially different from those of French Polynesia, and compared to other sites in Pacific region, litter abundance in Can Gio was still low. This may due to low population density of the area when compared to other sites of studies like Indonesia, where high amount of waste was mismanaged [7]. However, the abundance of ML is within the range of values for SIDS in Pacific region [30], [35]. However, there were differences in the types of litter in different studies, of which plastic was still the most dominant type of ML in all studies. When comparing to other studies in Vietnam [11], [12], we have difficulties since these studies only focused on beach clean-up aspect and they did not publish data on litter items as well as amount of item collected.

Table 6. Abundance of marine litter in different studies. Data were adapted from [30]

| Area                        | Items/m² | Study          |
|-----------------------------|----------|----------------|
| Can Gio beach               | 0.98 (0.12 – 2.79) | This study     |
| Solomon Islands (Guadalcanal Island) | 2.5 (0.38 – 6.2) |                |
| Vanuatu (Efate Island)      | 1.25 (0.38 – 3.54) |                |
| French Polynesia Mo'Orea Island | 0.9 (0.05 – 2.03) |                |
| French Polynesia Tahiti Island | 0.9 (0.22 – 1.85) |                |
| Bootless Bay, Papua New Guinea | 4.5 (1.2 – 11.8) |                |
| Cocos (Keeling) Islands, Australia | 21.6 (4.72 – 55.67) |                |
| Henderson Islands           | 239 (max 671.6) |                |
| Tasmania Island             | 0.016 – 2.03 |                |
| Indonesia                   | 41.6     |                |

Top ten items were compared between different beaches (Table 7) in the Pacific Ocean region, and the results reflected the characteristics of areas. Top ten items were very similar to those found in Vanuatu and Solomon Islands [30] and French Polynesia [35]. The similarity of top ten items in these regions may be due to the fact that the main source of ML is from land-based activities. Moreover, this study also showed that a large amount of ML originated from sea-based activities, which is different from the SIDS in Pacific region where most ML came from land-based activities. In this study, the top ten items were all plastic groups and belonged to fish related items as well as single use plastics, while in other studies, there were products belonging to groups other than plastic (e.g., glass, metal). Overall, the results in this study showed the similarity of ML sources with other studies in the Asia Pacific region; these sources were mostly related to land-based activities.
Table 7. Comparisons of top items found in this study and in Vanuatu and Solomon Islands and in French Polynesia. Items are ranked by abundance

| Rank | This study                          | Solomon Island          | Vanuatu Island         | French Polynesia                |
|------|-------------------------------------|-------------------------|------------------------|---------------------------------|
| 1    | String and cord (diameter less than 1cm) | Foam food packs         | Glass broken           | Glass beverage bottle and fragments |
| 2    | Shopping Bags incl. pieces           | Polysterene pieces 0 – 2.5 cm | Plastic pieces 0 – 2.5 cm | Hard plastic fragments |
| 3    | Plastic/polystyrene pieces 2.5 cm > < 50 cm | Drink bottles, containers, drum | Plastic pieces 2.5 – 50 cm | Sheet plastic fragments |
| 4    | Crisps packets/sweets wrappers      | Cigarette butts         | Polystyrene pieces 2.5 – 50 cm | Cigarette butts and filters |
| 5    | Cups and cup lids                   | Drink cans              | Crisp and sweet packets | Tile fragments                |
| 6    | Small plastic bags, e.g. freezer bags incl. pieces | Glass broken           | Polystyrene pieces 0 – 2.5 cm | Sheet plastic food and confectionary wrappers |
| 7    | Cutlery and trays                   | Plastic pieces 0 – 2.5 cm | Cigarette butts        | Polystyrene fragments         |
| 8    | Plastic caps/lids drinks            | Crisp and sweet packets | Caps and lids          | Hard plastic beverage bottle caps |
| 9    | Straws and stirrers                 | Ice lolly plastic containers | String and cord (diameter < 1 cm) | Rubber strapping/inner tubes |
| 10   | Other plastic/polystyrene items (identifiable) | Caps and lids              | Lolly sticks          | Metal beverage caps           |

The results of this study could be useful for addressing preventive measures of ML. Since a large amount of found litters was SUP; a ban on plastic bags, food packaging especially Styrofoam food container is suggested. This measure could help to reduce 3% of ML in Vanuatu and 17% of ML in Solomon Islands [30]. SUP is known as an easily break-down plastics in the environment [36], especially in coastal area [37]. The release of large amounts of SUP microplastics into the environment of Can Gio beaches might affect the bivalve culture activities in this region, as it makes easier to introduce microplastics through ML degraded wastes into the human food chain. Therefore, strong preventive measures of SUP in Can Gio are needed. This study also showed that waste mismanagement coupled with low awareness of people (both tourists and residents) are the main contributors of ML in Can Gio.

The effectiveness of a preventive measure should be monitored overtime; therefore, it is necessary to apply a standardized method for beach litter monitoring and data collection and comparison with other data in the world. This study used OSPAR guideline and showed the applicability of this method for the future applications; however, it is important to modify the protocol and expand the list of litter categories to include local-specific items, adding more value for waste management as well as providing preventive measures. In addition, understanding how the new country-specific ML categories fit within the original OSPAR list is critical to maintain comparability in the assessment approach.

5. Conclusion

This research is the first to document the abundance and composition of beach litter along Can Gio coast. For the first time, an OSPAR protocol was used in this region in order to gather data of beach litter to support the development of marine litter action program.

Through twelve surveys along sandy beaches of Can Gio coast, litters were classified into eight major groups (plastic, rubber, fabric, paper, wood, metal, glass, combination and other). Our study
showed that plastics was the most abundant group and accounted for 89.9% of found items, in which rope (diameter less than 1 cm) and plastic bag contributed the most. The rest of plastic litter was mostly single use plastics. Results of this study demonstrated that both sea-based activities and land-based activities are significant contributors to beach litter in Can Gio. Therefore, an active program to control and reduce litters from these sources is necessary.

This study also showed that it is possible to adopt an international protocol to region in order to collect data on marine litter, and sources of marine litter could be identified for future legislations in this region. However, additional items should be added to the OSPAR category list to allow global comparisons and to measure the effectiveness of active programs in terms of reducing marine litter in future assessments.

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### Supplementary Table S1. Macro litter classification for Can Gio beach. Empty spaces represent zero values.

|                 | VT1 Dry season | VT1 Rainy season | VT2 Dry season | VT2 Rainy season | VT3 Dry season | VT3 Rainy season | VT4 Dry season | VT4 Rainy season | VT5 Dry season | VT5 Rainy season | VT6 Dry season | VT6 Rainy season |
|-----------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|
| Plastics        |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Shopping Bags   | 338            | 39               | 121            | 291              | 193            | 724              | 197            | 942              | 466            | 231              | 42             | 665              |
| incl. pieces    |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Small plastic   | 93             | 1                | 16             | 75               | 63             | 145              | 86             | 339              | 265            | 66               | 4              | 173              |
| bags, *e.g.*    |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| freezer bags    |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| incl. pieces    |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Drink bottles   | 10             | 5                | 12             | 14               | 8              | 25               | 34             | 37               | 10             | 21               | 22             | 33               |
| <= 0.5l         |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Drink bottles   | 1              | 5                | 2              | 5                | 2              | 1                | 2              |                  |                |                  |                |                  |
| > 0.5l          |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Cleaner bottles | 1              | 1                | 2              | 2                | 7              | 3                |                |                  |                |                  |                |                  |
| and containers  |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Food containers | 139            | 6                | 8              | 78               | 17             | 17               | 117            | 50               | 75             | 17               | 50             |                  |
| incl. fast      |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| food containers |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Beach use related | 32            | 2                | 14             | 23               | 21             | 10               | 45             | 11               | 7              | 17               | 13             |                  |
| cosmetic bottles |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| and Jerry cans  |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| (square plastic | 1              | 1                |                |                  |                |                  |                |                  |                |                  |                |                  |
| containers with |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| handle)         |                |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Car parts       | 3              |                  |                |                  |                |                  |                |                  |                |                  |                |                  |
| Plastic caps/lids drinks | 77 | 8 | 55 | 210 | 43 | 31 | 66 | 197 | 89 | 46 | 29 | 95 |
| Plastic caps/lids chemicals, detergents | 9 | 3 |
| Cigarette lighters | 4 | 2 | 5 | 26 | 5 | 12 | 13 | 44 | 4 | 14 | 4 | 18 |
| Cigarette butts and filters | 1 | 44 | 7 | 2 | 15 | 3 | 44 | 1 | 4 | 5 |
| Pens and pen lides | 3 | 1 | 10 | 1 | 3 | 7 | 10 | 5 | 4 | 1 | 5 |
| Item                                | 1  | 2   | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|-------------------------------------|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Comb/hairbrushes/sunglasses         | 1  | 10  | 6  | 35 | 4  | 102 | 107| 147| 387| 26 | 141| 230| 574| 230| 149| 149| 149| 149| 149| 149| 149 |
| Crisps packets/sweets               | 210| 355 | 35 | 4  | 102| 107| 147| 387| 26 | 141| 230| 574| 230| 149| 149| 149| 149| 149| 149| 149| 149 |
| Toys and party poppers              | 18 | 67  | 13 | 198| 107| 147| 387| 388| 82 | 121| 148| 641| 574| 230| 149| 149| 149| 149| 149| 149| 149 |
| Cups and trays                      | 1  | 14  | 18 | 35 | 25 | 15  | 15  | 10 | 35 | 4  | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 |
| Cutlery and trays                   | 67 | 13  | 59 | 188| 107| 147| 387| 388| 82 | 121| 148| 641| 574| 230| 149| 149| 149| 149| 149| 149| 149 |
| Straws and stirrers                 | 1  | 2   | 10 | 5  | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Fertiliser/animal feed              | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Mesh vegetable bags                 | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Gloves (washing up)                | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Gloves (industrial/professional)   | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| String and cord (diameter less than 1cm) | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Nets and pieces of net             | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Floats for fishing nets            | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Strapping bands                    | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Hard hats/Helmets                  | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Shoes/sandals                      | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Foam sponge                        | 1  | 1   | 2  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Category                          | 3  | 10  | 122 | 3  |
|----------------------------------|----|-----|-----|----|
| Plastic/polystyrene pieces 0 - 2.5 cm | 15 | 10  | 122 | 3  |
| Plastic/polystyrene pieces 2.5 cm > < 50 cm | 35 | 120 | 136 | 450 |
| Plastic/polystyrene pieces > 50 cm | 1  | 9   | 2   | 1  |
| Masking tape                     | 1  | 7   | 5   | 11 |
| Telephone (incl. parts)          | 2  | 2   |     |    |
| Plastic flower pots              | 2  | 2   | 1   | 4  |
| Cable ties                       | 2  |     |     |    |
| Diapers/nappies                  | 40 | 3   | 9   | 9  |
| Syringes/needles                 | 2  | 3   | 1   | 4  |
| Medical/Pharmaceuticals containers/tubes | 42 | 2   | 2   | 6  |
| Dog faeces bag                   |    |     |     |    |
| Flip-flops                       | 3  | 2   | 25  | 2  |
| Other plastic/polystyrene items (identifiable) | 5  | 6   | 68  | 83 |
| Total                            | 1193 | 266 | 878 | 3712 |

**Rubber**

| Category                          | 3  | 2  | 1  |
|-----------------------------------|----|----|----|
| Balloons and balloon sticks       |    |    |    |
| Inner-tubes and rubber sheet      |    |    |    |

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| Category                                      | Wheel 1 | Wheel 2 | Wheel 3 | Wheel 4 | Wheel 5 | Wheel 6 | Wheel 7 | Wheel 8 | Wheel 9 | Wheel 10 | Wheel 11 |
|----------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|-----------|
| Rubber bands (small, for kitchen/household/post) | 2       | 2       | 1       | 4       | 4       | 5       | 11      | 12      | 3       | 2         |           |
| Total                                        | 5       | 0       | 4       | 1       | 8       | 2       | 17      | 9       | 19      | 24        | 6         |

**Cloth/textile**

| Category                                      | Wheel 1 | Wheel 2 | Wheel 3 | Wheel 4 | Wheel 5 | Wheel 6 | Wheel 7 | Wheel 8 | Wheel 9 | Wheel 10 | Wheel 11 |
|----------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|-----------|
| Clothing / rags (clothing, hats, towels)      | 162     | 6       | 10      | 22      | 9       | 41      | 60      | 36      | 16      | 14        | 23        |
| Shoes and sandals (e.g. Leather, cloth)      | 2       |         |         |         |         |         |         |         |         |           |           |
| Backpacks and bags                           |         |         |         |         |         |         |         |         |         | 1         |           |
| Carpet and Furnishing                        | 1       |         |         |         |         |         |         |         |         | 3         | 14        | 3         |
| Tampons and tampon applicators               | 10      | 2       | 1       | 2       | 3       | 2       | 4       | 4       | 4       |           |           |
| Other textiles (incl. rags)                  | 90      | 1       | 2       | 14      | 5       | 7       | 19      | 105     | 31      | 17        |           |
| Total                                        | 263     | 3       | 9       | 28      | 34      | 16      | 77      | 169     | 75      | 70        | 21        |

**Paper/Cardboard**

| Category                                      | Wheel 1 | Wheel 2 | Wheel 3 | Wheel 4 | Wheel 5 | Wheel 6 | Wheel 7 | Wheel 8 | Wheel 9 | Wheel 10 | Wheel 11 |
|----------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|-----------|
| Cardboard (boxes and fragments)               |         |         |         |         |         |         |         |         |         | 6         |           |
| Cartons/Tetrapack Milk                       | 5       | 9       | 15      | 91      | 31      | 37      | 79      | 80      | 96      | 65        | 24        |
| Cartons/Tetrapack (others)                   | 1       |         |         |         |         |         |         |         |         | 34        |           |
| Cigarette packets                            | 2       | 3       | 4       | 3       | 4       | 21      | 17      | 10      | 10      | 2         |           |
| Newspapers and magazines                     |         |         |         |         |         |         |         |         |         |           | 6         |
| Material Type                        | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Total |
|-------------------------------------|--------|--------|--------|--------|--------|--------|-------|
| Paper fragments                      | 13     | 8      | 141    | 35     | 7      | 7      | 18    |
| Other paper items                   | 37     | 11     | 4      | 8      | 6      | 167    | 36    | 3     | 6     |
| Total                               | 43     | 11     | 29     | 112    | 39     | 40     | 103   | 443   | 184   | 91    | 41    | 73    |

**Processed/worked wood**

| Subcategory                        | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Total |
|------------------------------------|--------|--------|--------|--------|--------|--------|-------|
| Ice-cream sticks, chip forks, chopsticks | 3      | 10     | 7      | 5      | 2      | 13     | 14    | 4     |
| Paint brushes                       | 3      | 3      | 3      | 6      | 3      | 9      | 4     |
| Other woods < 50 cm                 | 1      | 7      | 12     | 33     | 21     | 40     | 23    | 98    | 33    | 15    | 23    | 46    |
| Other woods > 50 cm                 |        |        |        | 9      |        |        | 4     |
| Total                               | 1      | 7      | 15     | 46     | 28     | 45     | 28    | 123   | 47    | 21    | 23    | 57    |

**Metal**

| Subcategory                        | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 | Total |
|------------------------------------|--------|--------|--------|--------|--------|--------|-------|
| Aerosol/Spray cans industry        |        |        |        | 1      |        |        |       |
| Cans (beverage)                    | 11     | 1      | 4      | 4      | 4      | 2      | 14    | 5      | 5      | 2      | 5      | 11    |
| Cans (food)                        |        |        |        | 1      |        |        |       |
| Bottle caps, lids and pull tabs    | 20     | 2      | 1      |        |        |        |       |
| Appliances (refrigerators, washers, | 1      |        |        |        |        |        |       | 2      |       |
| Other cans (< 4 L)                 | 2      |        |        |        |        |        |       | 1      |       |
| Gas bottles, drums and buckets (> 4 L) |        |        |        |        |        |        |       | 1      |       |
| Item                                                      | Count |
|-----------------------------------------------------------|-------|
| Wire, wire mesh, barbed wire                              | 43    |
| Other                                                     | 1     |
| Total                                                     | 75    |

**Glass/ceramics**

| Item                                                      | Count |
|-----------------------------------------------------------|-------|
| Bottles incl. pieces                                      | 1     |
| Jars incl. pieces                                         | 4     |
| Light bulbs                                               | 3     |
| Construction material (brick, cement, and)                | 1     |
| Fluorescent light tubes                                   | 1     |
| Glass or ceramic fragments >2.5cm                         | 1     |
| Other glass items                                         | 3     |
| Total                                                     | 2     |

**Other (glass, metal, tar)**

| Item                                                      | Count |
|-----------------------------------------------------------|-------|
| Glass/ceramics                                            | 1     |
| Bottles incl. pieces                                      | 5     |
| Jars incl. pieces                                         | 6     |
| Light bulbs                                               | 2     |
| Construction material (brick, cement, and)                | 2     |
| Fluorescent light tubes                                   | 1     |
| Glass or ceramic fragments >2.5cm                         | 1     |
| Other glass items                                         | 1     |
| Total                                                     | 2     |