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Baseline Marine Litter Surveys along Vietnam Coasts Using Citizen Science Approach

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Abstract: Marine litter is a significant threat to the marine environment, human health, and the economy. In this study, beach litter surveys along Vietnamese coasts were conducted in a local context to quantify and characterize marine litter using the modified GESAMP marine litter monitoring guideline. A total of 21,754 items weighing 136,820.2 g was recorded across 14 surveys from September 2020 to January 2021. Plastic was the most abundant type of litter by both quantity (20,744 items) and weight (100,371.2 g). Fishing gear 1 (fishing plastic rope, net pieces, fishing lures and lines, hard plastic floats) and soft plastic fragments were the most frequently observed items (17.65% and 17.24%, respectively). This study not only demonstrates the abundance and composition of marine litter in Vietnam, it also provides valuable information for the implementation of appropriate preventive measures, such as the redesign of collection, reuse, and recycling programs, and informs policy and priorities, with a focus on action and investment in Vietnam. Moreover, insights from this study indicate that citizen science is a useful approach for collecting data on marine litter in Vietnam.

Keywords: marine litter; plastic pollution; GESAMP guideline; citizen-science; beach monitoring

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1. Introduction

Marine debris (or marine litter) is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" [1]. For decades, marine litter has been found everywhere in the world, from the polar regions [2,3] to the deepest depths of the ocean [4], and it increasingly accumulates in various marine environments, such as the sea surface, sea floor, water column, and beaches [5–7]. Due to its persistence, it takes tens to hundreds of years to remove or degrade marine litter in the natural environment. Most studies have found plastics to be the most abundant component of marine debris [5,8–10]. Plastic pollution has received increasing attention due to the fact that it could be mistaken as food and ingested by a number of marine organisms [11–13]. Entanglement in abandoned fishing gear is another major hazard to animals [11], and the effects of exposure to toxic compounds released from plastic fragments is also of concern [14,15]. Furthermore, floating litter makes it easier for non-native marine organisms (such as bryozoans and barnacles) to migrate to new environments [16,17]. Education and public awareness are effective ways to reduce marine litter [18,19]; however, it is critical to monitor the abundance of marine litter in order to implement more effective pollution control measures.

In Vietnam, economic development and rapid population growth, together with urbanization and lifestyle behavior change, have led to an increased generation of domestic solid waste [20], tourism, and marine activities [21], all of which are main sources of marine litter. This country witnessed a surging increase in plastic imports, production, and use, which grew from 3.8 kg/capita in 1990 to 33 kg/capita in 2010, [22] and then to 81 kg/capita in 2019 [23]. The recent rapid growth is partially attributable to the waste import ban implemented by China in 2017, which banned the import of certain wastes, including waste plastics. The plastic refuse from developed countries that had been processed in China were diverted to countries with less stringent regulations, including Vietnam [24]. Currently, 8 million tons of plastic materials is used annually in Vietnam for industrial purposes, an estimated 80% of which are imported [23]. Moreover, the COVID-19 pandemic in Vietnam has seemingly resulted in a great upsurge of single-use plastics and waste, suspended recycling activities, and interrupted funding for waste management. The impact is due to increased discards of personal protective equipment such as masks, gloves, clothes, and healthcare waste, together with the packaging of food and consumer products for home and office delivery [25,26]. While only 15% of the country's generated plastic waste is recycled [27], the rest—the equivalent of 3.6 MT/year—ends up mainly in landfills, open dumpsites, incinerators, or in the environment [23]. This poses serious threats to human health and environmental impacts such as groundwater and soil contamination by leachate, hazardous emissions from open burning, and the spread of disease. [28]. Furthermore, it is widely considered that more than 80% of marine plastic debris originates from land-based sources [29], and 92% of collected marine debris is plastic [30]. As a result, Vietnam's coral reefs and coastal mangroves are severely threatened by plastic waste [31].

The Vietnamese government has planned to solve the plastic pollution problem through various measures. In the National Strategy of Integrated Solid Waste Management, the government has set the goals of collecting and treating up to 90% of the municipal solid waste (MSW) in urban areas by 2025 and recycling or reusing more than 70% of it to produce energy or composting (Decree 491/QĐ-TTg, 2018). Vietnam is determined to reverse the problem of plastic pollution in general and marine plastic litter in particular. Those determinations are most clearly expressed in the Decision No.1746/QD-TTg, promulgating the National Action Plan for Management of Marine Plastic Litter by 2030, which sets the goal of "Preventing, controlling, and significantly reducing pollution of the marine environment; becoming a regional leader in minimizing ocean plastic waste." [22]. In addition, the newly amended Law on Environmental Protection 2020, which sets out the principles and defines the legal frameworks in the Extended Producer Responsibility (EPR) mechanism for businesses in Vietnam, also demonstrates the intentions of the government on plastic pollution reduction (72/ 2020/QH14, 2020).

Citizen science (CS) is identified as a practice promoting the collaboration of non-specialist individuals in scientific discovery, who can be involved at any stage of the research process from designing the research scope to gathering data or analyzing the results [32]. There have been many studies using CS for scientific research, especially in ecology [33–39]. Recently, a lot of research using CS to assess marine litter has been carried out on beaches around the world [40–43]. By participating in marine litter assessment programs, citizens can enhance their environmental knowledge and awareness, which provides potential for propagating subsequent policy or institutional changes [44]. Although many coastal clean-up activities have already been conducted over the last recent years in Vietnam, there are very few activities aiming at monitoring and reporting marine litter in coastal sites throughout Vietnam [30,45]. As public interest and awareness of the plastic waste problem across Vietnam is increasing, the application of CS campaigns for monitoring marine litter has become achievable. This study provides the first baseline measurement (quantification and characterization of marine litter) of marine litter along the Vietnamese coast by using the GESAMP marine litter monitoring guideline and engaging local volunteers in a citizen science campaign.

2. Materials and Methods

2.1. Study Area

A total of 14 beaches were monitored along coasts of Vietnam (Figure 1). These coastal beach sites were grouped into the Northern subzone (two sites in Hai Phong City and one site in Hue City), Transitional subzone (two sites in Da Nang City, one site in Quang Nam Province, and three sites in Khanh Hoa Province) and Southern subzone (one site in Ho Chi Minh City, two sites in Soc Trang Province, and two sites in Phu Quoc Island). Criteria for location selections were based on a number of factors: population level, national geographic distribution, expected amount of plastic waste, potential area impacted by plastic waste (e.g., tourism area, ecological reserve area), priority areas defined by the government and commitments at the local level to address plastic waste challenges. These included local legislation and waste management initiatives and plans, which were collected through desk surveys of publications and gray literature, as well as interviews with national and local authorities.

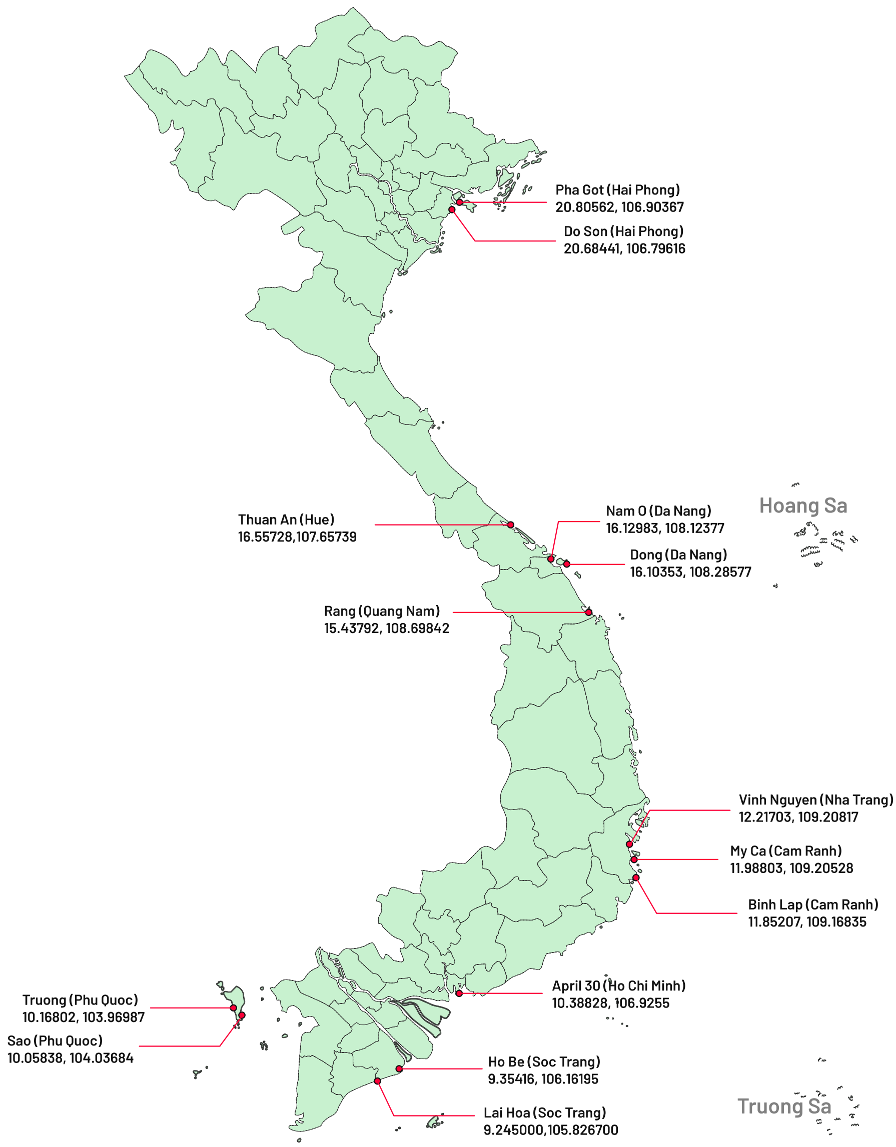


Figure 1. Location of marine litter survey sites in Vietnam.

According to the guidance of GESAMP [46], the selection of coastal sampling locations had to satisfy the criteria below:

(1) Sandy beach or pebble shoreline;
(2) Clear, direct, year-round access;
(3) No breakwaters or jetties;
(4) At least 100 m in length parallel to the water;
(5) Minimum length of 100 m parallel to the water (i.e., measured along the water's edge);
(6) If a survey is conducted at 2 coastal sites in a location, we select a beach with no regular clean-up activities (or cleaning at least three months prior to the survey time) and a beach with regular clean-ups. If the survey is at only one coastal site in a location, we choose either.

2.2. Sampling Methods

We recruited local volunteers through advertising on fan pages, through local administrative units, and through environment clubs in universities. After recruiting the volunteers, we provided training on the survey method. In each location, at least two members of the experienced survey team and six to ten local volunteers carried out the surveys. The experienced survey team members managed the entire survey process and ensured its quality. This included collecting information from the local authority; identifying survey sites; and managing and participating in the collection, classifying, counting, and weighing of litter items, as well as data entry. The volunteers were responsible for waste collection, classification, and counting and weighing. Before the start of survey work in each location, volunteers practiced the survey method, including the size of items to collect, how to classify items into different categories, how to count and weigh items, and safety protocols.

The survey method was based on Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean [46]. The litter categories were adapted for citizen science and for the Vietnamese context as follows: Plastic bag and beverage bottles (PET) were categorized into two types, respectively: plastic bags size 1 (bags with a weight-holding capacity of up to 5 kg) and plastic bag size 2 (bags with a weight-holding capacity of more than 5 kg); beverage bottle size 1 (0–500 mL) and beverage bottle size 2 (more than 500 mL). A detailed list of litter categories can be found in Supplementary Materials Table S1.

Table 1 describes details of the sampling area and the characteristics of the 14 sampling locations. These locations were surveyed between September 2020 and January 2021, and each location was surveyed once. At each location, a 100 m-long transect parallel to seawater line was defined; in the transect, 4 random strips of five-meter length each were selected. In each strip, all anthropogenic items larger than 2.5 cm were collected for further processing. This involved cleaning, identification, and counting and weighing of samples according to the GESAMP guideline. Each item was assigned to a litter category, and similar items were grouped into single-use plastics (SUP) and fishing-related items (FR) according to GESAMP protocols. The percentage of single-use plastics (SUP) and fishing-related items (FR) in each beach location was evaluated based on the total number of plastic items collected.

2.3. Data Analysis

We calculated two parameters including density of items (i.e., number of items per m^2 and weight of items per m^2) and the Clean Coast Index (CCI) [47]. Item density was calculated as follow:

$$D = \frac{N}{w \times l} \tag{1}$$

where D is the density of items, N is the total number/weight of items on four random strips, w is the width of the strip (5 m), and l is the total length of four strips.

As for beach cleanliness, we applied the CCI ranking using the following equation:

$$CCI = \frac{TL}{TA} \times K \tag{2}$$

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

Table 1. Beach locations surveyed in Vietnam and a brief description of the locations. The awareness here is to refer to the concern about plastic waste of local residents and tourists.

No.	Survey Locations	Name of Survey Sites	Coded Site	Survey Date	Surved Area (m^2)	Urban/Rural	Tourism	Clean-Up	Awareness
1 2	Hai Phong	Do Son Cat Hai	HP_C1 HP_C2	September 2020	288 844	Urban Urban	Yes Yes	Yes No	Yes Yes
3	Thua Thien Hue	Thuan An	H_C1	November 2020	800	Urban	Yes		No
4 5	Da Nang	Dong Nam O	DN_C1 DN_C2	November 2020	367 370	Urban Urban	Yes Yes		No Yes
6	Quang Nam	Rang	QN_C1	November 2020	1000	Rural	Yes	No	No
7 8 9	Khanh Hoa	Vinh Nguyen My Ca Binh Lap	NT_C1_n1 CR_C1 CR_C2	January 2021 January 2021 January 2021	200 212 88	Urban Urban Rural	Yes No No	Yes No No	No No
10	Ho Chi Minh city	April 30	HCM_C1	October 2020	3430	Rural	Yes	No	No
11 12	Soc Trang	Lai Hoa Ho Be	ST_C1 ST_C2	October 2020	605 335	Rural Rural	No Yes	No Yes	No No
13 14	Kien Giang (Phu Quoc island)	Sao Truong	PQ_C1 PQ_C2	October 2020	237.5 614.5	Urban Urban	Yes No	Yes No	Yes Yes

Table 2. CCI index.

CCI	Very Clean No Litter is Seen	Clean No Litter Is Seen over a Large Area	Moderate A Few Pieces of Litter Can Be Detected	Dirty A Lot of Litter on Shore/Sites	Extremely Dirty Most of the Beach/Site Is Covered with Litter
Numeric index	0–2	2–5	5–10	10–20	20+

Source: [47].

Statistical analyses were performed to determine whether the number of items differed significantly among the survey sites; one-way ANOVA tests were conducted. Prior to the statistical analyses, log transformation was applied to stabilize the variances. When differences were detected, post-hoc Tukey's tests were applied. In order to assess the difference in marine litter abundance between tourism and non-tourism locations and between urban and rural areas, an ANOVA including an interaction term was performed. All statistical data analyses were performed using R Statistical Software (version 3.6.1) (R Foundation for Statistical Computing, Vienna, Austria).

We also compared the results of this study with previous studies from Southeast and East Asian countries related to densities of items and the CCI index.

3. Results

3.1. Marine Litter Abundance and Composition

A total of 21,754 items weighing 136,820.2 g were collected along fifty-six beach strips during the survey campaign and were classified into seven major groups. Litter composition on each beach along the Vietnamese coast can be found in Supplementary Materials Table S2. Table 3 shows the abundance of litter collected from fourteen beaches, and Table 4 lists the densities of litter, the percentage of SUP, FR, and the Clean Coast Index (CCI). The highest percentage of SUP was found at CR_C2 (78.10%), and most of the SUP (58.41%) were from plastic bags. The highest percentage of FR (54.70%) was recorded at DN_C1, mainly Styrofoam blocks used as floats for boats and nets.

Table 3. Abundance of litter collected from fourteen beaches during survey campaign (from September 2020 to January 2021).

	HP_C1	HP_C2	H_C1	DN_C1	DN_C2	QN_C1	NT_C1_n1	CR_C1	CR_C2	HCM_C1	ST_C1	ST_C2	PQ_C1	PQ_C2	Mean	SD
	Abundance (number of items per site)															
Plastics	1057	392	2822	880	235	2673	331	2036	1671	2716	236	2964	1944	787	1481.86	1042.73
Metal	53	21	6	1	2	3	0	14	6	6	1	8	15	14	9.29	14.18
Glass	2	10	16	1	0	33	0	71	7	8	4	5	21	7	7.64	9.72
Rubber	17	4	2	1	2	1	7	20	6	20	2	5	2	42	7.50	11.68
Paper/wood	3	1	0	0	4	0	0	13	0	19	0	0	0	42	4.93	11.80
Textile	24	2	0	2	4	7	0	53	14	28	4	124	1	14	15.00	32.67
Other litter	35	40	3	7	2	5	3	8	19	35	1	5	0	22	11.29	14.87

Table 4. Beach litter densities (items/m^2), %SUP, %FR, and CCI in 14 beaches of Vietnam.

Location	Urban	Tourism	Items/m^2	g/m^2	%SUP	%FR	CCI
HP_C1	Yes	Yes	4.14	53.71	48.25	39.17	73.40
HP_C2	Yes	Yes	0.56	6.16	33.42	38.78	9.29
H_C1	Yes	Yes	3.56	10.51	48.16	29.55	70.55
DN_C1	Yes	Yes	2.44	8.03	39.89	54.32	47.57
DN_C2	Yes	Yes	0.67	4.84	63.83	14.47	12.70
QN_C1	No	Yes	2.72	18.33	53.31	30.64	53.46
NT_C1_n1	Yes	Yes	1.71	2.71	65.86	16.92	33.10
CR_C1	Yes	No	9.60	84.84	50.05	44.40	192.08
CR_C2	No	No	18.99	226.56	78.10	10.35	379.77
HCM_C1	No	Yes	0.83	2.97	44.22	42.12	15.84
ST_C1	No	No	0.41	6.73	47.88	41.53	7.80
ST_C2	No	Yes	9.29	59.44	66.46	21.29	176.96
PQ_C1	Yes	Yes	8.35	30.76	51.44	43.00	163.71
PQ_C2	Yes	No	1.51	7.70	57.05	22.36	25.61

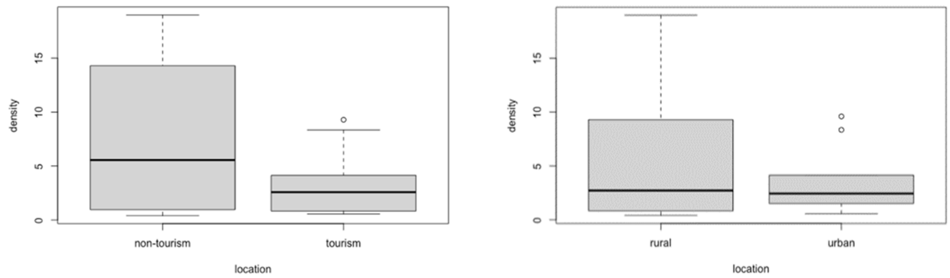
In this study, the number of items ranged from 248 to 3111 items at each survey location, with a mean of 1553.86 ± 1065.73 items at each survey location. This corresponds to the weight of beach litter, which varied from 542 to 19,937 g per site, with a mean of 9169.16 ± 9770.78 g per site (Table 3). The high standard deviation values show that beach litter abundance varied substantially at each location. The number of items on the least polluted beaches (ST_C1) and the most polluted ones (ST_C2, Table 3) differed by an order of magnitude, and it is notable that these two sites were located in the same province (Soc Trang province) within a radius of about 40 km. Plastic was the most abundant group of marine litter found on the beaches, representing 95.37% (ranging from 83.4 to 99.05%) of sampled items. Other litter (litter with more than one type of material) was the second most abundant group (1.42%), followed by textile (1.13%), metal (1.02%), rubber (0.92%), glass (0.83%), and paper/wood (0.56%).

3.2. Comparisons of Marine Litter Compositions, Quantities and Distribution among Locations

Tables 3 and 4 showed the results of marine litter in fourteen sites. In some cases, we observed high densities of marine debris in areas that have no regular clean-up activity and/or have poor public awareness.

The highest amount of marine litter was observed at the ST_C2 location, whereas the lowest was observed at the ST_C1 (Table 3); this difference is more than 12 times, despite the fact that these two points are in the same province and are not more than 40 km apart. A high abundance of marine litter was observed in some of the locations with little or no clean-up activity (e.g., CR_1, CR_2, HCM_C1); however, at locations HP_C2 and ST_C1, there were low amounts of litter, despite the fact that there was no clean-up activity at these two locations.

The abundance of marine litter in tourism and non-tourism locations is shown in Figure 2A, and the ANOVA result shows a significant difference (p = 0.01); moreover, there is higher variability in the non-tourism areas. In addition, there is a significant difference (p = 0.02) between urban and rural areas (Figure 2B); similarly, there is higher variability in the rural areas. However, the interaction between Tourism and Urban/Rural indicates that there is a trend towards lower debris in tourism areas, since they have a more regular clean-up.



(**A**) (**B**)

Figure 2. Comparison of the abundance of marine litter between (**A**) tourism and non-tourism locations and (**B**) urban and rural areas. Data are presented in a box-and-whisker plot, with the middle box representing 50% of the values and the upper and lower whiskers representing the values outside of the 50% range.

The mean marine litter count density was 4.63 ± 5.26 items/m^2, ranging from 0.41 items/m^2 at ST_C1 to 18.99 items/m^2 at CR_C2. In addition, the mean density of litter was approximately two times higher in non-tourism areas than in tourism areas. The litter count density ranged from 0.56 to 9.29 items/m^2 (mean of 3.43 items/m^2) and from 0.41 to 18.99 items/m^2 (mean of 7.63 items/m^2) in tourism and non-tourism areas, respectively (Table 4). Mean beach litter by weight was 37.38 g/m^2, ranging from 2.71 g/m^2 in the NT_C1_n1 to 226.56 g/m^2 in the CR_C2 (Table 4). According to the CCI, only ST_C1 was found to be moderately dirty; HP_C2, DN_C2, and HCM_C1 were ranked as dirty, and the remaining locations were ranked as extremely dirty (Table 4). Regarding the SUP quantities, the highest percentage was recorded at the CR_C2 (78.10%). Most of the SUP material was plastic bags and bag fragments. Overall, SUP accounted for a high percentage of the debris on the coasts of Vietnam (53.42%). In addition, fishing gear also accounted for a significant proportion of marine litter (32.06%), possibly due to the development of aquaculture and fishing activities.

There were significant differences in the amount of debris collected at different sites along the Vietnamese coast (ANOVA, $F_{13;327}$ = 4.67, p < 0.05). In general, for the Northern subzone, there is no significant difference among locations in the region; for the Transitional subzone, there are significant differences between QN_C1 and two sampling sites in Da Nang city, and there is no significant difference in the remaining sites. For the Southern subzone, ST_C1 showed significant differences from all remaining locations, while there is no significant difference between the remaining locations. In addition, it is noted that there are significant differences between ST_C1 and H_C1 and QN_C1, and between HCM_C1 and DN_C1, DN_C2, and NT_C1_nt1. The main reason why ST_C1 is different from locations in the same subzone and different from locations in other subzone is because of the amount of litter collected here is the lowest, mainly consisting of foam plastics.

3.3. Top Ten Marine Litter Items

The top ten items for 14 surveys are shown in Table 5 and Figure 3, and the top ten items for each location are listed in Supplementary Materials Table S3. All are plastics, and account for 81% of the items found. The top three items, fishing gear 1, soft plastic fragments, and fishing gear 2, were mainly small pieces rather than whole items, and account for nearly one half (48.78%) of the total number of collected items. Six items out of the top ten are single-use plastics.

Table 5. Top ten items found in fourteen surveys.

Rank	Item	Percentage
1	Fishing gear 1: Fishing plastic rope, net pieces, fishing lures and lines, hard plastic floats	17.65
2	Soft plastic fragments (mostly from plastic bag fragments)	17.24
3	Fishing gear 2: Polystyrenes—EPS, buoys and floats	13.37
4	Plastic bags size 1 (0–5 kg)	6.80
5	Styrofoam food containers	6.50
6	Hard plastic fragments (from plastic toy, kitchenware, unidentified objects)	6.07
7	Straws	4.69
8	Other plastics (slippers, sanitary products, diaper, etc.)	2.69
9	Crisp/Sweet packages	2.68
10	Food wrappers	2.44
	Total percentage	80.14

Figure 3. Top ten items in coastal beach sites in the survey.

3.4. Comparisons of Marine Litter Results at Vietnamese Beaches with Previous Studies

Marine litter abundance was compared with previous studies from other countries in Southeast and East Asia (Table 6). Marine litter was calculated as the number of items per square meter of the studied areas and the CCI index was used to compare the cleanliness level between different beaches. Although the density of marine litter in Vietnam is higher than that of the Philippines, the Solomon and Vanuatu Islands, and Korea, only the Philippines' coast was classified as clean. The rest of the beaches are classified as extremely dirty.

Table 6. Abundance of marine litter in different studies.

Area	Items/m^2	CCI	CCI Rank	Study
Vietnam	4.63	92.6	extremely dirty	This study
Muara beach (Brunei Darussalam)	74.43	1488.6	extremely dirty	[48]
Indonesia	41.6	832	extremely dirty	[49]
Seberang Takir Beach (Malaysia)	780	15,600	extremely dirty	[50]
Macajalar Bay (Philippines)	0.12	2.4	clean	[51]
Guadalcanal Island (Solomon Islands)	2.5	50	extremely dirty	[52]
Efate Island (Vanuatu)	1.25	25	extremely dirty	[52]
Korean beaches	1.5	30	extremely dirty	[53]

4. Discussion

4.1. Assessment of Marine Litter Composition and Abundance

This study presents the first set of baseline data on marine litter abundance and composition in Vietnam using a citizen science approach. Despite the difference in litter composition, plastic is the most abundant group of litter in all sampling locations. The proportion of plastic varied between 83.4 and 99.05% by count, which was higher than the global average (75%) [5,54], and by 34.81 and 94.46% by weight. These results are in line with the findings obtained from other surveys around the world [55–59]. It is known that the presence of plastics in the environment could have a great potential impact on ecosystems, since they are persistent and can break into microplastics, potentially causing far greater harm than the debris itself [60]. Fragmentation makes it possible for plastic to be transported further and increases its ability to enter the food chain; furthermore, during the plastic manufacturing process, compounds and plasticizers are added, and these substances are known to have adverse effects on organisms [61–63]. In addition, plastics could also absorb toxins in the environment, and adsorbing–desorbing hazardous chemicals could leach out and be absorbed by animals that ingest plastics [15,62,64,65]. Therefore, actions are needed to reduce plastics in the environment.

In this study, the highest amount of marine litter was recorded at the ST_C2 location, whereas the lowest was observed at the ST_C1 (Table 3). A high abundance of marine litter was observed in some of the locations with little or no clean-up activity; however, at locations HP_C2 and ST_C1, there were low amounts of litter despite the fact that there is no clean-up activity at these two locations. The reason for this is that, at HP_C2, the sampling was conducted during the Southwest monsoon season, when the wind blows primarily offshore. Marine litter had been pushed out to the sea, leading to a decrease in the amount of litter. At ST_C1, there was different situation, as a small number of households (less than 30) and people here disposed of their waste by burning; therefore, the amount of litter collected here is the lowest compared to other locations.

The present findings showed that there were high amounts of SUP and fishing-related items found along Vietnamese coasts. This reflects people's consumption habits and consciousness as well as waste management practices in the country. Solid waste management in Vietnam has many challenges [66], and the combination of poor waste management and a lack of public awareness could lead to large amounts of waste being released into the environment. The number of litter items was usually higher on beaches with no regular clean-up activity, whether it is urban or rural, as well as the presence of tourism. Generally, tourist beaches are cleaner than non-tourist beaches, which is probably a result of the increased beach cleaning performed to appeal to and attract tourism and/or because people have higher awareness in these locations. Improving the waste management system and raising people's awareness such that clean ups are also undertaken in non-tourist areas are both critical interventions.

ML results also suggested that both land-based activities and sea-based activities are major contributors. Fishing gear represented more than one fifth of items in the surveys, mainly from aquaculture and fishing activities. The remaining litter items were domestic products or items routinely found in local stores. This study is also consistent with findings that the majority of marine litter originates from land [67,68]. In this study, we found foreign brands (as mentioned in other studies [69–71]), especially in Phu Quoc, where many Thai products were collected. This indicates that marine litter is a transboundary problem and requires the cooperation of all countries around the globe.

In Vietnam, marine litter came from a variety of sources, and a major portion of them were SUP (plastic bags, crisp/sweet packets, disposable cutlery, etc.) and fishing gear. For example, fishing gear was widely utilized by local fishermen and seafood farmers; plastic bags could come from daily use or were disposed directly on the beaches by visitors (local residents or tourists). Food-related SUPs (cups, crisp/sweet packets, disposable cutlery, straw, etc.) are likely to primarily come from beach visitors, with the exception of polystyrene pieces from Styrofoam food containers, which are utilized widely by both inland residents and beach visitors. Other polystyrene debris likely originated from blocks of Styrofoam which are used by local fishermen and seafood farmers as buoys for their nets.

The density of marine litter in this study was also compared with other studies in Southeast and East Asian countries. Marine litter in Vietnam was less abundant than in more populated countries such as Indonesia, where high amounts of waste are mismanaged [72]. However, most of the beaches in Southeast and East Asian countries were classified as extremely dirty. Another point should be noted that, due to differences in litter classification, it is difficult to compare the top ten items among studies. However, similar to other studies, this study also showed that a large amount of marine litter originated from land-based and sea-based activities [73–76].

Fishing gear is a common type of litter along the coast of Vietnam, and this has also been observed in other areas [77–80]. One of the reasons for this may be due to the favorable natural conditions for fishing and aquaculture activities.

4.2. Benefits and Disadvantages of Citizen Science

Many studies have demonstrated that citizen science is suitable for marine litter monitoring [3,81–86]. Our study showed the potential of citizen science to provide scientifically valuable data in the assessment of marine litter pollution. In addition to assisting in data collection, citizen science also offers opportunities for raising awareness and education through the collection and analysis of local marine litter. Local volunteers participating in field activities are key to environmental awareness and education: volunteers could see with their own eyes and touch with their hands and analyze the amount of waste that exists on the beaches where they live nearby or go to swim every day. Moreover, citizen science could also support citizen action in reducing marine litter pollution, including beach clean-up activities and in reducing the use of single-use plastic. The novelty of this study is that we used citizen science in combination with a suitable litter classification system for Vietnam to collect baseline data on marine litter pollution.

Although citizen science is very supportive in collecting spatial and temporal marine litter data, there are certain limitations. One of them is the potential for introduced error due to the use of different surveyors [83]. It is very important to ensure the quality of the survey; hence, it is necessary to include experienced survey team members when conducting a survey. Additionally, the application of standard marine litter-monitoring methods such as OSPAR [87] or MSFD [54] will be difficult to implement in the conditions of Vietnam due to the complexity of litter lists. Therefore, instructions should be simple and clear, and volunteers should be trained so that the quality of the survey is not compromised [82]. All of these requirements are met by our monitoring method. However, future application of mobile technology will be considered as it can increase the number of participants as well as facilitate the project's implementation [88–90].

4.3. Preventive Measure Implications

The results of this study could be useful for proposing preventive measures of marine litter. A large amount of litter was SUP, and fishing gear and plastic bags made up a large proportion of the top ten items (55.07%). Therefore, a ban on plastic bags and food packaging, especially Styrofoam food containers, is suggested. This measure could help to reduce 3% of marine litter in Vanuatu and 17% of marine litter in the Solomon Islands [52]. SUP is known to break down easily in the environment [91], especially in coastal areas [92]. The release of large amounts of SUP microplastics into the environment of Vietnamese beaches might affect fishing and aquacultural activities in the country, since there are a lot of bivalves, shrimp, and fish-farming activities along the coast. In addition, seafood is a source of nutritious food and is very popular in Vietnam, thus microplastics can easily be introduced into the human food chain through degraded marine litter. Therefore, strong measures should be taken to reduce the use of SUP in Vietnam. This study also showed that waste mismanagement coupled with the low awareness of people (both tourists and residents) are the main contributors of marine litter.

Fishing gear is another issue that we must also prioritize. This type of litter mainly comes from coastal communities. Plastic rope and net are extensively used by local fishermen and seafood farmers; however, they were buried in the sand and in a deteriorated state. Buoys and floats were mainly made from polystyrene and are used by local fishermen and seafood farmers as floats for their nets. This material is easily broken down into small pieces. Fisheries such as commercial fisheries and marine aquaculture have contributed to the majority of beach debris in Vietnam. The most commonly found fishing gear item, ropes, originate both from commercial fisheries and marine aquaculture, though it is not possible to differentiate them on the beaches. The second most frequent fishing gear item, Styrofoam buoys, likely comes mostly from marine aquaculture and processing. Therefore, education to raise the awareness of local communities is necessary, and the mandatory control and recycling of discarded fishing nets and polystyrene foam should be implemented. Moreover, principles and standards could be applied to reduce the loss and abandonment of gear, as recommended by FAO Code of Conduct for Responsible Fisheries [93]. The Vietnam Action Plan on Reducing Ocean Plastic (2019) also set the target to reduce marine plastic litter by 75 percent in Vietnam's waters by 2030, with all abandoned, lost, or discarded fishing gear being collected and disposed of.

The effectiveness of preventive measures and policy implementation should be monitored over time; therefore, it is necessary to apply a comprehensive monitoring system for beach litter monitoring and data collection and to compare with other data in the world. This study used the GESAMP guideline, combined with citizen science, to demonstrate the applicability of this approach for the future. It is noted that the adjustment of the list of litter categories to suit a Vietnamese context and the use of citizen science added more value for waste management as well as providing the opportunity to both propose and gather data on the effectiveness of preventive measures. In addition, understanding how the new country-specific marine litter categories are used in the citizen science approach is critical to ensure its continued use in the future.

5. Conclusions

This study presented the abundance and composition of marine litter along the Vietnamese coast using the citizen science approach, a simple and easy method that can be implemented on a large-scale in order to collect data on marine litter to support potential preventive measures.

Through fourteen surveys along the beaches of the Vietnamese coast, litter items could be classified into seven groups with a litter classification system suitable for citizen science. Similar to other studies, this study showed that plastics were the most commonly found items and accounted for 96.38%, in which fishing gear and soft plastic fragments contributed the most. Six out of the top ten items were single-use plastic. This study also showed that local sources of litter are major contributors to marine litter in Vietnam. Therefore, a strong preventive measure to control and reduce litter from local sources is needed.

This study also showed that it is possible to use citizen science to collect data on marine litter, thereby increasing education and raising community awareness. However, further research is needed to improve the method.

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