

## Article

# Beach Litter Variability According to the Number of Visitors in Cádiz Beaches, SW Spain

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**Abstract:** The amount and composition of litter was evaluated during May and June 2021 at two urban beaches, i.e., La Victoria and La Cortadura, in Cádiz, SW Spain. Surveys were carried out daily in the morning and in the evening during the weekends to quantify the daily accumulation of beach litter and relate it to the number of beach users, which was assessed at around 1:00 p.m. Litter amount was also related to cleanup operations that were very mechanically and manually carried out each day very early in the morning. A total of 8108 items were collected at the two investigated sectors during the study period and beach visitors were quantified in 22 surveys. Plastic was the most common material, representing 82% in La Victoria and 68% in La Cortadura. The most common items were cigarette butts and small, hard plastic fragments. Some litter items that were hazardous to beach visitors were identified, such as broken glass. The number of visitors was positively related to the amount of litter. Significant differences were seen in the litter abundance between the morning and evening assessments since the beaches were cleaned daily and bins were available to facilitate trash disposal. Cleaning operations remove many of the litter items but always leave small quantities of small items uncollected. Efforts to prevent litter on these beaches should focus on informing visitors properly in order to avoid littering and on improving cleanup operations.

**Keywords:** Andalusia; beach users; cigarette butts; cleaning efforts; coastal management; plastic pollution; 3S tourism



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## 1. Introduction

Travel and tourism are one of the world's most relevant industries [1], and international tourism revenue reached USD 1 trillion in 2022 on a world scale, growing 50% compared to 2021 and representing 64% of the pre-COVID pandemic levels. More than 900 million tourists travelled in 2022, doubling the numbers recorded in 2021, and Europe was the largest destination region, with 585 million arrivals in 2022 [1]. In the first three months of 2023, the trend continued to rise, and 235 million tourists traveled internationally, i.e., 80% of pre-pandemic levels and more than double those in the same period in 2022.

In 2022, Spain, with 71.6 million visitors, recorded a 129.5% growth in tourist arrivals with respect to 2021, and visitors spent EUR 87,061 million, i.e., 95% of the tourism income recorded in 2019 [2,3]. Tourist sector revenue recorded the same trend and accounted for 12.6% of the gross domestic product (GDP) in 2019, 5.8% in 2020, 8% in 2021, and 12.2% in 2022 [3]. During the first seven months of 2023, 47.6 million international tourists visited Spain, comprising a ca. 21% increase with respect to the same months in 2022 [4], and predictions claimed that a full recuperation of the number of pre-pandemic tourism visitors and revenue would take place in 2023 (<https://www.mincotur.gob.es/es-es/>, accessed on 15 September 2023).

International tourists are mostly interested in coastal areas, especially because of the “Sun, Sea, and Sand” (3S) market [5–7]. Therefore, beaches and associated with tourism are

worth billions of USD and represent a very powerful socio-economic driver that generates investment opportunities and associated employment and income growth [1,8,9]. This is especially observed along the Mediterranean coastal areas, which host almost a third of international tourist arrivals [1]. In Spain, 75% of international visitors are interested in coastal areas, and the most visited regions are Catalonia, the Balearic and Canary Islands, and Andalusia. Andalusia was visited by 10 million international tourists in 2022, and in the first months of 2023, the trend of incoming tourists increased by 26% with respect to 2022, recording 6.8 million visitors, and 12 million visitors were expected for 2023 [3,4]. Andalusia is an attractive 3S destination for national tourists, too, and was visited by a total of 23 million national and international tourists in 2022, a trend confirmed during the first semester of 2023. The most visited provinces were Málaga and Cádiz, with the latter recording 5.4 million visitors in 2022 and 2.4 million visitors in the first semester of 2023 (<https://www.juntadeandalucia.es>, accessed on 15 September 2023).

Williams (2011), who carried out >4000 questionnaire surveys with beach users in many countries regarding their preferences and priorities, affirmed that visitors are especially interested in five main parameters: safety, water quality, no litter, facilities, and scenery, known as the “Big Five” [10]. In Mediterranean countries and in the Caribbean, users are especially interested in swimming and, therefore, in water quality, safety, and a lack of litter [11]. The latter is the topic of this paper.

Marine litter has social and economic impacts in coastal and marine areas, which include the aesthetic deterioration of the scenery and the negative reactions of beach visitors (who prefer to visit other beaches, producing a decrease in the number of tourist days), damage to fishing activities and recreational boats, and injuries to swimmers being recorded due to cuts and sharp objects. Marine litter may produce entanglement, suffocation, and ingestion in marine organisms and favors non-native species dispersal, and the adsorption of heavy metals and persistent organic pollutants have been detected in plastic litter [12–14]. The above-mentioned issues have special relevance along the coasts of the Mediterranean Sea, one of the zones of the world that is most affected by marine litter. This is a topic of concern that has been discussed since the 1970s within the framework of the Barcelona Convention [15]. According to that report, efforts have to be devoted to reducing the production and use of plastics: It is estimated that 6–10% of global annual plastic production (ca. 391 million metric tons in 2021, <https://www.statista.com/statistics>, accessed on 15 September 2023) ends up in marine environments, where plastics represent the most abundant pollutants (ca. 80% of all litter items found along the coast) and potential pollutants [16] include glass, processed wood, metal, rubber, textiles, paper, and other common materials [14,16]. An important step to reduce coastal pollution involves determining beach litter sources, which can be related to (i) land-based activities, which are responsible for ca. 80% of all beach litter, and (ii) marine-based activities, which account for ca. 20% of beach litter [17,18]. In the former case, items are disposed of on land and are then transported to the marine/coastal environment by winds, rivers, runoff waters, etc., or are directly abandoned on the beach by visitors; in the latter case, items arrive from the sea and are essentially related to maritime transport, fishing activities, and offshore gas/oil extraction [18]. Finally, efforts have to be devoted to regular and special beach cleanup operations to keep tourist beaches free of litter [16] and to the development of sound educational programs at different school levels [19].

Despite the presence of litter on beaches being an issue of worldwide interest, few papers present the results of beach monitoring programs and relate litter content and abundance to variables such as marine climate, number of visitors, cleanup operations, etc. [11]. The current paper deals with a beach litter-monitoring program carried out during the weekends of May and June 2021 at two tourist beaches on the Cádiz coast (SW Spain), with the goal of characterizing beach litter items and the relationships between beach litter content and the number of visitors and evaluating the efficacy of cleanup operations.

## 2. Materials and Methods

### 2.1. Study Area

The Cádiz province, on the Atlantic side of Andalusia (Southwestern Spain, Figure 1), is a densely populated area with 1,246,781 inhabitants recorded in 2022, with ca. 9% of them located in the town of Cadiz. In 2022, the province of Cádiz recorded 8 million overnight visitors, with 80% of them located within 30 km of the shoreline [20] due to the special interest in coastal tourism since swimming is possible for several months per year [21,22].



**Figure 1.** Location map of the study areas: La Victoria and La Cortadura beaches.

The coast has a NW–SE orientation and is a mesotidal environment with mean neap and spring tides of 1.0 and 3.5 m, respectively. It is exposed to both westerly and easterly winds. Westerly winds are associated with Atlantic low-pressure systems and easterly winds, blowing in an E to SE direction, are originally formed in the Mediterranean Sea. Concerning morphological state of the beach, the two investigated coastal sectors are characterized by fine quartz-rich sediments that give rise to dissipative conditions reflected by wide foreshore zones [23–25]. Regular beach-cleaning operations are carried out manually and mechanically every day early in the morning by local authorities at the investigated beaches from April to October [25].

Two coastal sectors 100 m in width were investigated in Cádiz town (Figure 1), both of which are urban beaches according to the terminology of Williams and Micallef [26]. One sector was located in La Victoria, a very frequented urban beach backed by a promenade with houses, restaurants, hotels, etc., and the other was in La Cortadura, a less urbanized area with a smaller number of visitors that is backed along the study sector in the northern part of the beach by defensive walls of an ancient military fort constructed in the early 1800s and by well-developed dune ridges in the central and southern areas (Figure 1). There were trash bins in the evaluated sectors, with a total of four at the La Victoria and two at the La Cortadura beach sectors. There are usually two trash bins at each beach access and accesses are usually 100 m apart. Beach cleaning is carried out by the town council, and it was observed that at La Victoria beach it is carried out both manually and mechanically. At La Cortadura it is mechanical.

## 2.2. Data Analysis

To study relationships between beach litter, the number of beach visitors, and weather conditions, 22 surveys per site were carried out two times per day every Saturday and Sunday from 2 May to 13 June 2021 at La Victoria and La Cortadura beaches in Cádiz (SW Spain). Following the EA/NALG [27] technique, the surveys were carried out during low-tide conditions covering a 100 m-long coastal sector parallel to the shore and extending to the low-water strandline (Figure 1). The observer reported litter data while moving along transects 5 m apart parallel to the coastline in order to cover the dry beach and the foreshore, i.e., from the landward limit of the beach up to the shoreline. The surveys were carried out in the morning, usually around 9:00 a.m., which is after beach cleanup operations, and in the evening, usually around 9:00 p.m., to assess the content of beach litter left by beach users during the day. During each survey, the number of beach visitors within the investigated areas was counted at 1:00 p.m., i.e., when the sites showed the maximum number of visitors.

A wide list of litter items was obtained [16] by combining three litter classifications from different entities, i.e., the United Nations Environment Programme (UNEP), the OSPAR Commission, and the National Oceanic and Atmospheric Administration (NOAA) [28–30]. Data gathered were also grouped into 7 categories according to the EA/NALG (2000) methodology [27], which enables a beach to be graded on a four-interval scale ranging from “A” (excellent grade) to “D” (poor grade, Table 1), taking into consideration that the final score of each site corresponds to the lowest grade obtained, i.e., if any one category scored a “D” and all the rest an “A”, the overall beach grade was “D”. The advantage of this method is that it allows beach managers to gain a quick overview of the severity of the litter at a beach site. Litter categories include “**general sewage litter**”—items such as feminine hygiene products (sanitary towels, tampons and applicators, contraceptives, toilet paper, feces of human origin); “**cotton bud sticks**”—harmless in and of themselves but denoting a sewage input; “**gross litter**” (at least one dimension > 50 cm) such as shopping trolleys, pieces of furniture, road cones, large plastic or metal containers, bicycles, strollers, tires, and large items of processed wood, e.g., pallets (driftwood is not included); “**general litter**” (all other items < 50 cm in dimension) such as drink cans, food packaging, cigarette packets, etc.; “**potentially harmful litter**” (dangerous to either humans or animals using the beach) such as sharp broken glass (counted as a separate category), medical waste (e.g., used syringes), colostomy bags, sharp objects (metal waste, barbed wire, etc.), soiled disposable diapers, containers marked as containing toxic products, and other dangerous products such as flares, ammunition, explosives, and dead domestic animals; “**accumulations of litter**”—discrete aggregations of litter that are clearly visible when approaching the survey area, either as a result of being blown by the wind or dumped by users of the beach, and in the high water strandline, often in seaweed; “**oil and other oil-like substances**”—all oil waste (mineral or vegetable), either from fresh oil spills or due to the presence of weathered oil deposits and tarry wastes; and “**feces (non-human)**”—dog waste (sheep and horse feces are not counted) (Table 1).

Weather conditions, i.e., daily maximum and minimum atmospheric temperatures, cloud cover (i.e., sunny, cloudy, and rainy days), and wind intensity, were obtained from the Spanish Meteorological State Agency (AEMET).

Statistical analyses were performed with the “R” computer program (<http://www.rproject.org/>, accessed on 12 January 2022) to assess differences in litter abundance between the two sites and the litter temporal evolution and to evaluate cleanup management efforts. For each data set, the requirements of analysis of variance (ANOVA), i.e., normality and homogeneity of variance, were checked using Kolmogorov–Smirnov (KS) and Bartlett’s tests, respectively. A square root data transformation was applied, and all statistical tests were conducted with a significance level of  $\alpha = 0.05$ .



**Table 1.** Litter grade categories and scores [27].

	Category	Type	A	B	C	D
1	Sewage-related debris	General Cotton buds	0 0–9	1–5 10–49	6–14 50–99	15+ 100+
2	Gross litter		0	1–5	6–14	15+
3	General litter		0–49	50–499	500–999	1000+
4	Harmful litter	Broken glass Other	0 0	1–5 1–4	6–24 5–9	25+ 10+
5	Accumulations	Number	0	1–4	5–9	10+
6	Oil		Absent	Trace	Nuisance	Objectionable
7	Feces		0	1–5	6–24	25+

### 3. Results and Discussion

#### 3.1. Number of Beach Users and Weather Conditions

The number of visitors ranged from 0 to 221 at the beach sector investigated in La Victoria and from 0 to 64 in the La Cortadura sector, with an average value of 139 (0.028 visitors/m<sup>2</sup>) and 36 (0.008 visitors/m<sup>2</sup>) visitors for La Victoria and La Cortadura, respectively (Figure A1a). The days with no visitors were not considered when calculating the above-presented average values. The number of visitors at La Victoria increased during the study period, whereas at La Cortadura an increasing trend was less evident (Figure A1a). The elevated number of visitors (and the increase) during the study period was related to the good weather conditions recorded, characterized by an average maximum temperature of 23 °C and an average minimum temperature of 17 °C. The weather conditions were always sunny, and only two cloudy days were recorded on 8 May and 12 June and two rainy days on 9 May and 5 June—during those days no beach visitors were recorded (Figure A1a). During the study period, wind velocity ranged from 15 to 37 m s<sup>−1</sup> and approached from both western and eastern directions. This negatively influenced the number of visitors at both study sectors only on 22 and 23 May, when it blew at 37 km/h.

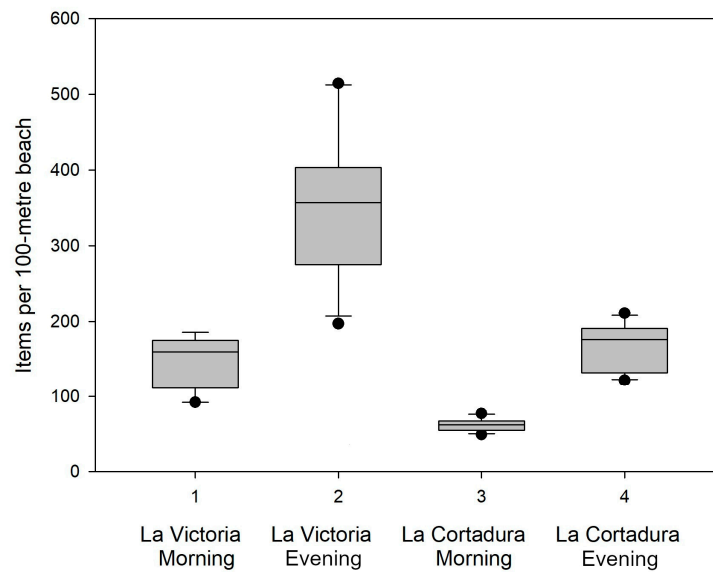
#### 3.2. Beach Litter Spatial and Temporal Distribution

The surveyed beach width (i.e., in the cross-shore direction) did not range much at either of the two investigated beaches during the study period. It varied from 40 to 50 m at the La Victoria beach sector and from 35 to 45 m at La Cortadura. A total of 8108 items were collected at the two investigated sectors during the study period: 5585 items were recorded at La Victoria from a total of 5000 m<sup>2</sup> of surveyed beach surface, and 2523 items were recorded at La Cortadura from a total of 4500 m<sup>2</sup> of surveyed beach surface.

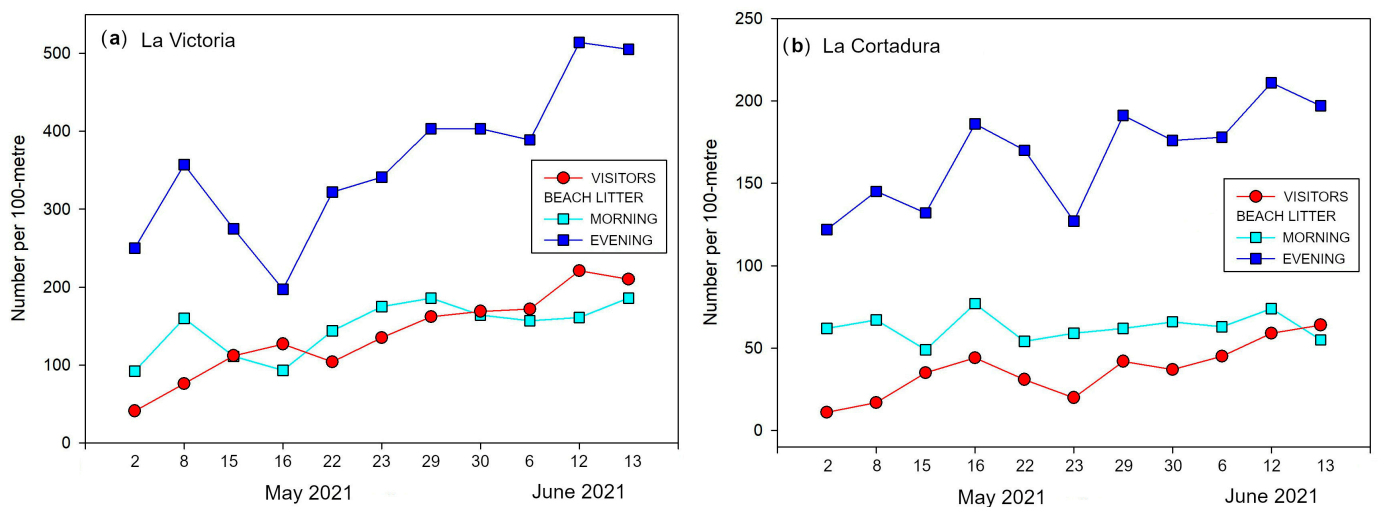
Beach litter abundance at the two study sectors recorded during the morning and evening surveys is presented in Figures 2 and 3. The amount of litter recorded during the morning beach litter survey represented the quantity of litter observed after the cleanup operations that were carried out daily very early in the morning, and the amount recorded during the evening beach survey reflected the number of litter items left by beach users during the day.

Concerning the La Victoria beach sector, an increase in the amount of litter was observed during both the morning and (especially) the evening survey (Figures 2 and 3). The amount of beach litter recorded during the morning survey showed a small and unclear ( $R^2 = 0.49$ ) trend, with a final increase in litter content of 102.17%. The data collected during the evening survey showed a constant and evident ( $R^2 = 0.70$ ) increasing trend, and the amount of litter demonstrated a 50.5% increase during the study period. Further, for the morning survey, the amount of litter ranged from 0.018 items m<sup>−2</sup> (or 0.115 items m<sup>−1</sup>) on 2 May to 0.037 items m<sup>−2</sup> (or 0.233 items m<sup>−1</sup>) on 29 May and 13 June, with an average value of 0.019 items m<sup>−2</sup> (or 0.118 items m<sup>−1</sup>). For the evening survey, the amount of litter ranged from 0.039 items m<sup>−2</sup> (or 0.246 items m<sup>−1</sup>) on 16 May to 0.103 items m<sup>−2</sup> (or

0.643 items  $m^{-1}$ ) on 12 June, with an average value of 0.064 items  $m^{-2}$  (or 0.397 items  $m^{-1}$ ) (Figure A1b).



**Figure 2.** Box plots of the total number of beach litter in each of the 22 surveys at La Victoria and La Cortadura.



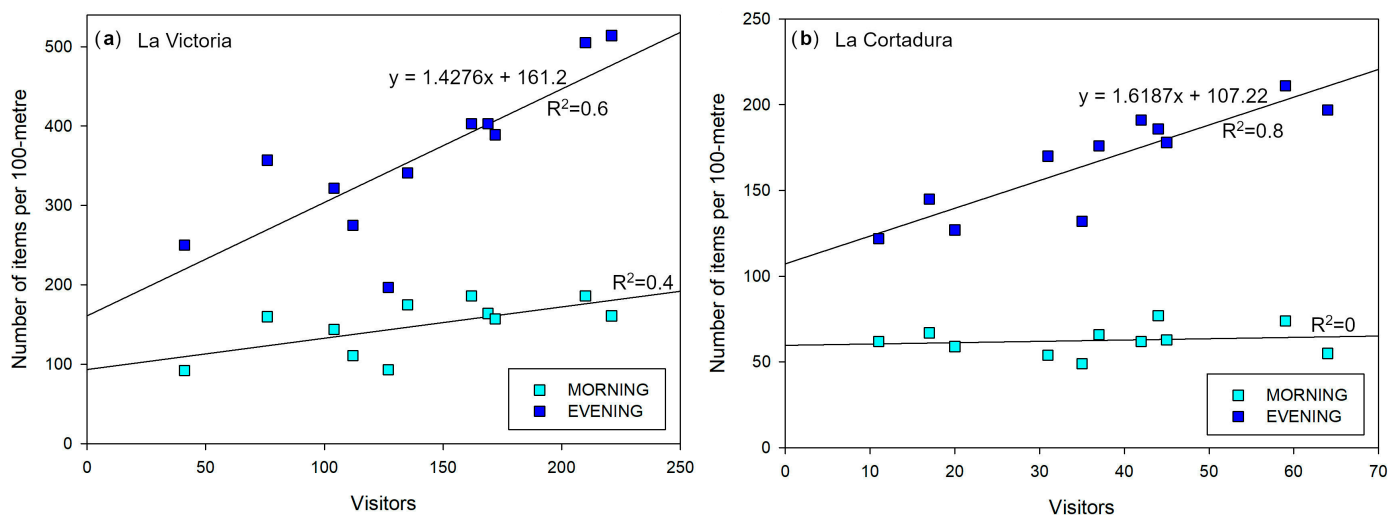
**Figure 3.** Numbers of beach visitors and amount of beach litter (recorded during the morning and evening surveys) during the study period at the investigated sectors: (a) La Victoria and (b) La Cortadura beaches.

Concerning the La Cortadura beach sector (Figures 2 and A1c), the litter content recorded during the evening survey presented a definite (72.95%) and constant ( $R^2 = 0.60$ ) increase. The litter content ranged from 0.027 items  $m^{-2}$  (0.152 items  $m^{-1}$ ) on 2 May to 0.047 items  $m^{-2}$  (0.264 items  $m^{-1}$ ) on 12 June, with an average value of 0.020 items  $m^{-2}$  (0.112 items  $m^{-1}$ ). The amount of beach litter observed during the morning survey did not change significantly during the investigated period and ranged from 0.011 items  $m^{-2}$  (0.061 items  $m^{-1}$ ) on 15 May to 0.017 items  $m^{-2}$  (0.096 items  $m^{-1}$ ) on 16 May, with an average value of 0.006 items  $m^{-2}$  (0.035 items  $m^{-1}$ , Figure A1c).

Box plots that enclosed 50% of the data were drawn to represent the abundance of litter. The median value, represented by a single black line, reflects the midpoint of the data distribution. Concerning the evolution of the litter density, the amount of litter was higher in the evening than in the morning (Figure 2). At La Victoria beach, the average number

of litter items per beach was 148 in the morning and 360 in the evening. At La Cortadura beach, the average values were lower, with 62 items in the morning and 167 in the evening (Figure 2). Statistical analyses revealed that the observed differences in litter abundance did not depend on the sampling time ( $p = 0.5$ ). However, there were significant differences in litter abundance between the beaches and for the sampling time ( $p$  values  $< 0.001$ ).

An increase in beach litter was observed during the study period, which covered the beginning of the summer season, due to the increase in beachgoers (Figure 4). Trash bins were used daily by visitors and were quite full. Concerning seasonal trends in litter abundance, greater quantities of litter related to beach users are observed during summer compared to other seasons [31]. This increase in litter on beaches is noticeable, especially in tourist areas. For example, in Alicante (SE Spain), some litter items related to beach users triple their abundance in summer, such as cigarette butts [16], despite the increase in the cleaning efforts carried out during the summer season. Higher densities of beach litter in Sarayköy Beach (SE Black Sea) are also recorded during summer compared to the rest of the year [32].



**Figure 4.** Beach visitors versus litter amount recorded during the morning and evening surveys at La Victoria and La Cortadura beaches.

### 3.3. Litter Grade

The EA/NALG [27] protocol (Table 1) was used to determine the litter grade for the two investigated sites and for the 22 surveys carried out at each site (Table A1).

Despite La Victoria beach scoring an “A” (i.e., “very good” conditions) for almost all litter categories and surveys, a total score of “B” (i.e., “good”) was obtained for most of the surveys (17 out of 22) and “C” (“fair”) for the rest of surveys, with all of them but one based on evening litter data (Table A1). It is interesting to highlight that the “B” score was always related to “general litter” and “C” to “harmful litter” such as broken glass. In summary, the overall litter grade for La Victoria was “C”, which was essentially related to the “general litter” and especially the “harmful litter” categories, which confirms the significant effect of beach visitors on the amount of litter recorded, e.g., the last two “C” values were observed in correspondence with the large number of visitors recorded on 12 and 13 June 2021, and demonstrates the relevance of beach cleanup programs that lead to a considerable reduction in beach pollution, as confirmed based on the “B” scores recorded after cleanup operations.

La Cortadura beach presented a very similar trend to that of La Victoria. Despite “A” being the most observed score, “B” (i.e., “good”) and “C” (“fair”) scores were essentially recorded for “general litter” and “harmful litter” (broken glass), respectively. The overall litter grade for La Cortadura was “C”, and it is interesting to highlight that this negative score was not only exclusively reordered in the evening but also during the morning

surveys (Table A1), evidencing the low efficacy of cleanup operations, especially for the “harmful litter” category.

In the study carried out in 2018 by Asensio-Montesinos et al. [33], La Victoria and La Cortadura beaches also obtained a grade of “C” using the EA/NALG [27] protocol. In the case of La Victoria, this was due to sewage-related debris, general litter, and broken glass. In the case of La Cortadura, it was due to broken glass [33]. The main reasons for the poor scores for these two beaches are still relevant and are the same as when they were first assessed: the abundance of general and harmful litter.

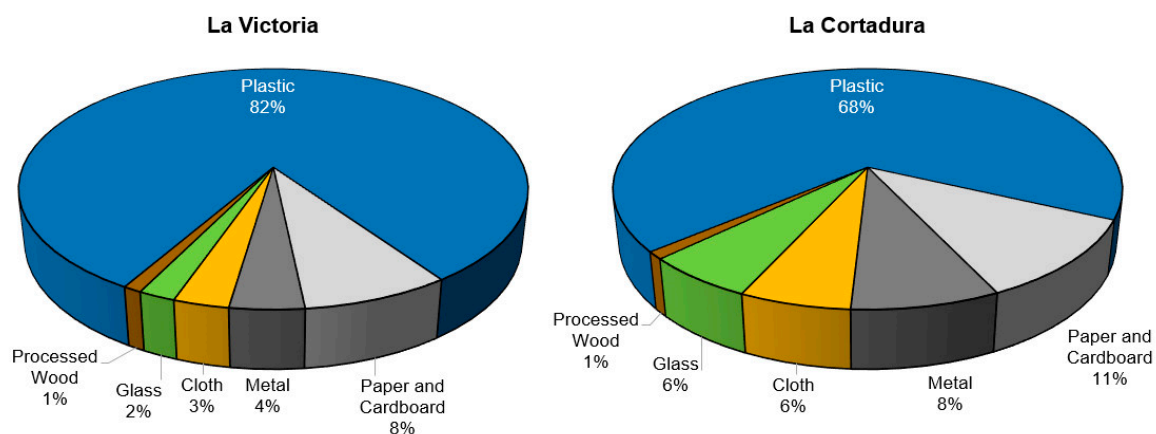
### 3.4. Beach Litter Composition

The most numerous litter items at each of the investigated sites are presented in Table 2. At both sites, cigarette butts were the most abundant items, accounting for 42.61% and 20.53% of the total amount for La Victoria and La Cortadura, respectively. This were followed by hard plastic pieces (0–2.5 cm), which constituted 16.01% of all items at La Victoria and 13.83% at La Cortadura. Other items common to both sites represented less than 5% and included hard (2.5–50 cm) and film (0–2.5 cm) plastic pieces (Table 2). Concerning less frequent items, La Victoria had plastic cups (2.20%), plastic bags (1.15%), and glass bottles (0.98%), and La Cortadura presented cloths (4.88%), foamed plastic pieces (0–2.5 cm, 4.43%), aluminum foil wrappers (3.80%), and glass fragments (0–2.5 cm, 3.53%).

**Table 2.** Most abundant litter items at La Victoria and La Cortadura beaches.

La Victoria	%	La Cortadura	%
Cigarette butts	42.61	Cigarette butts	20.53
Hard plastic pieces (0–2.5 cm)	16.01	Hard plastic pieces (0–2.5 cm)	13.83
Hard plastic pieces (2.5–50 cm)	4.49	Cloths	4.88
Film plastic pieces (2.5–50 cm)	3.33	Hard plastic pieces (2.5–50 cm)	4.84
Film plastic pieces (0–2.5 cm)	3.24	Film plastic pieces (0–2.5 cm)	4.76

Considering all surveys carried out at each site, the litter composition per type of material was similar at La Victoria and La Cortadura beaches (Figure 5). Plastic items were the most abundant and accounted for 82% at La Victoria and 68% at La Cortadura, followed by paper and cardboard, metal and cloth (which were more abundant at La Cortadura), glass, and processed wood items (Figure 5).



**Figure 5.** Beach litter composition at the investigated sites of La Victoria and La Cortadura.

Three plastic items were the most abundant and in the same order at each beach. Cigarette butts accounted for 51.87% and 30.03% of all plastics at the La Victoria and La Cortadura sectors, respectively, followed by hard plastic pieces (0–2.5 cm) with ca. 20% at each beach sector and hard plastic pieces (between 2.5 cm and 50 cm) ranging from 5 to 7%. These were followed by different items that amounted to less than ca. 4% and 7% of



all items at the La Victoria and La Cortadura sectors, respectively, i.e., film plastic pieces between 0 and 50 cm, hard plastic cups, and foamed plastic food containers. This was followed by caps/lids (2.5%) at La Cortadura, bags (1.4%) at La Victoria, and chip/candy packages and lollipop sticks, which were found in smaller proportions at both beaches (Table 3).

**Table 3.** Ten most abundant plastic items recorded at La Victoria and La Cortadura considering all surveys.

La Victoria	%	La Cortadura	%
Cigarette butts and filters	51.87	Cigarette butts and filters	30.03
Hard plastic pieces 0–2.5 cm	19.49	Hard plastic pieces 0–2.5 cm	20.23
Hard plastic pieces 2.5–50 cm	5.47	Hard plastic pieces 2.5–50 cm	7.07
Film plastic pieces 2.5–50 cm	4.05	Film plastic pieces 0–2.5 cm	6.96
Film plastic pieces 0–2.5 cm	3.95	Foamed plastic pieces 2.5–50 cm	6.49
Hard plastic cups	2.68	Film plastic pieces 2.5–50 cm	5.86
Foamed plastic pieces 2.5–50 cm	1.72	Foamed plastic food containers	3.54
Foamed plastic food containers	1.68	Hard plastic cups	2.90
Bags (e.g., shopping)	1.39	Caps/lids	2.55
Chip/candy packages and lollipop sticks	1.39	Chip/candy packages and lollipop sticks	2.20

The type and quantity of litter varied based on the distance from the shoreline. For example, in La Cortadura, items such as ropes and nets predominated in the areas closest to the shore.

The results obtained in this study confirm the data recorded in previous studies on Cádiz beaches that observed plastic as being the most abundant material, followed by cigarette butts and hard plastic pieces [25,33]. In Morocco, plastic was also the main material found on Mediterranean beaches, and other common items were bottle caps, chip packages/candy wrappers, and cigarette butts [34].

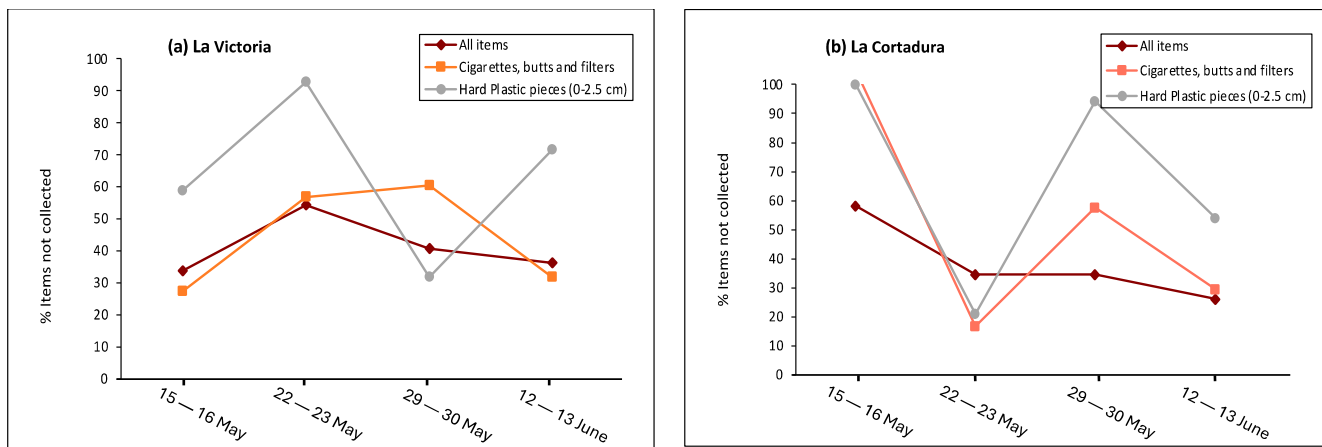
### 3.5. Litter Content versus Beach Visitors and Cleanup Operations

The progressive increase in beach litter content recorded during the evening survey reflected the progressive increase in the number of beach visitors during the study period (Figures 3 and A2) due to the improvement in weather conditions and the beginning of summer vacation.

In the La Victoria sector (Figures 3 and A2), the beach litter content observed during the study period during both the morning and evening surveys demonstrated an increasing trend but with different values. At La Cortadura (Figures 3 and A2), an increase in the amount of litter during the study period was only shown in the evening data. Such trends demonstrate that, despite the increase in the amount of litter recorded during the evening survey, cleanup operations were able to keep the quantity of litter at La Cortadura almost constant. However, this was not the case for La Victoria, where it seems that cleanup efforts were less effective, especially when the litter content was  $>0.06$  items  $m^{-2}$  (Figure A2). The percentage of items not collected presented different and opposite values for the two beaches investigated for the 15–16 and 22–23 May surveys and then decreased in both sectors (Figure 6).

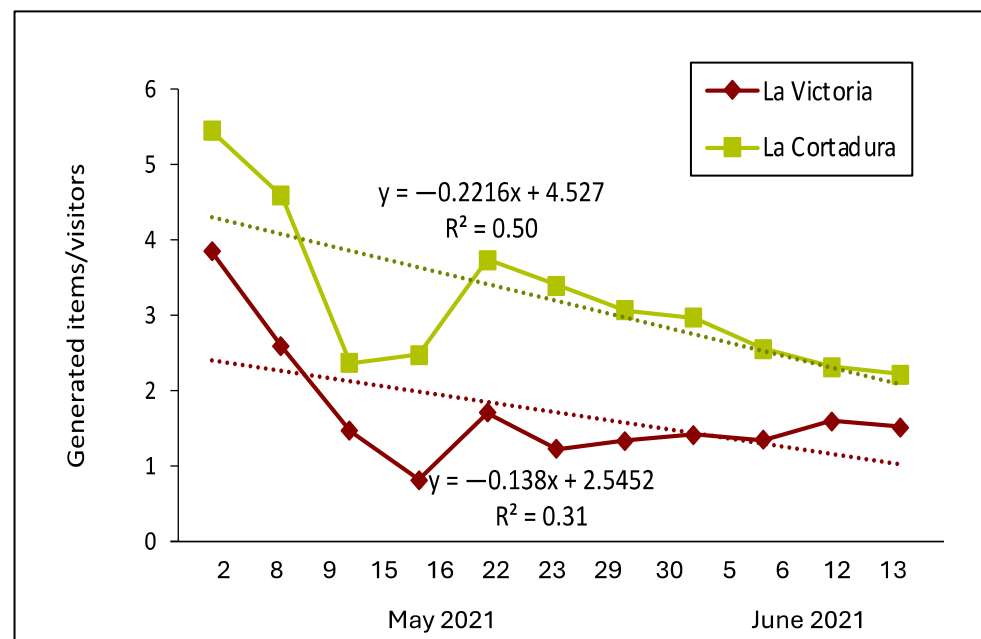
The increase in beach litter content recorded at the La Victoria and La Cortadura beach sectors (Figure 4) was related to the increase in small litter items such as hard plastic pieces (0–2.5 cm) and cigarette butts, which probably passed through the mesh of the beach-cleaning machines. These machines have a mesh size of 2 cm, which allows some but not all cigarette butts to be picked up [25]; therefore, the efficacy of mechanical operations in collecting small items is low [35]. Further, the results obtained involve a certain level of inaccuracy since there was a margin of error in counting small items that could have been easily buried/unburied by wind action and trampling due to beach users. They may also

have remained for several months on the same beach area or moved to (or arrive from) other beach sectors to the one being studied because of wind processes [36].



**Figure 6.** Efficacy of beach cleanup operations at the two beach sectors in La Victoria and La Cortadura, expressed as a percentage of items not collected. The level of efficacy was obtained by comparing the amount of morning beach litter, i.e., the data recorded after the beach cleanup operations, with the amount of beach litter observed the previous evening and due to the use of the beach during the day.

The litter generated daily on the beach, i.e., the amount of litter recorded in the evening sampling minus the amount recorded in the morning sampling, was divided by the number of users observed on the considered day (Figure 7). It was observed that at La Victoria each user was responsible for one to four litter items accumulated daily during the study period, whereas at La Cortadura, each user was responsible for approximately two to six litter items. In both cases, this trend decreased due to an increase in the efficacy of the cleaning operations (Figure 6).



**Figure 7.** Items generated daily (litter amount in the evening minus in the morning) divided by the number of visitors at La Victoria and La Cortadura beaches.

As previously demonstrated by Williams et al. (2016) and Asensio-Montesinos et al. (2020), the bulk of litter on Cádiz beaches is generally distributed in the high-tide water

level and the backshore area [25,33]. This spatial distribution of litter on beaches has also been observed in other countries such as Korea [37] and Japan [38]. The final part of the beach usually always accumulates a lot of litter (Figure A3). It was observed by Williams et al. (2016) that this litter accumulation may be due to the fact that cleaning machines are not able to move close to walls and pathways, so items accumulated there are not collected [25]. In addition, as previously observed, cleaning machines are less effective for small litter items than for general-sized litter [35].

Differences between surveys were also documented on other Mediterranean beaches and were linked to marine storms and river discharge, frequency and modality of cleanup operations, beach user abundance, and beach typology [39]. Numerous researchers have related the amount of litter recorded on urban beaches to local population density. Some of these researchers include Ariza et al. [35], Williams et al. [25], and Asensio-Montesinos et al. [16], who conducted studies on different coasts of Spain; Maziane et al. (2018), who conducted a study on beaches in Morocco [40]; Topçu et al. (2013), who studied the Turkish Western Black Sea Coast [41], and Katsanevakis and Katsarou (2004), who studied beaches in Greece [42]. Generally, the amount of litter is directly related to the number of beach users and inversely related to its geographical distance to a population center [43,44]. Last, changes in the number of beach visitors due to seasonality increase the amount of litter, and such seasonal variability makes it difficult to establish a proper waste management plan that includes facilities aimed at prevention and recycling [35].

#### 4. Conclusions

The differences recorded between the two beaches investigated were remarkable in terms of both abundance and type of litter. The amount of litter present at La Victoria doubled from the beginning to the end of the study, whereas at La Cortadura the increase was not as significant. This was due to the difference in the number of visitors and the activities carried out on each beach. In addition, differences in litter amount recorded during the morning and the evening surveys were very remarkable and related to the number of users that visited the beaches.

The presence of litter is linked to the presence of users, and in turn, the presence of users is linked to favorable meteorological conditions. On days with worse weather conditions (e.g., windy, rainy, or cloudy days), the absence of/decrease in users was evident. On the contrary, sunny days resulted in a higher number of visitors, which evidently increased the number of items of beach litter.

In terms of litter composition, as observed in previous studies, plastic was the most common material identified (80% at La Victoria and 68% at La Cortadura) and was mostly represented by cigarette butts and small fragments of hard plastic pieces.

The cleaning services on both beaches were very effective against medium- and large-sized items; however, most of the small fragments (regardless of the material) remained on the beach surface or buried in the sand after beach-cleaning operations. For this reason, one of the main problems in these areas is the presence of cigarette butts and glass fragments. Concerning the litter grade, category “C” (“fair”) was mainly based on the presence of hazardous items. This highlights a certain degree of mismanagement during previous years that allowed the accumulation of hazardous items. Therefore, efforts must be devoted to making beaches less dangerous for users and consequently improving litter grade scores. The removing of small hazardous items such as glass fragments and small items in general probably has to be carried out manually, because it seems that cleaning machines are currently unable to cope. The large number of small items left behind by cleaning machines is a real problem, because such items persist on beaches during long periods of time. This study shows that even if beaches are cleaned every day, they are still contaminated by different litter typologies, especially small-sized items. The methodology used in this work can easily be applied in other similar areas, and the results obtained can be employed to promote sound management actions to reduce beach litter pollution. Environmental awareness campaigns are necessary to prevent further litter.

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## Appendix A

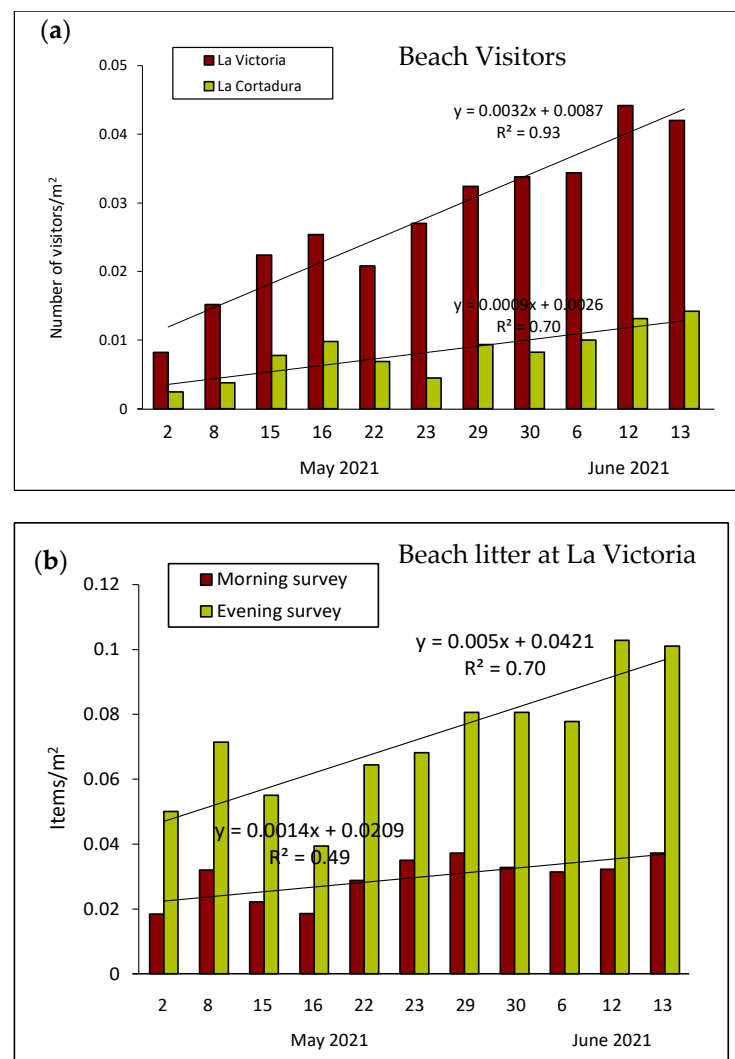
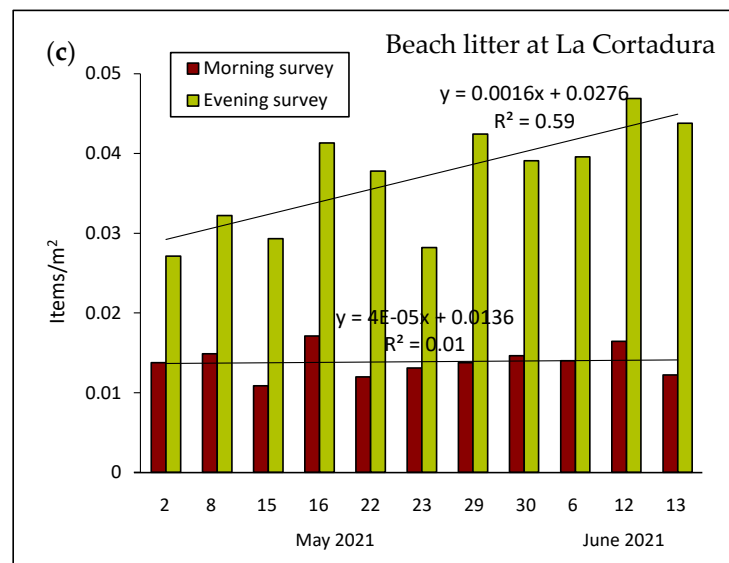
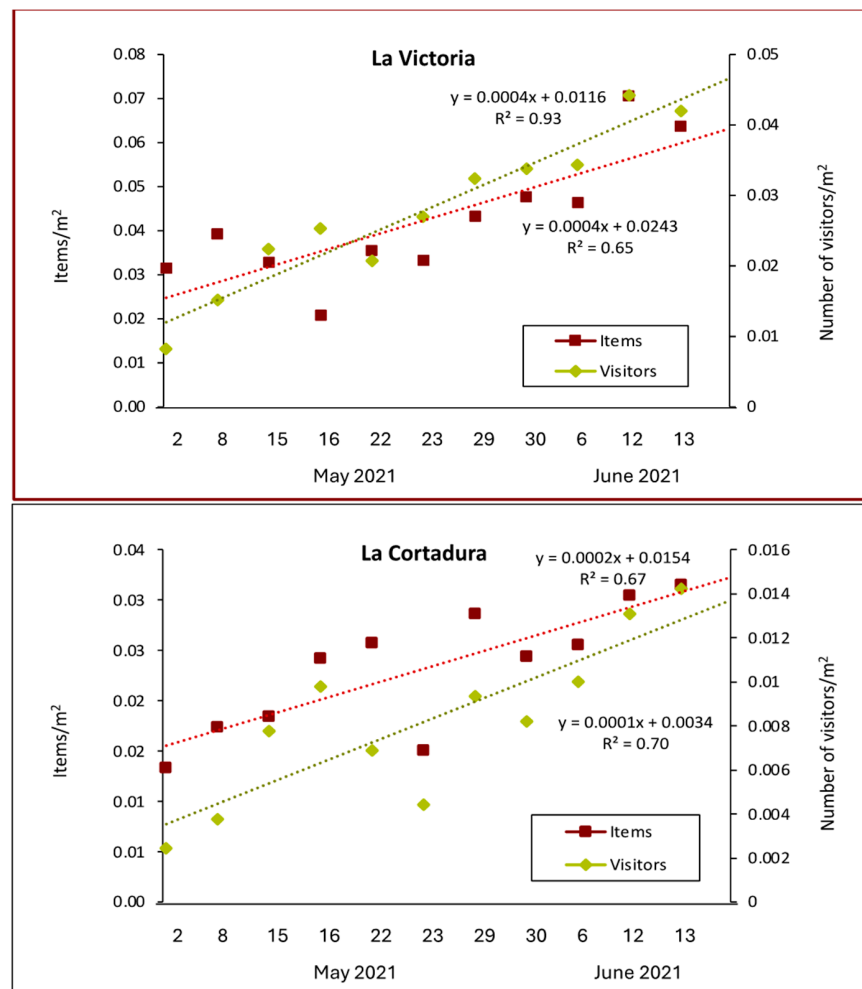


Figure A1. Cont.

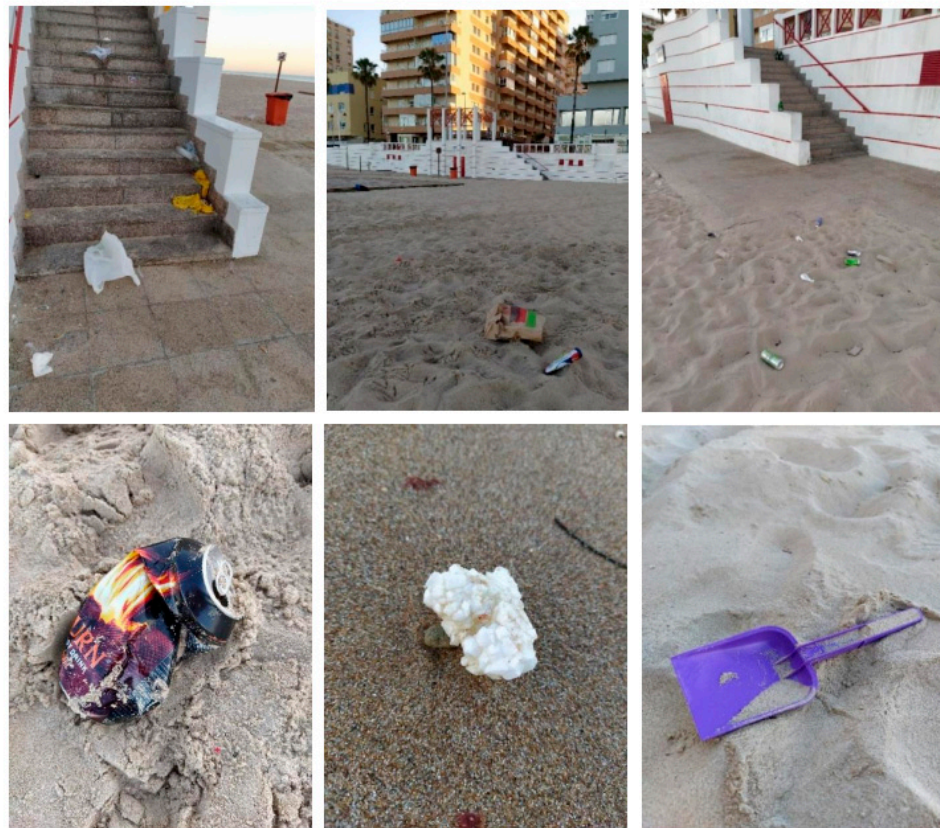


**Figure A1.** (a) Numbers of beach visitors during the study period at the investigated sectors at La Victoria and La Cortadura beaches. Regression lines and  $R^2$  values are also presented. Amount of beach litter at La Victoria (b) and La Cortadura (c) recorded during the morning and the evening surveys. Regression lines and  $R^2$  values are also presented.



**Figure A2.** Normalized beach litter content recorded during the evening survey versus normalized number of visitors at the La Victoria and La Cortadura beach sectors.





**Figure A3.** Some of the most common litter items observed during the study.

**Table A1.** Litter grade calculated for the morning and evening surveys at the investigated beach sectors.

Day	Survey Time	La Victoria	La Cortadura
2 May	Morning	B	B
2 May	Evening	B	C
8 May	Morning	B	B
8 May	Evening	B	C
15 May	Morning	B	C
15 May	Evening	B	C
16 May	Morning	C	B
16 May	Evening	C	B
22 May	Morning	B	B
22 May	Evening	C	C
23 May	Morning	B	C
29 May	Evening	B	B
29 May	Morning	B	B
30 May	Evening	B	C
30 May	Morning	B	B
6 June	Evening	B	C
6 June	Morning	B	C
12 June	Evening	B	C
12 June	Morning	B	C
13 June	Evening	C	C
13 June	Morning	B	B

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