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Article

Abundance and Temporal Distribution of Beach Litter on the Coast of Ceuta (North Africa, Gibraltar Strait)

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Abstract: Twelve beaches located in Ceuta (Spain) were studied from February to April 2019 to assess litter amounts (expressed as number of items), categories and temporal distribution. At each beach, three surveys were conducted, i.e., one per month (i.e., 36 in total). Selected beaches covered urban (7), rural (2) and remote (3) bathing areas. Plastic represented the dominant material, i.e., 35.2% of all debris, followed by glass (18.2%), pottery/ceramics (14.6%), wood (11.4%), metal (11.4%), paper/cardboard (4.8%), cloth (3.5%), rubber (0.7%), organic (0.3%) and other materials (0.1%). The Clean Coast Index was calculated to classify beaches in five categories for evaluating the cleanliness level of the coast observed at each survey: "Very Clean" (7 surveys), "Clean" (10), "Moderately Dirty" (8), "Dirty" (2) and "Extremely Dirty" (9). Litter occurrence was assessed by the Litter Grade methodology, which allowed to classify beaches in four grades: "A": very good (0); "B": good (4); "C": fair (7); and "D": poor (25). In a few surveys, some beaches were considered "good", but their management should not be ignored because in other surveys those beaches reached fair and poor scores. Several potentially harmful litter items were related to beach users. Severe eastern storms removed litter at many of the beaches investigated and favored accumulation at others. Data analysis shows significant differences in litter abundance with respect to site, beach typology and the presence of cleaning operations but no important differences between the studied months. Rural beaches recorded the most litter, followed by urban and remote beaches. All beaches require immediate and more appropriate management actions to improve their environmental status.

Keywords: beach typology; Clean Coast Index (CCI); coastal pollution; harmful litter; litter grade; Mediterranean; marine debris; plastic; polymer; sewage-related debris

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1. Introduction

One of the largest growing industries in the world is "Travel & Tourism" [1], and in 2019, international tourist arrivals recorded an increase (with respect to 2018) of 6% to reach 1460 million and are supposed to arrive at 1.8 billion by 2030. International tourism receipts grew worldwide by 3% in 2019 with corresponding incomes of USD 1481 billion [1]. Despite that tourism's average contribution to GDP is ca. 10%, which increased by 3.6% in 2019, tourism incomes account for up to 25% of GDP in some destinations, e.g., small islands and some developing countries, where it can represent the most relevant pillar of the economy [2]. Spain, in 2019, represented the second destination in the world in the number of international tourism arrivals (i.e., 84 million) and related incomes (i.e., USD 80 billion) [1].

"Leisure, recreation and holidays" accounted for 55% of all international tourist arrivals in 2019 [1], and such visitors are essentially interested in beaches [3], described by [4] as "the most significant flow of tourists ... a sun, sea and sand (3S) market" (p. 58) which, since the 20th century, when coastal areas started to be considered as ideal places for rest and relaxation, have moved billions of tourist dollars [5]. Numerous beach surveys concerning beachgoers' preferences were carried out by Ergin et al. [6] and Williams [7]. Such authors highlighted that five parameters were of the greatest importance to coastal visitors: safety, scenery, facilities, water quality, and no litter, and the last is the focus of this paper. The impact of marine debris (solid waste materials) and litter (discarded man-made objects) is increasingly reported worldwide [8,9] along shorelines as well as pelagic, benthic, marine and lake systems [10–13], and even in extremely isolated and inaccessible settings such as the deep ocean floors and polar regions [14–17]. Litter presence negatively affects ocean wildlife because of the entanglement of animals in abandoned nets, fishing lines, ropes and ribbons [18,19], as well as human health because injuries and cuts [20–22], and it causes the aesthetic deterioration of beaches and loss of associated economic value [23–25]. Further, it promotes microbial communities that may include opportunistic pathogens growing as a biofilm on the plastic surface, a novel ecological habitat in the marine environment denominated the "Plastisphere" [26].

At beaches, litter generally consists of a wide assortment of plastics, paper, metal, cloth, wood, glass and other materials, which may come from marine (20%, e.g., from fishing activities, ships and offshore installations) and land-based (80%) sources [27,28], such as trash left by recreational beach users or carried by wind, sewage, runoff and rivers [29–31]. On average, 60–80% of litter items consist of plastics [32], but this fraction, in certain areas, can be higher than 95% [33,34]. Such high values are fundamentally linked to greater plastic durability and persistence along with its rising production and low rates of recovery [13]. Further, due to the propensity of plastic fragments to shatter as well as their low density, they are able to be easily transported in buoyancy in the sea and water courses. A 25-fold increase in the production of plastic resin goods was observed in the 1960–2000 period with a recovery rate of less than 5% [35,36]. In 2019, global plastics production almost reached 370 million tons [37]. The United Nations Environment Programme (UNEP) estimated that plastic debris has cost USD 13 billion in damage to ecosystems per year and issued a report that proposed the use of a "plastic footprint" to manage the plastic burden in the environment [38]. Arguably, plastic pollution is the second most important global environmental issue after climate change [39].

Beach litter accumulation rates, obtained by means of beach surveys, are useful indicators of litter flows into the ocean [40,41] and depend on different aspects. Beach litter abundance and composition are influenced by different factors such as beach and hydrodynamic characteristics [42,43]; beach clean-up operations; beachgoer abundance, which is related to proximity to metropolitan areas; facility of access to the public [44]; and, as observed in the south of Spain [32,45,46], beach use typology, which includes urban, village, resort, rural and remote areas.

The present paper analyzes data, gathered from February to April 2019, concerning litter content and abundance at 12 beaches in Ceuta Province (Spain), which is located in North Africa and confines with Morocco. The aim of this study is to analyze the spatial and temporal variations of litter content at investigated sites according to approaching waves' characteristics, sediment composition (e.g., sand vs. gravel beaches), beach typology (e.g., remote, urban, etc.) and clean-up operations.

2. Study Area

Ceuta Province, administratively belonging to Spain, is located in North Africa in the easternmost part of the Gibraltar Strait realm, which constitutes the convergence area between the Atlantic Ocean and the Mediterranean Sea (Figure 1).

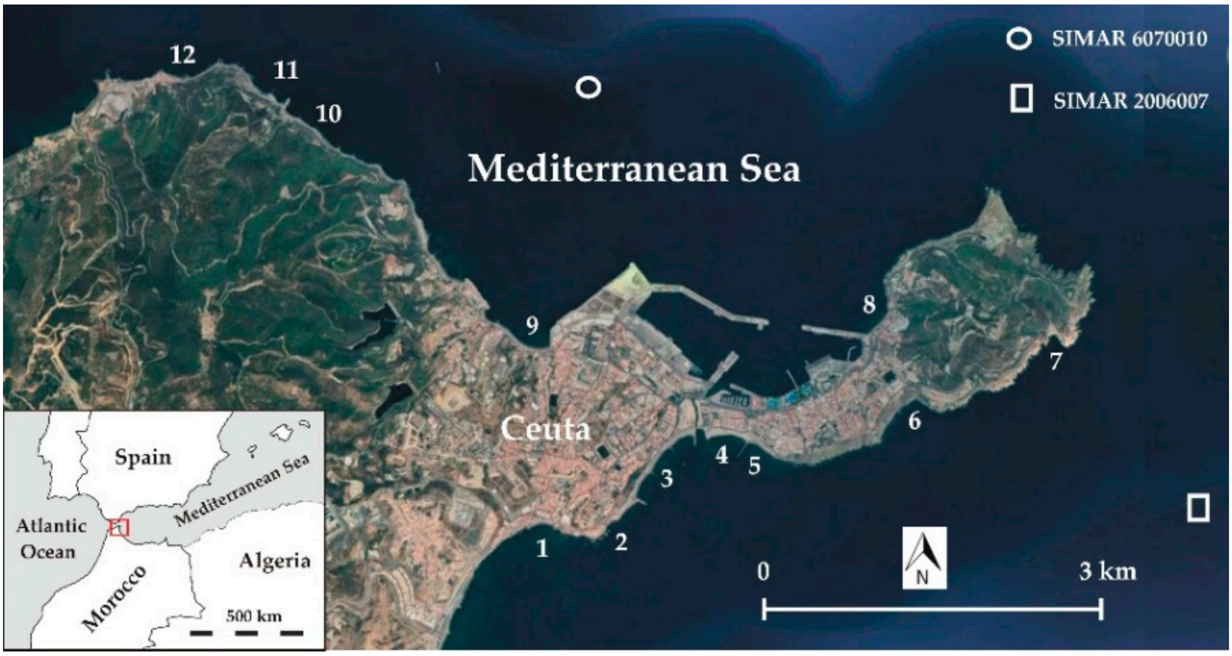

Figure 1. Location map of the beaches investigated and "SIMAR" wave points.

Ceuta has a population of ca. 85,000 inhabitants and, in 2019, revived ca. 77,000 visitors, especially from Morocco [47]. The coast is a microtidal semidiurnal environment composed by sandy, gravel and pebble beaches as well as cliffed sectors. A total of 16 sites [48] are officially declared as beach recreational areas, divided into bathing areas, i.e., beaches with facilities and manual and mechanical cleaning operations (with a weekly frequency during the survey period of this study) and no-bathing areas, i.e., beaches with a limited number of facilities and litter bins with no clean-up operations. This paper deals with litter data obtained at 12 beaches, including both bathing and no-bathing areas (Figure 1, Table 1).

Table 1. Principal characteristics of studied beaches.

Beach No. and Name	Typology	Sediment	Beach Width (m)	Cleaning Operations
1. Miramar	Urban	Sand/Gravel	19	Yes
2. Juan XXIII	Urban	Sand/Gravel	14	Yes
3. El Chorrillo	Urban	Sand	27	Yes
4. La Ribera	Urban	Sand	36	Yes
5. Fuentecaballo	Urban	Sand/Gravel	19	No
6. El Sarchal	Rural	Sand/Gravel	7	No
7. El Desnarigado	Remote	Pebbles	15	No
8. San Amaro	Urban	Sand/Gravel	14	No
9. Benítez	Urban	Gravel	27	Yes
10. Calamocarro	Remote	Gravel	10	Yes
11. Punta Blanca	Remote	Sand/Gravel	24	Yes
12. Benzú	Rural	Sand/Gravel	19	Yes

The study area is affected by winds approaching from east and west directions with velocities reaching more than 8 m/s. The northern part of the coast is principally affected by waves that originate in the Atlantic Ocean, cross the Gibraltar Strait and finally approach from WNW with significant wave height (H_s) values between 1 and 2 m and, secondarily, by more energetic but less frequent waves originating in the Mediterranean Sea and approaching from the East and North (Figure 2a). The Southern part of the coast is exposed to energetic waves that approach from the East (Figure 2b).

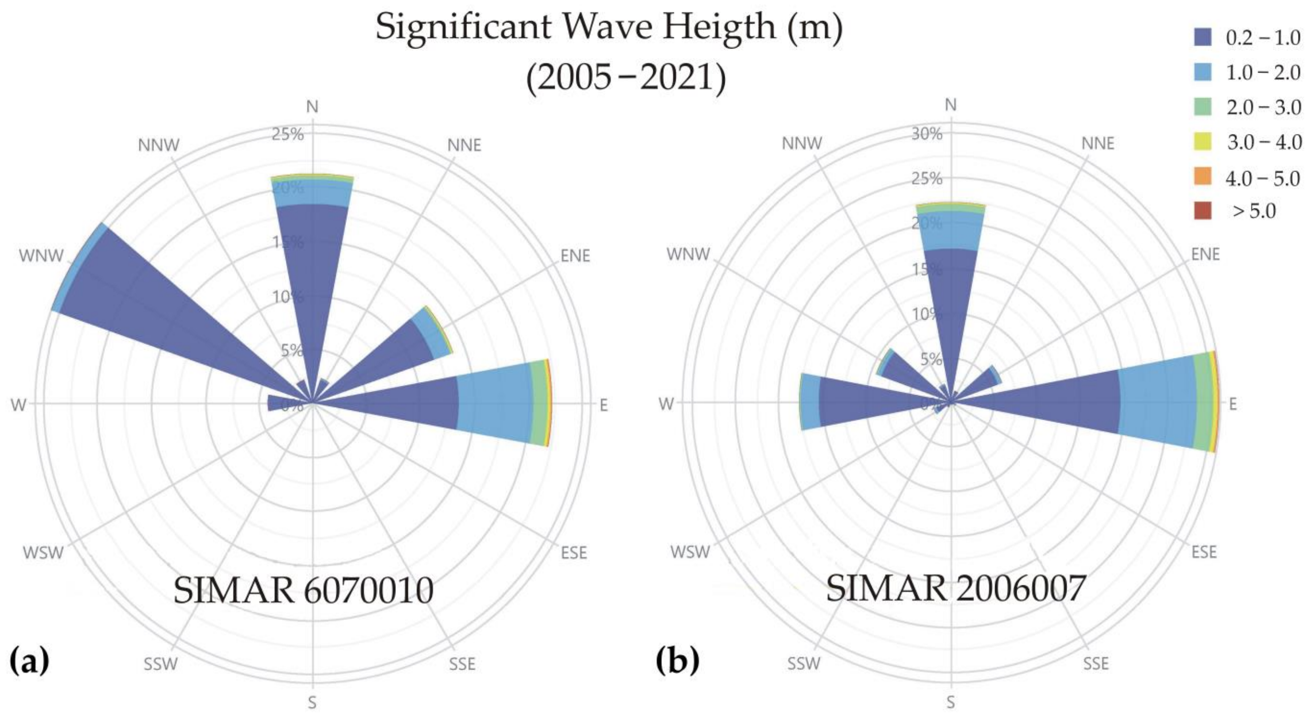

Figure 2. Wave roses for the investigated area ("Puertos del Estado", www.puertos.es, accessed on 1 March 2020).

3. Materials and Methods

3.1. Litter Survey, Quantification and Analysis

A total amount of three surveys, i.e., on 7th–10th February, 15th–17th March and 19th–21st April 2019 (Figure 3), were carried out at 12 beaches in Ceuta Province to have an overview on the characteristics and amount of litter, spatial and temporal distribution, clean-up operations, beach sediment characteristics and beach typology. Beach sediment was visually characterized distinguishing among sandy, gravel and pebble beaches, which determine the type of cleaning actions (i.e., manual vs. mechanical clean-up).

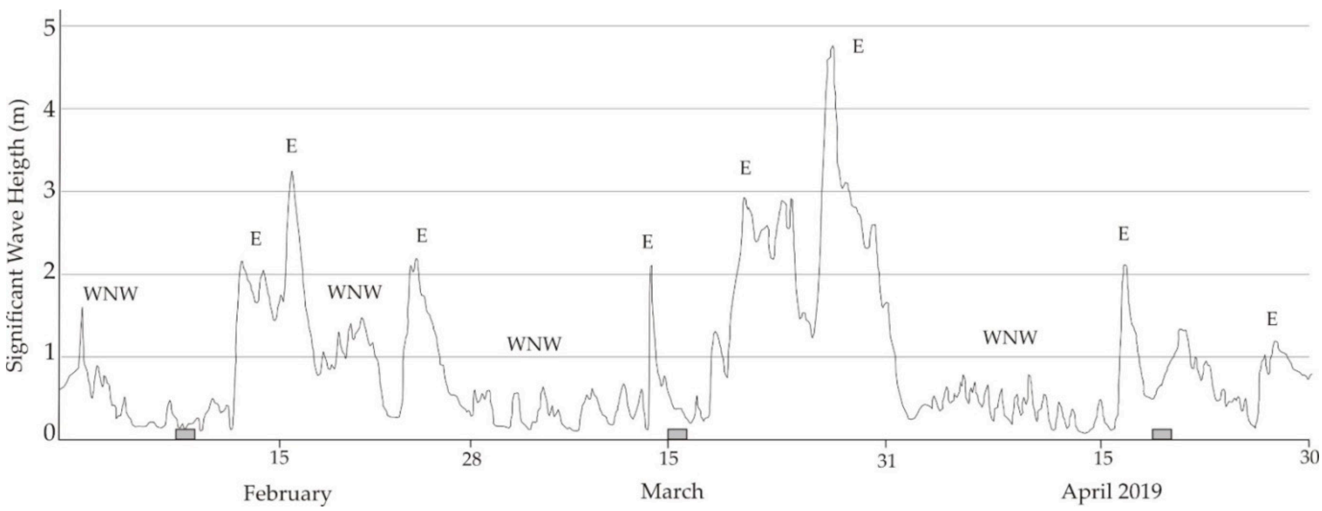

Figure 3. Significant wave height and approaching direction during the investigated period. Grey rectangles represent beach litter surveys.

In order to compare litter content with wave characteristics during the study period, wave height and approaching direction were obtained from "Puertos del Estado" (SIMAR point 2006007; www.puertos.es, accessed on 1 March 2020).

Regarding litter content and abundance, beach surface was examined at the 12 sites investigated along a 100 m wide alongshore sector, 50 m at each side from an access point usually in the central part of the beach, and extended from the landward beach limit (dune toe, promenade, seawall, etc.) to the water line at the moment of the survey [34,40,49,50]. The observer virtually covered the whole beach surface by moving along 5 m separated transects parallel to the shoreline. Surface litter items were visually identified, collected and counted at each one of the different parts of the beach, i.e., the backshore, strand line, foreshore and water position at the moment of the survey. All litter items >2.5 cm in the longest linear dimension were collected, while ensuring the inclusion of bottle caps and cigarette butts as recommended by UNEP/MAP [51].

Litter items were identified by assigning them to different categories according to their composition [11,40,51] (Table A1). Data on litter amount were quantified and expressed as total number of items per linear meter of beach length (items m^{-1}) and as items per square meter of beach surface (items m^{-2}). The values observed at the investigated beaches are comparable because the whole beach area was surveyed at each site; further, litter cross-shore and longshore distribution was homogeneous along each sector, i.e., no anomalous litter concentration was found at mean sea level or at any other specific place.

Statistical analyses were performed with "R" computer program (http://www.r-project.org/, accessed on 20 January 2021) to see the possible differences in litter abundance among sites, beach typology, months and management efforts. For each data set, the requirements of a (one-factor) analysis of variance (ANOVA), i.e., normality and homogeneity of variance, were checked using Kolmogorov–Smirnov (KS) and Bartlett's tests, respectively. If the requirements were not met, a square root data transformation (sqrt) was performed. When ANOVA were significant, a posthoc mean comparison test (Tukey's test) was realized. All statistical tests were conducted with a significance level of $\alpha = 0.05$.

3.2. Beach Typology

Beach typology was determined according to the Bathing Area Registration and Evaluation (BARE) classification system by Williams and Micallef [52]. Such authors considered environmental conditions, accessibility, habitation/accommodation level and community services to classify beaches on an anthropogenic dimensions such as urban, village, resort, rural and remote. In this paper, three categories were considered, i.e., urban, rural and remote bathing areas. Urban areas are large, populated centers with well-established public services and commercial activities, e.g., fishing/boating harbors and marinas, and urban beaches are often observed within or adjacent to the urban area, in this case the town of Ceuta. Rural areas are located outside the urban/village environment; they are not readily reached by public transport and have virtually no facilities. They are appreciated by beachgoers for their quietness and natural qualities. Remote areas have a difficult access (by boat or on foot—a walk of 300 m or more is required), are not served by public transport and, in the case of the Mediterranean, remote beaches have a very limited number of restaurants and second homes, if any [52].

3.3. Clean Coast Index and Litter Grade

In order to determine the level of beach cleanliness, the Clean Coast Index (CCI), developed by Alkalay et al. [53], was calculated as follows:

$$\mathrm{CCI} = \frac{\text{Total litter on sampling unit}}{\text{Total area of sampling unit}} \times \mathrm{K}, \quad (1)$$

The index reflects the total number of items m^{-2}, which is the product between the transect beach length (100 m in this case) and beach width (from water level position to beach landward boundary). Consistent with the CCI index calculation [53], a coefficient K = 20 was inserted into equation (1) to make sure that the value of the resulting index would not fall between 0 and 1. CCI varies from "Very Clean" (0–2), "Clean" (2–5), "Moderate Dirty" (5–10), and "Dirty" (10–20) to "Extremely Dirty" (>20), [53–55].

The Litter Grade [49] technique was also used and applied at the 12 coastal sites. The classification takes into account the presence of “Sewage-Related Debris”, “Potentially Harmful Litter”, “Gross Litter”, “General Litter”, “Accumulations of Litter”, “Oil Pollution” and the “Occurrence of Feces” (Table 2). The abundance of such elements was calculated according to the data gathered at the standard beach sampling unit mentioned above. Beaches can be classified into four litter grades: “A”: very good; “B”: good; “C”: fair; and “D”: poor. The final grading is the worst grade for any of the above considered parameters. For example, if a beach is graded “B” for all parameters except “General Litter”, which is “D”, the final grade assigned to the beach will be “D”.

Table 2. Litter grade categories [49].

	Category [1]	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

[1] Categories: General sewage litter—items include: feminine hygiene products (sanitary towels, tampons and applicators), contraceptives, toilet paper, feces of human origin. Cotton bud sticks—harmless in themselves, but they denote a sewage input. Gross litter (at least one dimension >50 cm)—includes: shopping trolleys, pieces of furniture, road cones, large plastic or metal containers, bicycles, prams, tires, and large items of processed wood, e.g., pallets. Driftwood is not included. General litter (all other items <50 cm in dimension)—includes drink cans, food packaging, cigarette packets, etc. Potentially harmful litter (dangerous to either humans or animals using the beach)—includes: sharp broken glass (counted as a separate category), medical waste (e.g., used syringes), colostomy bag, sharps (metal wastes, barbed wire, etc.), soiled disposable nappies, containers marked as containing toxic products, other dangerous products such as flares, ammunition and explosives ammunition and dead domestic animals. Accumulations of litter—discrete aggregations of litter 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 the presence of weathered oil deposits and tarry wastes. Feces (non-human)—dogs (sheep or horse feces are not be counted).

4. Results and Discussion

4.1. Wave Characteristics

Wave characteristics, i.e., height and approaching direction during the study period, are presented in Figure 3. Significant wave height and approaching direction reflect the local wave climate with the most important storms approaching from the east (Figures 2 and 3). March beach surveys were carried out after a few small storms approaching from the east and characterized by short durations and H_s maximum values of 2 m. Between March and April surveys, i.e., at the end of March (Figure 3), the most energetic events recorded during the investigated period took place because of highest H_s values and long durations. The characterization of wind, waves and currents is of great interest since such natural agents can have a significant effect on beach litter distribution as well as litter amounts and categories [56,57].

4.2. Beach Litter Spatial and Temporal Distribution

Beach width ranged a lot from beach to beach, La Ribera being the widest with 36 m and El Sarchal the narrowest with only 7 m (Table 1). During the three sampling periods, beach litter was recorded at all sites. An amount of 31,571 items were collected from a total of 63,645 m^2 of beach surface surveyed in February, March and April 2019 (Table 3). Beach litter abundance and types presented spatial and temporal variations. The number of recollected items ranged a lot from 8 (or 0.008 items m^{-2}) to 3688 (or 2.634 items m^{-2}) for Calamocarro (in April) and San Amaro beach (in March), respectively (Table 3).

Table 3. Litter abundance at investigated beaches (items per 100 m beach sectors and items m^{-2}).

No.	Beach	February		March		April		Total Items
		No. Items	Density	No. Items	Density	No. Items	Density	
1	Miramar	171	0.113	289	0.190	886	0.583	1346
2	Juan XXIII	290	0.319	194	0.213	343	0.377	827
3	El Chorrillo	397	0.147	512	0.190	565	0.209	1474
4	La Ribera	320	0.089	609	0.169	313	0.087	1242
5	Fuentecaballo	592	0.312	672	0.354	637	0.335	1901
6	El Sarchal	2231	5.312	2883	6.864	2554	6.081	7668
7	El Desnarigado	1303	1.703	1829	2.391	966	1.263	4098
8	San Amaro	1793	1.281	3688	2.634	2744	1.960	8225
9	Benítez	425	0.157	695	0.257	491	0.182	1611
10	Calamocarro	138	0.138	44	0.044	8	0.008	190
11	Punta Blanca	78	0.033	119	0.050	15	0.006	212
12	Benzú	573	0.275	829	0.436	1425	0.750	2777
	Total items	8261		12,363		10,947		31,561

The average abundance for each beach and for the three sampling periods showed the Calamocarro beach as the cleanest coastal site (average value: 63.3 items, or 0.063 items m^{-2}) and the San Amaro beach as the most litter-polluted (average value: 2742 items, or 1.96 items m^{-2}). ANOVA showed very highly significant effects ($p < 0.001$) when location is considered, i.e., these results indicate strong differences in beach litter abundance between sites. Differences between individual means were tested for significance using Tukey's HSD and 95% family-wise confidence level. The most significant differences were found between the following sites: San Amaro and El Sarchal vs. Calamocarro and Punta Blanca. The litter abundance in a few studied sites is comparable to that observed along the Mediterranean coast of Morocco [58], in the south of Spain [32,59], and on the littoral of the Adriatic and Ionian Seas [60]. The high content of litter at most polluted sites (e.g., El Sarchal and San Amaro) can discourage beachgoers [25], and this can affect the economic value of a beach [3] and also its adjacent economy (e.g., shops, bars, restaurants, etc.).

Considering all beaches, litter abundance showed some variations among the three surveys; i.e., 8261 items (26% of all items, on average 411 items/beach) were collected in February, an increase was recorded in March (12,363 items or 39%, on average 640 items/beach) and a slight decrease in April (10,947 items or 35%, 601 items/beach, Table 3). Box plots, which enclose 50% of data, were drawn to represent the total number of litter items and densities, and results presented as mean (or average) and median values because distributions were skewed towards higher values, i.e., mean value > median value (Figure A1a). The mean is conventionally an accepted estimator of the midpoint in a dataset, but is greatly affected by outliers, i.e., any single value of the data set that is extremely high or low compared to the rest. Therefore, in this investigation, the median value better reflects the midpoint of data distribution. Concerning litter density evolution (Figure A1b), the median value was recorded in February (0.216 items m^{-2}), which later increased in March (to 0.235 items m^{-2}) and especially in April (0.356 items m^{-2}). However, ANOVA shows no significant effect for the "month" factor ($p = 0.6$). Variations between surveys were also observed at the nearby Mediterranean coast of Morocco [58] and in the south of Spain [46,59], linked to marine storms and river discharge fluctuations, frequency and modalities of clean-up efforts, beachgoer abundance and beach typology.

The significance of river discharge fluctuations is not considered in this study because no relevant rivers or streams are present in the study area due to the mountainous morphology and elongated shape of the Ceuta peninsula. Marine storms probably achieved a relevant influence on litter spatial distribution and abundance observed in April survey. Two high energetic events approaching from the east occurred after the survey carried out in March, i.e., the periods 20–24th and 26–30th March, during which H_s respectively reached almost 3 and 5 m (Figure 3). In the area, eastern storms give rise to westward currents—local variations can of course take place due to specific bathymetric characteristics, presence of headlands, etc., which affect wave front propagation by controlling refraction and diffraction processes. Therefore, it is not possible to determine the detailed effects of such storms on each site of the coast investigated, but it is possible to argue the existence of a general westward directed current and associated transport. According to a such hypothesized transport direction, on the southern coast of Ceuta, i.e., from beach no. 1 to no. 7, litter diminution took place in all eastern beaches (which face South, namely beaches from no. 4 to no. 7, Figure 1) and an increase in litter abundance took place in western beaches (nos. 1, 2 and 3) that face SE, i.e., the shoreline at such locations forms a gentle angle with approaching waves fronts, thus further favoring accumulation processes. A similar behavior is observed on the northern coast of Ceuta where litter diminution was observed in all beaches but one (no. 12). More detailed investigations are especially required for the northern littoral because the studied beaches have different orientations and, further, the effects of the eastern storms that occurred at the end of March may have been partially masked by the impacts of successive WNW erosive events that did not affect the southern coast (Figure 3). Further, during storm events, flooding processes were relevant and affected all beach width (that is usually very limited, Table 1), i.e., waves easily reached the landward beach limit, essentially backing human structures, possibly carrying away litter items such as plastic bottles and other objects with good buoyancy (e.g., foamed plastic pieces), but also other litter items (e.g., wires, glasses, rope and strings, etc.) can be affected because of burial and exhumation processes. This is interesting to highlight as the most abundant decrease in litter content took place at El Desnarigado beach (no. 7), which is a high energetic one according to beach sediment characteristics (i.e., pebbles, Table 1). These litter behaviors have been also recently reported in cobble beaches located on the southeastern coast of the Iberian Peninsula [61]. In any case, more specific observations and short-time monitoring programs (with a 2–3 day frequency) are required to investigate the effects of energetic events at each investigated site. Therefore, despite no detailed information existing regarding the exact timing of clean-up efforts on the investigated coast, it is evident that March's eastern storms generally favored beach litter diminution with an increase only recorded at few specific sites. The hypothesis of litter removal by storms is confirmed when only no-cleaned beaches are considered, i.e., Fuentecaballo, El Sarchal, El Desnarigado and San Amaro (nos. 5, 6, 7 and 8, Table 3). Such beaches recorded a negative accumulation rate or no accumulation, in contrast with the litter increase observed between the first and second assessment (February–March) which presented a great spatial variability, i.e., from 80, 500, 600 to 1895 items (Table 3). By contrast, in cleaned beaches, cleaning operations were carried out with a weekly periodicity during all the investigated periods, and the increasing abundance of litter recorded over the surveys reflected a high rate of fresh litter accumulation.

With respect to litter abundance distribution and beach typology, variations were recorded among different beach typologies (Figure A1c, Tables 1 and 3). ANOVA showed significant differences in litter abundance with respect to beach typology (p = 0.007), especially between remote and rural typologies (p = 0.005).

4.2.1. Remote Area Beaches

Remote area beaches included three sites: from one side, Calamocarro and Punta Blanca, which presented the lowest pollution levels (average 201 items/beach) investigated in this paper (beaches no. 10 and 11, Figure 4). This occurred because of two main reasons: the location of the beaches, which categorizes them as remote sites, means that these coastal sites are less visited than the other categories during the winter period, and the clean-up actions prevent the accumulation that can occur over time. On the other side, El Desnarigado beach was highly polluted with 4098 items (no. 7, Table 3 and Figure 4). A lack of management and its remote location make this beach one of the most polluted and dangerous for visitors. It is also one of the most exposed beaches in the study to marine storms, coming from the south (especially) and east directions (Figure 1). Mean litter values (per 100 m wide coastal sector) in those three sites during the study period were 506 (February), 664 (March) and 330 (April) units (Figure 5a). In countries with tourist-intensive coastlines, remote beaches generally contain less litter than more urbanized beaches [46,59,62]. However, on remote and rarely visited beaches (e.g., those located on remote islands) the amount of litter can vary greatly as it is mostly conditioned by marine litter carried by waves, ocean currents and winds. There are remote beaches on pristine islands where litter can range from zero, as is the case of Antarctica [14,17], to hundreds of debris per square meter, as is the case of the North and South Pacific [63,64].

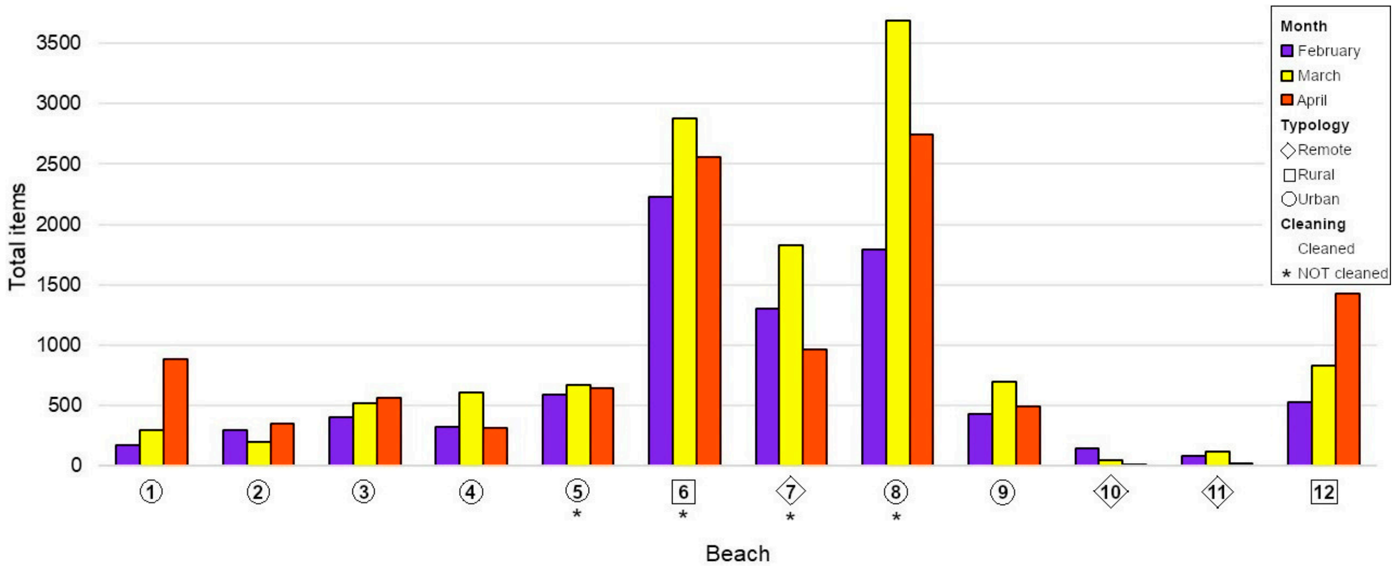

Figure 4. Beach litter amount recorded at each site and survey.

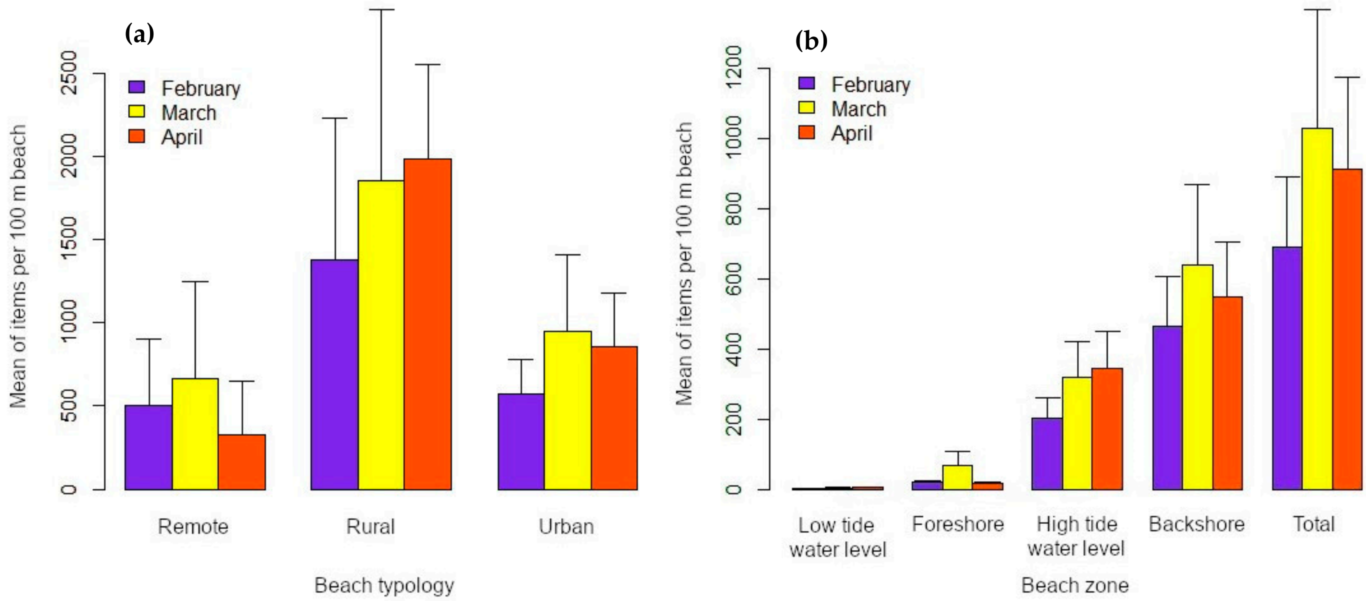

Figure 5. Interaction plots: (**a**) abundance of litter by beach typology for February, March and April; (**b**) abundance of litter by beach zone for February, March and April.

4.2.2. Rural Area Beaches

This category includes two beaches represented by El Sarchal and Benzú (no. 6 and 12, Figures 1 and 4). They presented higher pollution levels than those observed at urban and remote areas (Table 3 and Figure 5a). Both localities, often used as dump areas, presented litter items related to beach use, and these were often linked to parties with consumption of drugs and alcohol. At El Sarchal beach, dangerous items were observed such as wires, hooks, metal fragments, cutlery, glass fragments, syringes, plastic fragments, processed wood, etc. On this beach, almost half of the litter (49%) belonged to groups potentially hazardous to wildlife and humans. Rural areas had an overall average value of 1741 items (3.29 items/m^{-2}). As above, this value is higher than those observed on the nearby Moroccan rural beaches [58,62]. Other rural sites in the Spanish Mediterranean reached very high amounts of beach litter (e.g., 0.373 items/m^{-2}) [59], although these values were still lower than those reported in the rural beaches of Ceuta. Mean litter values (items per 100 m beach sectors) were the highest reported in this study for all surveys. In February, the two beaches included in rural category reached a mean value of 1377 items per beach. This value was on the rise over the next surveys, i.e., a mean of 1856 items in April and 1989 items in March (Figure 5a).

4.2.3. Urban Area Beaches

A total of seven of the studied beaches are located in urban areas. In this beach category, litter densities ranged a lot: Juan XXIII appeared as the lowest polluted site with a total of 827 items recorded in the three surveys (no. 2, Table 3 and Figure 4), and at San Amaro, the highest pollution level was recorded with 8225 items (no. 8, Table 3 and Figure 4) and is used as an illegal dump area where remains of furniture, barbecues, glass fragments, etc., are discharged. Litter abundance can be considered more or less constant during the three surveys. In these seven urban beaches, the mean values of litter items per 100 m of beach width for February, March and April were 570, 951 and 854 items, respectively (Figure 5a). The overall density average value was 792 items (0.48 items/m^{-2}). This value is higher than those observed on the nearby Moroccan urban beaches [58], on the Black Sea coast [65] and other urban sites along the Mediterranean coastline [59]. In urban beaches, the amount of litter was related to the density of population, as evidenced by numerous studies in Spain [45,46,66], in Morocco [62], in the Black Sea [67,68] or in Greece [69].

By one way, the above data highlight the absence of a clear relationship between beach typology and litter abundance, which has also been observed by different authors in some specific cases [59] because usually (not always), the beaches with the highest concentration of litter tend to be the most visited, and these are often village or urban beaches [62]. In other words, in many cases, the use of the beach has more influence on the abundance and type of litter than the beach typology itself.

By the other way, the total number of items observed at each beach was clearly related to beach clean-up operations: the highest litter-pollution levels were observed at no-cleaned beaches, i.e., Fuentecaballo, El Sarchal, El Desnarigado and San Amaro (Table 3). Indeed, ANOVA shows very highly significant effects ($p < 0.001$) when the cleaning factor is considered (see Figure A1d). The amount of beach litter observed at each survey varied in time in different ways, and in general, the highest values were recorded on beaches that are not cleaned, with some exceptions (i.e., from beach no. 5 to beach no. 8, Figure 4). Juan XXIII, El Chorrillo, La Ribera, Fuentecaballo, Benítez, Calamocarro and Punta Blanca beaches (no. 2, 3, 4, 5, 9, 10 and 11) presented small monthly variability; meanwhile, Miramar, El Sarchal, El Desnarigado, San Amaro and Benzú beaches (no. 1, 6, 7, 8, 12) presented a certain variability with maximum values in March (Figure 4). Since these beaches are not cleaned, litter amount variability is only related to litter inputs from land (including users) and from the sea (therefore due to marine processes). At such beaches, items (e.g., glass fragments, drinks, hard plastic pieces, wood fragments) clearly increased from February to March.

Lastly, clear differences regarding the abundance of litter by beach zone were recorded. The low tide line was where the lowest amounts of litter were counted, with mean values of 2, 3 and 4 items per 100 m of beach for the months of February, March and April, respectively. On the foreshore, the mean values were slightly higher with 19 items in February, 66 items in March and 16 items in April (Figure 5b). The bulk of litter was distributed among the backshore area and the high-tide water level, confirming some observations that were carried out in other places such as Korea [70], Japan [71] and Spain (Cádiz) [46]. The high-tide water level presented mean values of 203 items (February), 320 items (March) and 343 items (April), while the backshore area is the most polluted beach zone. In the backshore, a mean of 464 items were registered in February, 641 in April and finally, 549 in March (Figure 5b). February was the month in which the least amount of beach litter was counted, followed by April and March, the latter with the highest concentrations (mean values of 688,912 and 1030, respectively, Figure 5b).

4.3. Beach Litter Composition and Associated Toxicity

The abundance of beach litter per type of material in Ceuta is exceptional as generally it differs from that observed in other proximate coastal areas (Figure 6). Taking into account the three surveys (February, March and April), the litter composition per type of material was as follows: plastic (35.2%), glass (18.2%), pottery/ceramics (14.6%), wood (11.4%), metal (11.4%), paper/cardboard (4.8%), cloth (3.5%), rubber (0.7%), organic (0.3%) and other materials (0.1%).

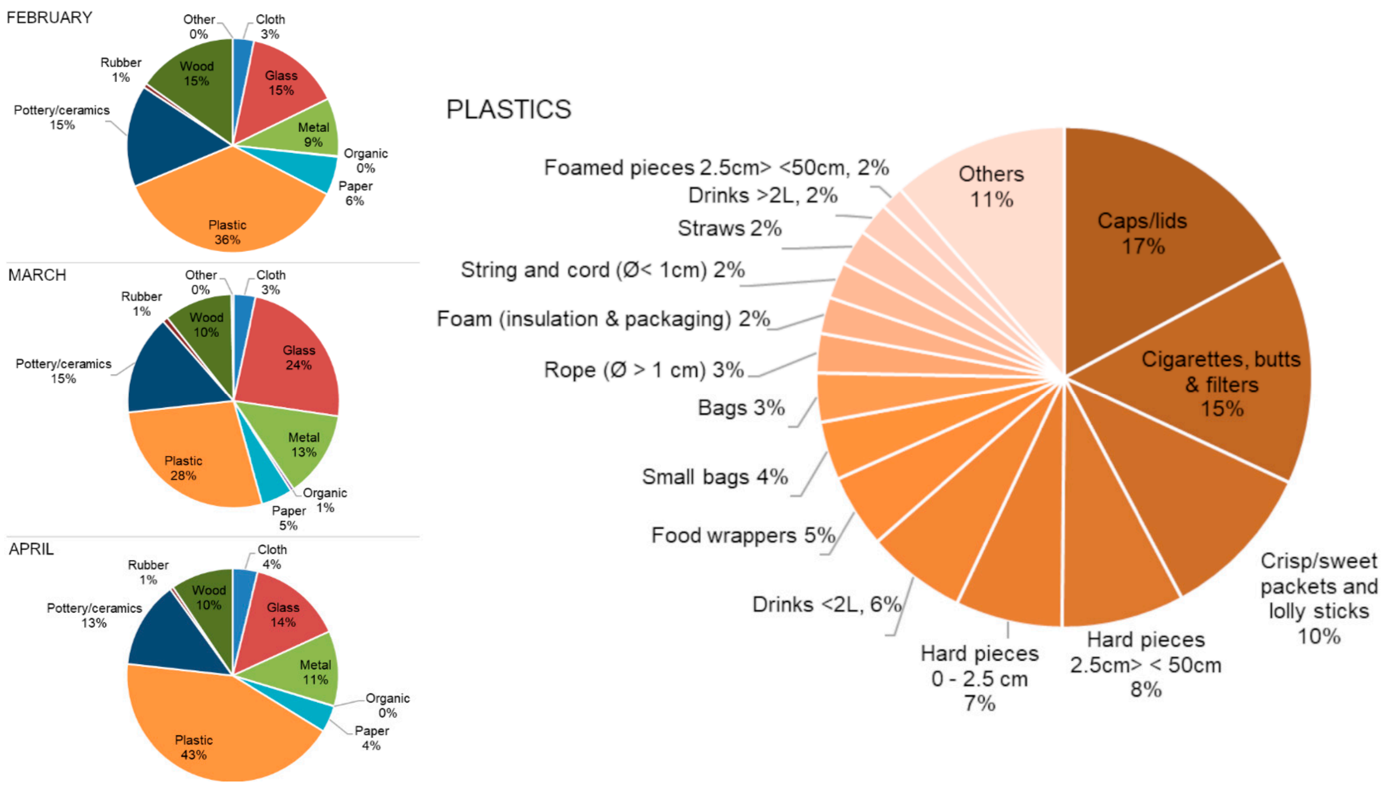

Figure 6. Beach litter composition during sampling period by material type (sector diagrams on the left). Most represent plastic litter categories (sector diagram on the right). The percentage of a specific litter category is calculated as the quantity of all items belonging to such category with respect to the total amount of litter items counted.

During the sampling period, the proportion of materials was similar but varied slightly in some cases. The highlights consist of by plastics that ranged from 28 to 43%, glass (14–24%) and processed wood (10–15%, Figure 6). On the coasts of the Iberian Peninsula, plastic litter ranged between 38 and 88.5% [46,59,72,73]. Plastic material increased at the end of the study (Figure 6) due to a higher abundance of users and the effect of previous storms (Figure 3) that may have brought on the beach floating plastic debris such as bottle caps, bottles and fragments (Table 4).

Table 4. Number of items of the most represented plastic litter categories per month. The highest values are highlighted in bold.

Plastic Category	February	March	April
Caps/lids	594	591	**729**
Cigarettes, butts and filters	222	533	**881**
Crisp/sweet packets and lolly sticks	417	271	**451**
Hard pieces between 2.5 and 50 cm	213	209	**467**
Hard pieces 0–2.5 cm	242	241	**293**
Drinks < 2 L	170	269	**282**
Food wrappers	**184**	179	164
Small bags	125	106	**189**
Bags	87	108	**160**
Rope (Ø > 1 cm)	89	**115**	78
Foam (insulation and packaging)	33	69	**159**
String and cord (Ø < 1 cm)	91	**122**	48
Straws	45	53	**162**
Drinks > 2 L	39	75	**122**
Foamed pieces between 2.5 and 50 cm	41	**86**	42

Among the most common plastic litter counted on beaches, bottle caps were the most numerous and accounted for 17% of all plastic, followed by cigarette butts and filters (15%), crisp/sweet packets and lolly sticks (10%, Figure 6). A similar result was reported for the nearby coast of Morocco [58,62]. The vast majority of the most common litter items recorded the highest values in April (Table 4). This may be due to an increase in the abundance of users as most of the categories involved are directly related to beach users such as cigarette butts, crisp packets, lolly sticks, drinks, bags and straws. Other items (e.g., foamed plastic, rope, string and cord) were more common in March, probably due to the influence of environmental parameters such as wind and waves (Table 4). The number of food wrappers was highest in February, although similar values were also recorded in March and April (Table 4). Food wrappers, although related to the beach users, are very light and can be easily transported by the wind.

As shown in Figure 6, plastic items represent the most abundant litter category accumulated on the beaches along the investigated period. Once in the environment, plastics are disintegrated by physico-chemical processes into smaller fragments [74]. These materials are now thought to be contributing to the build-up of chemicals in the environment via the leaching of chemical additives that are used in the manufacturing process [75]. Plastic products affect the viability of organisms at all trophic levels. The primary producers may be more sensitive to substances that have a biological action, while other organisms as such as non-selective and filter-feeding consumers could be susceptible to ingesting fragmented particles, leading to the potential passage up the food chain to secondary and tertiary consumers [76]. The major plastic litter items founded in the studied beaches are bottle caps, cigarettes butts, crisp/sweet packets and lolly sticks, hard plastic pieces, drinks and food wrappers (Figure 6). Raman spectroscopy results obtained in previous investigations showed cellulose acetate, polypropylene (PP) and polyethylene (PE) as major plastic compounds in the manufacture of cigarettes butts, caps, lids and hard plastic pieces [32].

With respect to cigarette butts, yearly, 4.5 trillion cigarettes are discarded in the environment. According to a report by the Ocean Conservancy (2011) [77], approximately 53 million cigarette butts were removed from coastal environments over 27 years. At least 150 components in the butts (of which 44 are found in large amounts) are considered to be highly toxic. Cellulose acetate (the filter material), a synthetic polymer made from cellulose, is readily biodegraded by organisms that use the cellulase enzyme. Although ultraviolet rays from the sun will eventually break the filter into smaller pieces under ideal environmental conditions, the source material never disappears; it essentially becomes diluted in water or soil [78]. The toxicity of cigarette butts affects organisms due to ingestion of littered filters [79]. The toxicity is attributed to the nicotine and ethylphenol in the leachates from cigarette butts [80] and to the toxicity of products used to treat the filter fibers such as titanium dioxide, triacetin (glycerol triacetate), glues and alkali metal salts of organic acids [78]. Moreover, other studies have also shown that heavy metals, pesticides, herbicides and chemical additives in cigarette butt leachate may be acutely toxic to marine species [81–83]. The occurrence of different metals in cigarettes (such as uranium) can mainly be attributed to the cultivation and growth of tobacco. Insecticide, herbicide and pesticide application may also introduce metals to the tobacco leaf [84]. Further introduction of metals may occur during cigarette manufacture [85,86] or during application of brightening agents on the wrapping paper [87]. The response of biota to the metal content level is extremely different [88]. The quantification of filters in coastal environments as well as the role of aging on filter toxicity are areas deserving of further research. Research into the impacts of smoked cigarette filters on marine life is crucial for consolidating a remedial policy [89].

On the other hand, polypropylene (PP) and polyethylene (PE) are the major compounds used to manufacture bottle caps, lids, pull tabs and hard plastic pieces. Most thermoplastics, including PP and PE, are made by mixing the basic polymer(s) with a variety of chemicals (additives) that can show a higher toxicity than the main plastic compound [90]. Several additives have been shown to adversely affect aquatic species [91,92]. Additives such as bisphenol A (BPA) and phthalates are listed as potential endocrine-disrupting chemicals as they are able to impair hormone regulation in wildlife and humans [93].

Copolupo et al. [90] studied the chemical composition of aqueous leachates from PP and PE and a broad range of organic additive chemicals were identified in the solvent extracts generated from the polymer test materials. The highest number of tentatively identified organic compounds in the polymer extracts was found in PP. With only one identifiable organic additive compound found in the original polymer material, the polyethylene terephthalate (PET) particles were the "purest" material used in the study. Acetophenone, phenoxyethanol and lead (Pb) were found in the PP and antimony in the PET particles and in both the PP leachates (freshwater and marine). All leachates, except PET, inhibited algal growth and affected mussel endpoints, with embryonic development being the most sensitive parameter in mussels, with EC50 values of 65% (PET) of the total leachate. For this reason, leaching toxicity from plastic debris should be strongly considered when assessing the risks of plastic pollution in the oceans.

4.4. Clean Coast Index

The CCI was calculated for every beach and for the three surveys. Values ranged quite a lot (Table 5): 19% of surveys corresponded to the "Very Clean" beach category, namely all surveys at Punta Blanca and two each at La Ribera and Calamocarro. The "Clean" beach category was observed at 10 surveys (27% of total), i.e., all surveys at El Chorrillo and two each at Miramar and Benitez (Table 5). "Moderate Dirty" and "Dirty" beach categories were respectively observed in 22% and 5% of surveys, and the "Extremely Dirty" category (25%) concerned all surveys at three beaches, i.e., El Sarchal, El Desnarigado and San Amaro.

Regarding differences among the sampling periods, no important variations were observed, i.e., six beaches maintained the same category and the others showed small variations, probably due to the fact that litter content variability was not linked to beachgoers, and the number of visitors was low and constant throughout the entire investigated period. Concerning relationships between CCI and Beach Typology (Table 5), a great variability was observed: the three cases presenting the "Extremely Dirty" category were observed at a remote, a rural and an urban beach. El Desnarigado, El Sarchal and San Amaro beaches are used as dump areas and for parties. Surveys carried out at other urban beaches showed the "Clean" category in 50% of cases, followed by the "Moderately Dirty" and the "Very Clean" categories. It is interesting to notice as the "Clean" category was recorded in all (but one) surveys at Punta Blanca and Calamocarro beaches, both being remote areas. Such beaches are rectilinear and open beaches exposed to the first quadrant of approaching waves (Figures 1 and 2) and therefore, probably areas of relevant morphological changes, which is a very different situation from the one recorded at the other remote beach (El Desnarigado), which is probably working as a sinking zone because it is constituted by a small pocket beach enclosed by large headlands.

Table 5. Clean Coast Index (CCI).

Beach No. and Name	Typology	February	March	April	Cleaning
1. Miramar	Urban	2.2	3.8	11.6	Yes
2. Juan XXIII	Urban	6.4	4.3	7.5	Yes
3. El Chorrillo	Urban	2.9	3.8	4.2	Yes
4. La Ribera	Urban	1.8	3.4	1.7	Yes
5. Fuentecaballo	Urban	6.2	7.1	6.7	No
6. El Sarchal	Rural	106.2	137.3	121.6	No
7. El Desnarigado	Remote	34.1	47.8	25.2	No
8. San Amaro	Urban	25.6	52.7	39.2	No
9. Benítez	Urban	3.1	5.1	3.6	Yes
10. Calamocarro	Remote	2.8	0.9	0.2	Yes
11. Punta Blanca	Remote	0.6	1	0.1	Yes
12. Benzú	Rural	5.5	8.7	15	Yes

Clean Coast Index: “Very Clean” (0–2), “Clean” (2–5), “Moderately Dirty” (5–10), and “Dirty” (10–20) to “Extremely Dirty” (>20).

Regarding differences among the sampling periods, no important variations were observed, i.e., six beaches maintained the same category and the others showed small variations probably due to the fact that litter content variability was not linked to beachgoers and the number of visitors was low and constant throughout the entire investigated period. Concerning relationships between CCI and Beach Typology (Table 5), a great variability was observed: the three cases presenting the “Extremely Dirty” category were observed at a remote, a rural and an urban beach. El Desnarigado, El Sarchal and San Amaro beaches are used as dump areas and for parties. Surveys carried out at other urban beaches showed the “Clean” category in 50% of cases, followed by the “Moderately Dirty” and the “Very Clean” categories. It is interesting to notice that the “Clean” category was recorded in all surveys but one for the Punta Blanca and Calamocarro beaches, both being remote areas. Such beaches are rectilinear and open beaches exposed to the first quadrant of approaching waves (Figures 1 and 2) and therefore, probably areas of relevant morphological changes, which is a very different situation from the one recorded at the other remote beach (El Desnarigado), which is probably working as a sinking zone because it is constituted by a small pocket beach enclosed by large headlands. Concerning the relationship between CCI and clean-up efforts, a certain trend is observed: three out of four of the non-cleaned beaches recorded the “Extremely Dirty” category, while the other was “Moderately Dirty” (Table 5). Overall, CCI values recorded along the investigated area were substantially higher than those observed at nearby Mediterranean beaches [58] probably due to the low clean-up efforts performed during the survey period, which is not a tourist one.

4.5. Litter Grade

The EA/NALG (2000) protocol [49] was applied for the 12 beaches assessed and for the three sampling periods (Tables 2 and 6). Only one beach, Punta Blanca, was in good condition with a Litter Grade of “B” and another (Calamocarro) was graded with “C”, and 10 showed very bad grading, i.e., “D”. The litter grade did not record any variation at six sites, which recorded always a “D” score; meanwhile, at other sites, usually one jump (e.g., from “B” to “C” or from “C” to “D”, Table 6) was recorded, and grade “A” was never observed. The litter categories that contributed the most to this grading were “Sewage-Related Debris” (mainly sanitary towels and a few condoms), “General Litter” (essentially caps/lids, cigarette butts and food wrappers) and “Harmful Litter” (i.e., glass fragments and cutting iron cables). During the assessments, “Feces” was also observed at all studied sites except El Sarchal rural beach and Punta Blanca remote beach. Their number varied considerably: in February, only 3 were observed, while in March and April, a total of 49 and 7 were respectively observed, linked to the presence of beach visitors.

Table 6. Litter grade [49].

Beach No. and Name	Typology	February	March	April	Total	Cleaning
1. Miramar	Urban	D	D	D	D	Yes
2. Juan XXIII	Urban	D	C	C	D	Yes
3. El Chorrillo	Urban	C	D	C	D	Yes
4. La Ribera	Urban	D	D	D	D	Yes
5. Fuentecaballo	Urban	D	D	D	D	No
6. El Sarchal	Rural	D	D	D	D	No
7. El Desnarigado	Remote	D	D	D	D	No
8. San Amaro	Urban	D	D	D	D	No
9. Benítez	Urban	D	D	C	D	Yes
10. Calamocarro	Remote	C	B	B	C	Yes
11. Punta Blanca	Remote	B	B	B	B	Yes
12. Benzú	Rural	D	D	C	D	Yes

In relation with beach typology, urban area beaches always had "D" litter grades. The three remote sites had "B", "C" and "D" grades and the two rural areas had "D". Litter categories recorded at the different beach typologies were essentially the same. Overall, it is not possible to observe any difference between urban and rural areas as observed by Nachite et al. [58], which also generally reported very poor Litter Grade scores along the Mediterranean littoral of Morocco, i.e., close to the study area. The better scores observed at two remote areas, i.e., Punta Blanca and Calamocarro (Table 6), confirm data reported along the Atlantic coast of Cádiz Province (South of Spain) [46] which evidenced that the most-visited beach typologies (village and urban) registered worse litter grades, i.e., "C" and "D"; meanwhile, remote beaches scored either "B" or "C", and rural beaches scored all grades ("A"–"D"). Therefore, along the investigated area, litter grade recorded only a slight direct trend with the number of beach visitors that are supposed to be more abundant in urban beaches than in rural or remote areas. This is very probably related to the overall low number of beachgoers observed during the temporal period investigated, i.e., February–April, when people go to the beach just to walk and play sports. The relationship between litter grade and cleaning efforts (Table 6) is partially evident if all surveys are taken into account, i.e., four out of the six beaches that always recorded a "D" grade have no cleaning efforts, confirming observations in the southern Spanish beaches [46]. If only the total score obtained at each site is considered (Table 6), this relation is not clear since six out of eight beaches cleaned have a "D" score. Such results evidence the poor efficiency of cleaning operations, probably due to the low (weekly) periodicity of such operations and/or the high litter accumulation rate that seems associated with marine sources and especially incorrect beach use as dump areas (e.g., El Sarchal San Amaro and Benzú) and areas for party. Therefore, it is necessary to modify management at almost all beaches, for example, by adapting cleaning operations or improving their frequency or by avoiding new illegal litter discharges.

5. Conclusions

The beaches of Ceuta have a particular litter content which hardly coincides with the rest of the Spanish beaches studied within other previous investigations. When litter proportions by type of material are considered, plastics acquire low values and, vice versa, other materials that are not very frequent in other places are more frequent in Ceuta, for example, metal, glass or wood. Moreover, overall litter content tends to be more numerous in Ceuta than in other Spanish provinces. This high level of pollution may be due to several factors acting simultaneously: (i) a lack of education of the people who pollute, (ii) the types of cleaning actions, which frequency are not the most appropriate, (iii) the unfavorable situations of many people that lead them to live on the coast (in shacks, tents, etc.), (iv) illegal construction and dumping, (v) poor general waste management.

Urgent actions are required on Ceuta's beaches because the amount of litter is very high, and it can be dangerous for beach visitors and wildlife. The methodologies applied in this study considered that the bulk of these beaches are in dirty conditions and within litter grade "D", i.e., "poor beaches". Sewage evidences, harmful items and general litter were the principal reasons for beach degradation, owing mainly to illegal dumping and beach user activities. The majority of beach litter consisted of plastic material: bottle caps, cigarette butts and wrappers were the most numerous items. The results showed the low efficiency of beach management during the study period, reflecting an inappropriate litter collection procedure which is probably linked to the low (weekly) clean-up frequency. The significance of litter amount related to beach users' activities requires the urgent need to improving beachgoers' awareness.

Lastly, further investigations can be focused to investigate the effects of eastern storms on beach litter content, but preliminary results evidence a general negative accumulation rate as a result of both westward litter transport and litter removal by waves due to the small beach width of studied sites. The understanding of litter dynamics can give important and applicate indications to local managers focused on spatially and temporally optimizing cleaning operations.

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Appendix A

Table A1. Category codes and description for litter items in the 12-site survey.

Code	Description	Material
CL01	Clothing	Cloth
CL02	Furnishing	Cloth
CL03	Canvas, sailcloth and sacking (hessian)	Cloth
CL04	Shoes (leather)	Cloth
CL05	Towels/rags	Cloth
CL06	Backpacks and bags	Cloth
CL07	Rope and strings/net pieces (non-nylon)	Cloth
CL08	Gloves (non-rubber)	Cloth
CL09	Towels/rags	Cloth
CL10	Rope/net pieces (non-nylon)	Cloth
CL11	Fabric pieces	Cloth
CL12	Sanitary towels/panty liners/backing strips	Cloth
CL13	Toilet fresheners	Cloth
CL14	Cloth pieces 0–2.5 cm	Cloth
CL15	Cloth pieces 2.5–50 cm	Cloth

Table A1. *Cont.*

Code	Description	Material
CL16	Cloth pieces > 50 cm	Cloth
CL17	Hair bands	Cloth
CL18	Cloth labels	Cloth
CL19	Bracelets	Cloth
CL20	Sanitary masks	Cloth
CL21	Hats and caps	Cloth
CLXX	Other textiles (please specify in other item box*)	Cloth
GL01	Beverage bottles	Glass
GL02	Other bottles	Glass
GL03	Jars	Glass
GL04	Tableware (plates and cups)	Glass
GL05	Incandescent light globes/bulbs	Glass
GL06	Fluorescent light tubes/globes/bulbs	Glass
GL07	Glass buoys	Glass
GL08	Glass fragments 0–2.5 cm	Glass
GL09	Glass fragments 2.5–50 cm	Glass
GL10	Glass fragments > 50 cm	Glass
GLXX	Other glass items (please specify in other item box *)	Glass
ME01	Metal medical containers/tubes	Metal
ME02	Aerosol/spray cans	Metal
ME03	Bottle caps, lids and pull tabs	Metal
ME04	Drink cans	Metal
ME05	Electric appliances	Metal
ME06	Fishing weights	Metal (Pb)
ME07	Fishing lures/hooks	Metal
ME08	Fishing traps and pots	Metal
ME09	Foil wrappers	Metal
ME10	Food cans	Metal
ME11	Industrial scrap	Metal
ME12	Oil drums	Metal
ME13	Paint tins	Metal
ME14	Lobster/crab pots and tops	Metal
ME15	Wire, wire mesh, barbed wire	Metal
ME16	Disposable BBQs	Metal
ME17	Tableware (forks and knives)	Metal
ME18	Tableware (plates, cups, spoons)	Metal
ME19	Batteries	Metal
ME20	Metal fragments 0–2.5 cm	Metal
ME21	Metal fragments 2.5–50 cm	Metal
ME22	Metal fragments > 50 cm	Metal
ME23	Nails and screws	Metal
ME24	Hair clips	Metal
ME25	Fishing rod pieces	Metal
ME26	Metal bottle	Metal
MEXX	Other metal items (please specify in other item box *)	Metal
OR01	Bagged dog faeces	Organic
OR02	Food residues	Organic
OR04	Dead marine animal (please specify)	Organic
OR05	Dead terrestrial animal (please specify)	Organic
ORXX	Other organic items (please specify in other item box *)	Organic
PP01	Bags	Paper • Cardboard
PP02	Cardboard	Paper • Cardboard
PP03	Tubes for fireworks	Paper • Cardboard
PP04	Cigarette packets	Paper • Cardboard
PP05	Cigarette butts papers	Paper • Cardboard
PP06	Cups	Paper • Cardboard
PP07	Paper (including newspapers and magazines)	Paper • Cardboard
PP08	Cartons, e.g., tetrapak (milk)	Paper • Cardboard

Table A1. *Cont.*

Code	Description	Material
PP09	Cartons, e.g., tetrapak (other)	Paper • Cardboard
PP10	Paper fragments 0–2.5 cm	Paper • Cardboard
PP11	Paper fragments 2.5–50 cm	Paper • Cardboard
PP12	Paper fragments > 50 cm	Paper • Cardboard
PP13	Firecrackers	Paper • Cardboard
PP14	Cardboard fishing box	Paper • Cardboard
PPXX	Other paper items (please specify in other item box *)	Paper • Cardboard
PW01	Paraffin or wax pieces 0–1 cm	Paraffin or wax
PW02	Paraffin or wax pieces 1–10 cm	Paraffin or wax
PW03	Paraffin or wax pieces >10 cm	Paraffin or wax
PL01	Syringes	Plastic
PL02	4/6-pack yokes	Plastic
PL03	Bags (e.g., shopping)	Plastic
PL04	Small plastic bags, e.g., freezer bags	Plastic
PL05	Drinks (bottles, containers and drums) < 2 L	Plastic
PL06	Drinks (bottles, containers and drums) > 2 L	Plastic
PL07	Cleaner (bottles, containers and drums) < 2 L	Plastic
PL08	Cleaner (bottles, containers and drums) > 2 L	Plastic
PL09	Cosmetics (bottles and containers, e.g., sun lotion, shampoo, shower gel, deodorant)	Plastic
PL10	Engine oil containers and drums < 2 L	Plastic
PL11	Engine oil containers and drums > 2 L	Plastic
PL12	Jerry cans (square plastic containers with handle)	Plastic
PL13	Medical containers/tubes	Plastic
PL14	Injection gun containers	Plastic
PL15	Other bottles, containers and drums	Plastic
PL16	Knives, forks	Plastic
PL17	Spoons, stirrers	Plastic
PL18	Straws	Plastic
PL19	Hard plastic food containers (fast food, lunch boxes and similar)	Plastic
PL20	Foamed plastic food containers (fast food, lunch boxes and similar)	Plastic
PL21	Balloons	Plastic
PL22	Gloves	Plastic
PL23	Cotton bud sticks	Plastic
PL24	Cigarettes, butts and filters	Plastic
PL25	Hard plastic cups	Plastic
PL26	Foamed plastic cups	Plastic
PL27	Food wrappers	Plastic
PL28	Crates	Plastic
PL29	Car parts	Plastic
PL30	Caps/lids	Plastic
PL31	Cigarette lighters	Plastic
PL32	Pens	Plastic
PL33	Combs/hair brushes	Plastic
PL34	Crisp/sweet packets and lolly sticks	Plastic
PL35	Toys and party poppers	Plastic
PL36	Fertilizer/animal feed bags	Plastic
PL37	Cigar tips	Plastic
PL38	Fishing gear (lures, traps and pots)	Plastic
PL39	Mesh bags (vegetable, oyster nets and mussel bags)	Plastic
PL40	Baskets, crates and trays	Plastic
PL41	Foam (insulation and packaging)	Plastic (PU)
PL42	Rope (diameter more than 1 cm)	Plastic
PL43	String and cord (diameter less than 1 cm)	Plastic
PL44	Tangled nets/cord/rope and string	Plastic
PL45	Fish boxes	Plastic (PS)
PL46	Fishing line (angling)	Plastic
PL47	Light sticks (tubes with fluid) inluding bags	Plastic

Table A1. *Cont.*

Code	Description	Material
PL48	Floats/buoys	Plastic
PL49	Buckets	Plastic
PL50	Strapping bands	Plastic
PL51	Industrial packaging, plastic sheeting, tarpaulin or other woven plastic bags, palette wrap	Plastic
PL52	Fiberglass fragments	Plastic
PL53	Hard hats	Plastic
PL54	Shotgun cartridges	Plastic
PL55	Shoes/sandals	Plastic
PL56	Plastic bag ends	Plastic
PL57	Resin pellets	Plastic
PL58	Lobster and fish tags	Plastic
PL59	Nets and pieces of net < 50 cm	Plastic
PL60	Nets and pieces of net > 50 cm	Plastic
PL61	Tampons and tampon applicators	Plastic
PL62	Hard plastic pieces 0–2.5 cm	Plastic
PL63	Hard plastic pieces between 2.5 and 50 cm	Plastic
PL64	Hard plastic pieces > 50 cm	Plastic
PL65	Film plastic pieces 0–2.5 cm	Plastic
PL66	Film plastic pieces between 2.5 and 50 cm	Plastic
PL67	Film plastic pieces > 50 cm	Plastic
PL68	Foamed plastic pieces 0–2.5 cm	Plastic (PS)
PL69	Foamed plastic pieces between 2.5 and 50 cm	Plastic (PS)
PL70	Foamed plastic pieces > 50 cm	Plastic (PS)
PL71	Artificial flowers	Plastic
PL72	Masks and snorkel tubes	Plastic
PL73	Bracelets	Plastic
PL74	Torches and lanterns	Plastic
PL75	Tubes	Plastic
PL76	Pieces of beach umbrella	Plastic
PL77	Wad-container from hunting cartridge	Plastic
PL78	Adhesive tape roll and fragments	Plastic
PL79	Cable ties/clamps	Plastic
PL80	Scourer	Plastic
PL81	Clothes pegs	Plastic
PL82	Eye drops	Plastic
PL83	Sunglasses	Plastic
PL84	Foamed plastic containers (fishing)	Plastic (PS)
PL85	Manual razor	Plastic
PL86	Test tubes	Plastic
PL87	Grid	Plastic
PL88	Hair bands	Plastic
PL89	Medical plasters	Plastic
PL90	Hair clips	Plastic
PL91	Beach ashtray	Plastic
PL92	Tissue packets, wipes packs, tampax packages . . .	Plastic
PLXX	Other plastic items (please specify in other item box *)	Plastic
PT01	Construction material (brick, cement, pipes)	Pottery • Ceramics
PT02	Octopus pots	Pottery • Ceramics
PT03	Other ceramic/pottery items (please specify in other item box *)	Pottery • Ceramics
PT04	Tableware (plates and cups)	Pottery • Ceramics
PT05	Ceramic fragments 0–2.5 cm	Pottery • Ceramics
PT06	Ceramic fragments 2.5–50 cm	Pottery • Ceramics
PT07	Ceramic fragments > 50 cm	Pottery • Ceramics
PTXX	Other ceramic items (please specify in other item box *)	Pottery • Ceramics
RB01	Balloons, including plastic valves, ribbons, strings, etc.	Rubber
RB02	Boots	Rubber
RB03	Tires and belts	Rubber
RB04	Rubber bands	Rubber

Table A1. *Cont.*

Code	Description	Material
RB05	Condoms	Rubber
RB06	Footwear (flip-flops)	Rubber
RB07	Gloves (typical washing up gloves)	Rubber
RB08	Gloves (industrial/professional gloves)	Rubber
RB09	Rubber fragments 0–2.5 cm	Rubber
RB10	Rubber fragments 2.5–50 cm	Rubber
RB11	Rubber fragments > 50 cm	Rubber
RB12	Tennis balls	Rubber
RB13	Elastic octopus straps	Rubber
RB14	Tubes	Rubber
RBXX	Other rubber items (please specify in other item box *)	Rubber
WO01	Corks	Wood
WO02	Pallets	Wood
WO03	Crates	Wood
WO04	Fishing traps and pots	Wood
WO05	Ice lolly sticks	Wood
WO06	Chip forks, chopsticks and toothpicks	Wood
WO07	Paint brushes	Wood
WO08	Fish boxes	Wood
WO09	Matches and fireworks	Wood
WO10	Logs, sticks and plant debris < 1 cm diameter	Wood
WO11	Logs, sticks and plant debris > 1 cm diameter	Wood
WO12	Wood fragments 0–2.5 cm	Wood
WO13	Wood fragments 2.5–50 cm	Wood
WO14	Wood fragments > 50 cm	Wood
WOXX	Other wood items (please specify in other item box *)	Wood
YY01	Other medical items (swabs, bandaging, ban aid, etc.)	Medical waste
YY02	Silica gel packets	Silica
YY03	Insulating cloth	Other
YY04	Shoe insoles	EVA foam, polypropylene ...
YY05	Sponge	Other
YY06	Cable	Other
YY07	Electronics	Other
YY08	Leather pieces	leather
YY09	Wetsuit boots	Neoprene
YYXX	Other (please specify in other item box *)	Other

* Other items that have not been reported in this research can be added in these boxes.

Appendix B

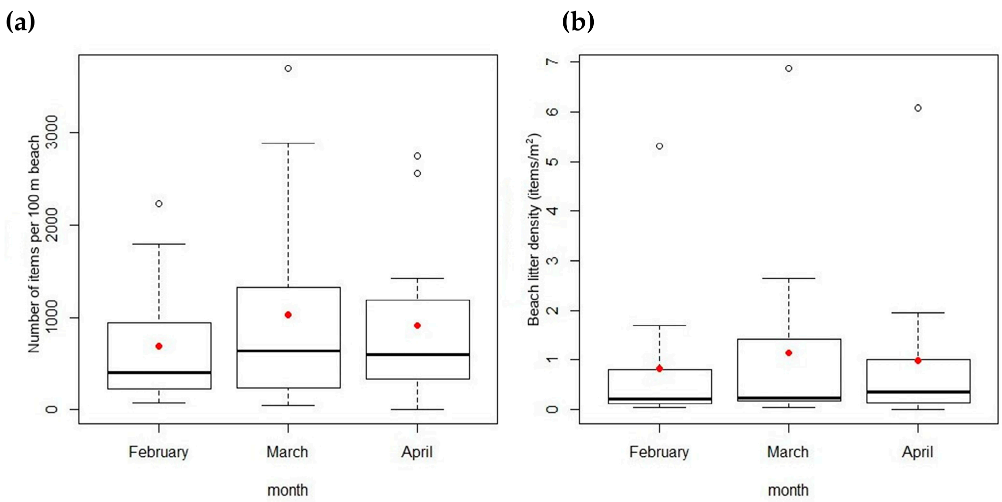

Figure A1. *Cont.*

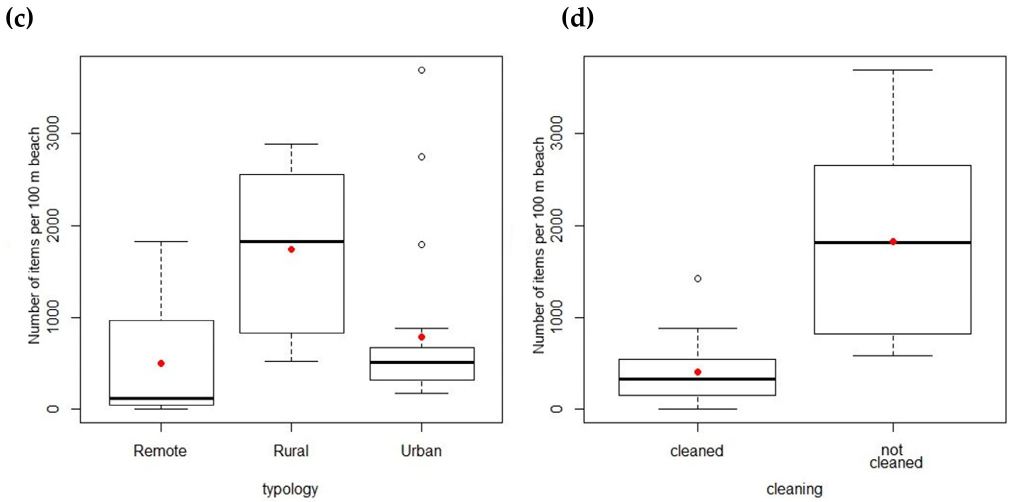

Figure A1. Total beach litter items (**a**) and densities (**b**) observed at the beaches investigated in February, March and April 2019. Total beach litter items per beach typology (**c**) and cleaning operations (**d**). Boxes enclose 50% of data; associated standard deviations are represented with whiskers, averages with red dots, outliers with white dots and median values with black lines.

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