Book Chapter

Marine Litter Composition in Port Areas on Mallorca Island

Livia Maglić[1]*, Lovro Maglić[2], Ana Grbčić[1] and Marko Gulić[1]

[1]Faculty of Maritime Studies, University of Rijeka, Croatia
[2]Center for Marine Technologies, Faculty of Maritime Studies, University of Rijeka, Croatia

***Corresponding Author:** Livia Maglić, Faculty of Maritime Studies, University of Rijeka, Studentska ulica 2, 51000 Rijeka, Croatia

Published **November 16, 2022**

This Book Chapter is a republication of an article published by Livia Maglić, et al. at Journal of Marine Science and Engineering in August 2022. (Maglić, L.; Maglić, L.; Grbčić, A.; Gulić, M. Composition of Floating Marine Litter in Port Areas of the Island of Mallorca. J. Mar. Sci. Eng. 2022, 10, 1079. https://doi.org/10.3390/jmse10081079)

How to cite this book chapter: Livia Maglić, Lovro Maglić, Ana Grbčić, Marko Gulić. Marine Litter Composition in Port Areas on Mallorca Island. In: Simone Mancini and Luigi Vitiello, editors. Prime Archives in Marine Science. Hyderabad, India: Vide Leaf. 2022.

Author Contributions: Conceptualization, Li.M.; methodology, Li.M.; software, Li.M.,and A.G.; validation, Li.M., Lo.M., and M.G.; formal analysis, Li.M., and A.G.; investigation, Li.M., and

A.G.; resources, Lo.M.; data curation, Li.M.; writing—original draft preparation, Li.M., Lo.M. and A.G.; writing—review and editing, Li.M., Lo.M., and M.G.; visualization, Li.M., Lo.M, and A.G.; supervision,Li.M., Lo.M., and M.G.; project administration, Li.M.; funding acquisition, Li.M. All authors have read and agreed to the published version of the manuscript.

Funding/Acknowledgement: The present study was carried out within the framework of the Interreg Mediterranean project "Ports small and medium alliance for sustainable development (PSAMIDES), reference number 5350, co-financed by the European Regional Development Fund.

Conflicts of Interest: The authors declare no conflict of interest.

Abstract

The paper examines the sampling effectiveness of seabin devices and the composition of floating marine litter in port areas. Sampling was carried out from May to September 2021 in Port of Cristo and Port of Colonia de Sant Jordi on Mallorca Island, Spain. During the study, 15,899 items and 336 kg of litter were collected and analyzed. The results indicate that seabin effectively collects floating litter from sea surfaces different in size (2 mm to 40 cm). Microplastics (60.8%) were the most commonly found litter, followed by soft plastic items >5 mm (11.6%) and unidentified hard plastic items >5 mm (9.6%). Significantly more marine litter was collected in the Port of Cristo (78.6%), compared to the collection of one device in the Port of Colonia de Sant Jordi (21.4%). Time series analysis showed that the average seasonal component was highest in May (68% above baseline). The linear time trend with an R2 of 52.25% indicated the acceptable significance of the model.

Keywords

Marine Litter; Pollution; Ports; Seabin; Mallorca Island; Friedman Test; Time Series Analysis

Introduction

Marine litter may be defined as any persistent, manufactured or processed solid material discarded into the sea, rivers or on beaches; brought indirectly to the sea with rivers, sewage, stormwater or winds; or discarded or lost at sea [1,2]. Different terms for marine litter may be found in scientific literature, e.g. marine debris, marine garbage, etc. However, in this paper, the term marine litter will be used. Marine litter poses environmental, economic, health, aesthetic and cultural threats, including degradation of marine and coastal habitats and ecosystems that incur socioeconomic losses in marine-based sectors.

Because of its broad applicability and economic and social benefits, plastic is one of the most commonly used materials in nearly all industry sectors. It is a synthetic organic polymer made from petroleum with properties ideally suited for a wide variety of applications, including packaging, building and construction, household and sports equipment, vehicles, electronics and agriculture. Plastic is cheap, lightweight, strong and malleable. Over 300 million tons of plastic are produced every year, half of which is used to design single-use items such as shopping bags, cups and straws. Furthermore, plastic is the most common category of marine litter and 14 million tons of plastic litter ending up in the ocean each year accounts for the largest share [3]. Most of the macro litter in the sea (particles >5 mm) originates from densely populated coastal areas or tourist destinations [4].

Marine pollution problem arises from activities at sea, such as fishing, aquaculture and nautical tourism, and from inadequately stored and disposed waste on land that can eventually end up in the sea. Such litter originating from land-based sources accounts for 80% of total marine plastic pollution [5]. It is estimated that globally 8 million tons of plastic litter end up in the oceans daily, of which only 1% of plastic marine litter floats on the sea surface [6].

Marine pollution by plastic materials is a widespread problem since it threatens the health of marine life, food safety and quality, human health, coastal tourism and contributes to climate change. Plastic litter poses a threat to marine organisms (fish, crustaceans, mollusks, mussels, etc.) as they can be accidentally contaminated by microplastics (particles smaller than 5 mm) or nano plastics (particles smaller than 100 nm). Such small particles are created by plastic deterioration due to exposure to UV radiation, winds, currents and other natural factors [7]. Such plastic particles also pollute the ocean from sewage treatment systems since they may pass through particular water filters. Many authors confirm the widespread distribution of microplastics on the water surface of the Mediterranean Sea and the ingestion of macro and microplastics by marine organisms [8–11].

The most common polymers found by the microplastic analysis were polyvinyl chloride, polypropylene, polyethylene, polyester polyamide and polystyrene [12–14]. Some variations in typology and size of particles were observed, highlighting the influence of the different distribution of microplastics and the water depth [15]. Microplastic ingestion levels were not related to sampling distance from land, providing further evidence of the ubiquity of microplastics in the marine environment [16].

Since marine pollution is an omnipresent problem on a global scale, actions must be taken at all levels of government, being local, regional, national and international, because this problem can only be eradicated through global awareness and sustainable solutions applied by individuals (namely consumers and society). At the international level, the United Nations Environment Assembly addresses the critical environmental challenges facing the world today to preserve and restore the environment following the 2030 Agenda for Sustainable Development [17]. In line with the Agenda, Sustainable Development Goal (SDG) 14 refers to the conservation and sustainable use of oceans, seas and marine resources for sustainable development. In addition, SDG 14.1. states that marine pollution of all kinds, especially from land-based activities, including marine litter and nutrient pollution, should be prevented and significantly reduced by 2025.

The Mediterranean Sea is named one of the world's most affected areas by marine litter and is considered a plastic pollution hotspot because it is a semi-enclosed basin [18–20]. High pollution can be attributed to the densely populated coastal areas with a range of intensive activities (tourism, fishing, shipping, industry) combined with the limited surface water runoff, such as the anti-estuarine water exchange with the Atlantic, which leads to an exceptionally high surface water residence time [21,22].

Studies where marine litter collected across the Mediterranean Sea coasts were classified by origin and material, and its abundance in habitats investigated, proved that plastic is the most abundant litter material while fishing and tourism are recognized as the most polluting activities [23,24]. Similar conclusions, that tourism (mainly beach users) and commercial fishing, followed by land runoff, are the primary sources of plastic litter all year round, with the highest peaks during the summer season [25,26].

A quantitative assessment of marine litter distribution across the Mediterranean Sea showed that, after plastic, abandoned or discarded fishing gear (mainly fishing lines) was the second predominant type of marine litter, representing a source responsible for entangling and harming marine fauna [27,28].

Similarly, microplastics significantly dominated in macro and micro-level analysis in different Adriatic Sea areas, including Marine Protected Areas (MPA) [29,30]. The same problem was confirmed in Italy. The authors in [10] confirmed the domination of microplastics in the coastal waters of Tuscany and proved that the greater the distance from the coast, the higher the concentration of floating microplastics. At the same time, it seems that seasonality does not affect the abundance of microplastics in that area.

In the particular case of Spain, many studies dealing with marine litter on different sampling points on coasts and beaches across Spain showed that plastic materials are the predominant ones, followed by fishing gear, metal and glass [31–33]. Furthermore, three Spanish sea areas with the highest plastic pollution concentration are the Alboran Sea, the Gulf of Alicante and the Barcelona area, probably due to fishing, industrial activities and high population density. Microplastic pollution was also detected at three beaches on the coast of Granada, namely La Herradura, Motril Beach and La Rábita [34]. The data showed higher contamination by microplastics at a beach in an enclosed bay (La Herradura) than on surrounding open-type beaches. It has been observed that the distribution and size of the particles are influenced by the geomorphological and sedimentary characteristics of these beaches, which are different from all others in Spain and the Mediterranean Sea in general.

Besides that, annual monitoring organized by the Spanish government revealed pollution of beaches with microplastics along the entire coast of the state, with exceptionally high concentrations in the Canary Islands, where polystyrene accounts for 40%-50% of the studied particles [35]. The origin of the polystyrene microplastic is probably from various food and commercial packaging containing polystyrene foam, which later breaks down into small floating particles [36].

In [37], the authors investigated the area of the Gulf of Cadiz (Northeast Atlantic, Spain), regarding the influence of sea currents and shipping routes, including routes of fishing vessels, on different habitats where a complex assemblage of litter is noticed to accumulate. Also, other studies investigate the significant influence of sea currents and geomorphological features of the coast and seabed as well, as essential factors in the distribution of marine litter. Regarding specific regions of the Balearic Islands, the Spatio-temporal patterns indicate a heterogeneous distribution of plastic litter in the coastal areas, with higher concentrations in the north-western and south-eastern regions of the islands, with a pollution peak occurring during the summer period [38].

After quantifying and comparing the litter on five sandy beaches in northern Portugal, litter accumulations showed high spatial and temporal variability. It is concluded that plastic litter from fishing activities was frequent in both observed periods (summer and winter). In summer, the litter was mainly formed by cigarette butts, while plastics used for mussel farming and cotton bud sticks dominated in winter [39].

Based on the existing literature, it has been determined that most of the previous research deals with the analysis of marine litter collected on the coastline, mainly manually on beaches. The authors did not find any papers dealing with the analysis of marine litter collected from the sea surface inside a particular port basin.

The present paper assesses the amount, weight and composition of marine litter collected by seabin devices installed in Port of Cristo and Port of Colonia de Sant Jordi on Mallorca Island. The main goal of this work is to withdraw statistical information from the observations about spatial and temporal variability of the floating litter in the study area. Furthermore, the sampling method and seabin features advantages and drawbacks noted and experienced during the research are presented.

Methodology

Study Area

This study was carried out in two Spanish ports on Mallorca Island, Port of Cristo and Port of Colonia de Sant Jordi, in the framework of the PSAMIDES project (Ports small and medium alliance for sustainable development, Interreg MED Programme, co-financed by the European Regional Development Fund).

Port of Cristo is located on the east coast of Mallorca Island, in a small town of the same name (Porto Cristo), 13.8 km from the town and municipality of Manacor. It is a natural port that consists of berths for fishing boats and a marina for pleasure boats and yachts. Port of Cristo is a public port with public ownership, having under 20 employees, and is primarily funded by regional funds. The capacity of the port is 276 berths, with

48,549 m2 of sheltered area and 60,290 m2 of unsheltered area (exposed to wind and waves) within the port limits. At the entrance to the port is situated the public beach Platja de Porto Cristo, which certainly impacts the amount and weight of marine litter in the area. In addition, there are 15 restaurants within the port area, which significantly increases the circulation of people through the port. The port of Cristo does not have a Waste Management Plan. Therefore, no employees are directly responsible for pollution monitoring and litter collection from the sea surface. Likewise, no procedure or technology is used to collect the litter disposed into the sea. Hence, introducing the floating seabin device was an excellent opportunity to see the advantages of using such technology. For research purposes, two seabin devices were installed in Port of Cristo in to collect data on marine litter (Figure 1).

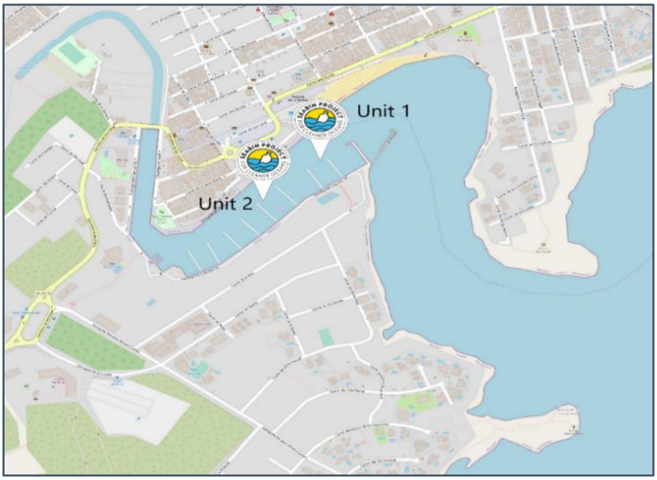

Figure 1: Seabin positions in Port of Cristo
Source: Adapted by the authors, based on Open Street Map

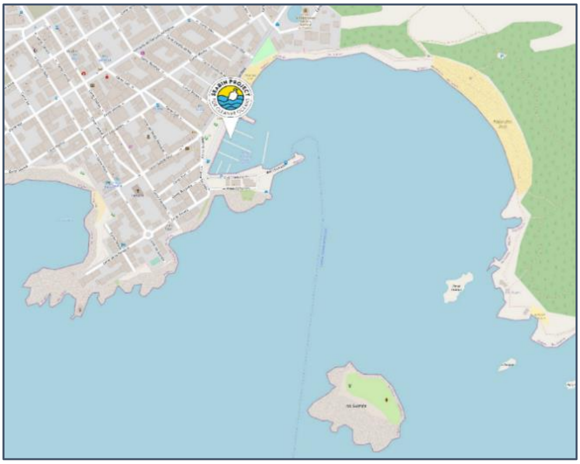

Figure 2: Seabin position in Port of Colonia de Sant Jordi
Source: Adapted by the authors, based on Open Street Map

The second port, Port of Colonia de Sant Jordi, is a marina with 318 berths, located in the south of Mallorca near the town of Ses Salines. Besides the pleasure boats and yachts, this port accommodates smaller fishing boats and ferries on lines to the island of Cabrera. Factors that may influence the amount of marine litter in this port are the vicinity of several sandy beaches (Arenal de Sa Ràpita, Platja des Trenc, Platja des Dolç, Platja de ca'n Curt, Platja d'es Carbó, Ses Roquetes and other), as well as the fact this port is the largest population centre and tourist resort in the municipality. Therefore, one seabin device was placed inside the marina basin to collect floating marine litter (Figure 2).

Locations for the installation of seabin devices were selected in accordance with port managers based on observations of the amount of marine litter accumulating in each port and the convenient place for the mounting installation. In addition, the influence of sea currents, wind and waves on marine litter accumulation was also considered when selecting locations for seabin devices, but based on experience and subjective assessment of port managing personnel.

Sampling Method and Statistical Analysis

Two sea bin devices were installed in Port of Cristo and one in Port of Colonia de Sant Jordi. The term "sea bin device" (plastic trap bin device) refers to a device designed to catch and remove any floating litter from the sea surface by filtering the seawater. Such devices are usually floating and mounted on a fixed installation near the shore or port infrastructure. Generally, these devices can collect natural material and artificial material (litter), i.e. any floating material which is not too large in a way that cannot enter the trap. In addition, such devices may collect even small patches of floating grease or hydrocarbon liquids depending on construction variations. These devices are relatively small and designed mainly for closed or partially closed water areas like ports, marinas, bays and canals, where:

- spots of accumulating and retaining litter may be identified,
- the oceanographic features are favorable (no high waves or strong currents),
- a device can be installed on an appropriate port infrastructure (e.g. quay, pier or floating pontoon),
- a source of electrical power is available and
- responsible persons can monitor and empty the collected content regularly.

The tested bin is a product of the Seabin Project company. The size of the catch container is 50 x 50 cm and can collect approximately 3.9 kg of floating litter per day or 1.4 tons per year, depending on weather and litter volumes [40]. The device operates on the following principle (Figure 3):

- the bin is designed to float and balance on the very surface of the sea, allowing water and litter to pass on top of its edges,
- surrounding water and litter are attracted to the bin by a weak sea current generated by the water pump whose suction point is on the bottom of the bin,
- once over the edge, water passes through a catch bag placed inside the seabin, while litter is retained in it,

- an electric water pump (110 or 220 V) which runs continuously and is capable of displacing 25,000 L/h is installed onshore in the vicinity of the device [40].

If a piece of litter is too large to be pulled over the edge into the bin, the suction force from the bin's pump will keep it against the side until it can be retrieved manually.

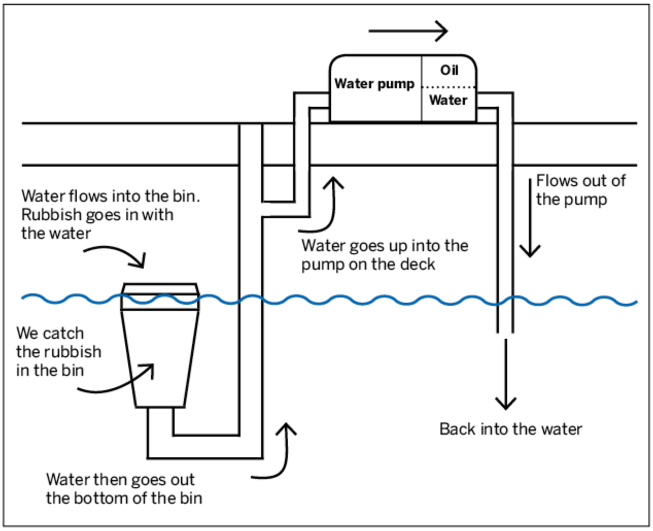

Figure 3: Seabin working principle.
Source: www.seabinproject.com

The tested Seabin model is working on the described principle. The devices are installed in a way that the bin is supported with two buys designed to keep the bin edge exactly on the sea surface. In this way, the bin can freely move vertically as the tide level is changing. The bins are connected with two elastic ropes to the key fixed points to prevent excessive unwanted horizontal movements (Figure 4).

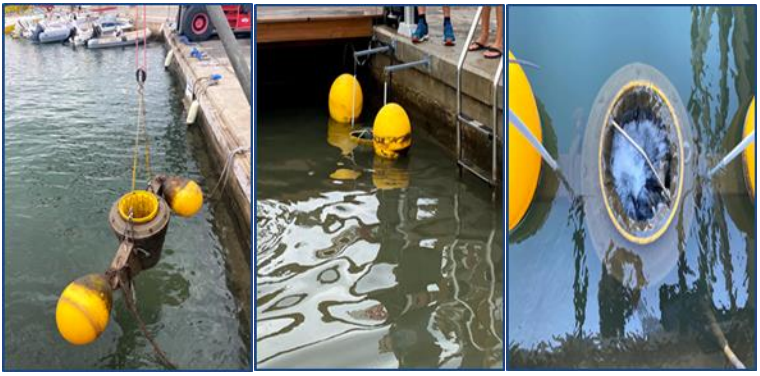

Figure 4: Seabin device installed in Port of Cristo and Port of Colonia de Sant Jordi.

The tested device can retain any particle larger than 2 mm, so it is suitable to filter microplastics. The three sites' device testing and litter collection were performed for four months, from May 2021 to September 2021.

The sampling procedure and litter analysis included the following determined steps:

- During the research period, all devices were emptied manually every Monday, i.e. once a week at the same time.
- After each removal, the entire content of the bin was separated on a large white fabric sheet for ease of identification (Figure 5).
- Following a thorough inspection, all litter items were placed onto separate sheets based on their material and size.
- Small plastic particles were separated and measured on a predefined pad for size analysis.
- After the separation and item count, the weighting took place.
- Upon completing the process, the litter was disposed of in the appropriate waste containers.

Methodology of marine litter categorization is done according to the Joint List of Litter Categories Manual for Marine Macro litter Monitoring published by the European Commission [41].

Figure 5: Various marine litter and microplastics collected by the seabin device in Port of Colonia de Sant Jordi (up) and Port of Cristo (down).

Statistical analyses based on collected litter data were performed using Friedman non-parametrical test to determine differences between the amounts of each marine litter category collected by seabin devices in different sampling sites. The test statistic is calculated as follows [42]:

$$Q = \frac{12}{nk(k+1)} \sum_{j=1}^{k} RJ^2 - 3n(k+1), \quad (1)$$

where: Rj= the sum of the ranks for sample j, n: is the number of independent blocks (here: the number of marine litter categories

=24) and k is the number of groups or treatment levels (here: the number of sampling sites= 3)

The law of probability of this test statistic is approximated by the chi-square distribution of k-1 degrees of freedom. A significant level of $\alpha = 0.05$ was accepted.

Time series analysis is applied to the monthly data on the weight of collected marine litter to search for a time trend. The objective of the time series analysis is to understand how the weight of marine litter collected changes over time (five months). A classical multiplicative time series model consists of a seasonal component, an irregular component, and a trend component. First, the data were visualized, and then the three components of the marine litter collected weight model were extracted: the seasonal component, the trend component, and the irregular (random) component, since month-to-month variations do not follow a pattern.

To perform a time series analysis of the monthly data on the weight of collected marine litter, the Moving Averages (MA) were first calculated when the total number of observed periods was an even number. Since there are 15 time periods (3 test sites x 5 months per test site), and this is an odd number, the MAs automatically represent Centred Moving Averages (CMA).

The CMA represents the baseline because it smooths the time series data (five months) to remove the seasonal and irregular components. Next, the differences between the original data and the CMA are extracted to see how much the original data falls on seasonality and irregularity.

Results

During the 4 months of sampling, 15,899 items and 336 kg of marine litter were collected from all three seabin devices. All marine litter was sorted and divided into 24 categories on each sampling site (Table 1).

Table 1: Total number of collected items per category.

Marine litter category	Sampling site			Total no. of items
	Port of Cristo / device 1	Port of Cristo / device 2	Port of Colonia de Sant Jordi	
Microplastics <5 mm (incl. pellets and nurdles)	2,584	4,433	2659	9,676
Unidentified plastic items - soft >5 mm	557	746	456	1759
Microfibers (plastic fibers derived from rope)	101	91	120	312
Unidentified plastic items - hard >5 mm	528	808	192	1,528
Cigarette butts	339	347	88	774
Plastic utensils	23	6	28	57
Soft plastic food packaging / wrappers	93	317	47	457
Rubber	0	0	12	12
Plastic lids	34	46	46	126
Face mask / gloves	13	12	21	46
Ropes	5	14	24	43
Plastic bags	19	20	16	55
Paper cups (coffee, ice cream, etc.)	29	9	9	47
Hard plastic food packaging (cups etc.)	22	8	10	40
Plastic lollipop / cotton bud sticks	30	54	32	116
Fishing line	0	2	6	8
Syringes	0	2	3	5
Plastic bottles	238	21	19	278
Fishing gear (floats, lures, etc.)	5	7	4	16
Plastic straws	18	16	5	39
Foam pieces	282	144	17	443
Tape	0	0	4	4
Tennis ball / toy	2	0	2	4

ball				
Cans	24	20	10	54
TOTAL	4,946	7123	3830	15,899
Average	206.1	296.8	159.6	662.4

The data presented in Table 1 shows that the greatest number of collected items was in Port of Cristo - device no. 2, which is situated approximately in the center of the port basin, with a total of 7,123 items (44.8%). This site is followed by the Port of Cristo device no. 1, situated at the entrance of the port basin, with a total of 4,946 items (31.1%). Finally, a single device in Port of Colonia de Sant Jordi, situated approximately in the center of the port basin, had the least collected items, with a total of 3,830 items (24.1%). The average amount of collected items for individual sites was: 296 for the Port of Cristo device no. 2, 206 for the Port of Cristo device no. 1 and 159 for the Port of Colonia de Sant Jordi considering all categories.

Observing the total amount of collected marine litter, the predominant category is Microplastics <5 mm (incl. pellets and nurdles) with a total of 9,676 collected items (60.8%), followed by Unidentified plastic items - soft >5 mm with a total of 1,759 collected items (11.6%) and Unidentified plastic items - hard >5 mm with a total of 1,528 collected items (9.6%). Other categories of marine litter account for a total ratio of 18.2%.

Figure 6 shows the composition of collected marine litter per site. It can be seen that, for most categories, the differences in the respective ratios are relatively small. The most prominent example is the ratio of Unidentified plastic items - hard >5 mm, which is as follows: Port of Cristo - device 2 (11%), Port of Cristo - device 1 (11%) and Port of Colonia de Sant Jordi (5%).

Although Port of Colonia de Sant Jordi with one seabin collected the least amount of litter, the percentage of collected microplastics (<5 mm) in this sampling site was the highest (69%), while in Port of Cristo - device 2 had approximately 62% and Port of Cristo - device 1 a total of 52% (Figure 6). At all sampling sites, prevailing marine categories are Microplastics <5 mm, Unidentified plastic items - soft >5 mm and Unidentified plastic items - hard >5 mm.

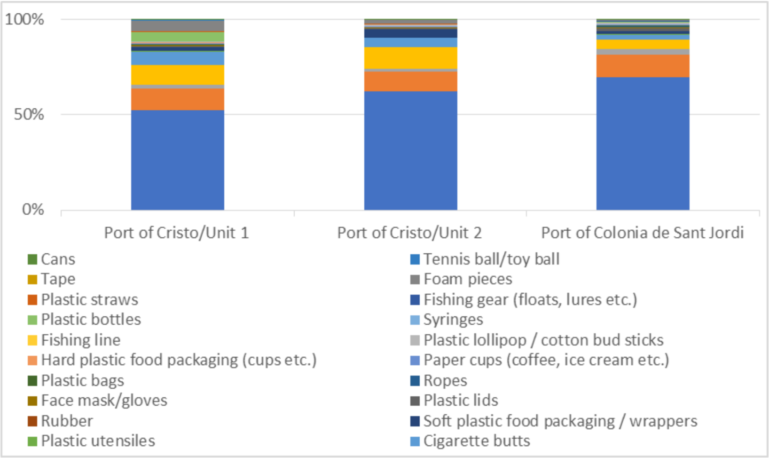

Figure 6: Composition of marine litter by sampling sites.

Figure 7 shows the ratio of each litter category at the different sampling sites. For example, device no. 1 in Port of Cristo collected 85% of the total collected plastic bottles on all three sampling sites, followed by foam pieces - 63% and paper cups - 62%. Device no. 2 in Port of Cristo has collected 69% of soft plastic food packaging or wrappers, 53% of Unidentified plastic items - hard >5 mm and 46% of Microplastics <5 mm (incl. pellets, nurdles) in a total sum of collected marine litter per each observed category. The seabin in Port of Colonia de Sant Jordi is the only device that collected rubber. Furthermore, the Port of Colonia de Sant Jordi collected 60% syringes and 55% ropes in a total sum of each mentioned category.

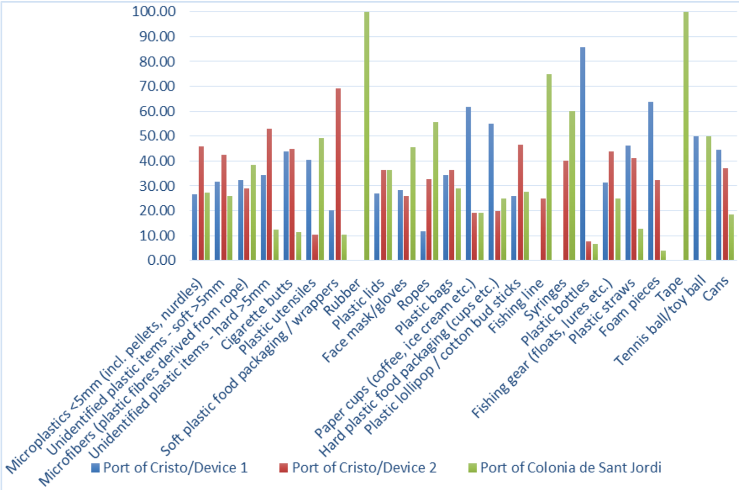

Figure 7: Percentage of collected marine litter at sampling sites by marine litter categories from May to September 2021.

The weight was analyzed cumulatively and per month during the research period. The data reveals that the highest accumulation of marine litter was in May and June. In these two months, all devices together collected 57% of the total weight collected during the whole study period (Figure 8). On the contrary, in July the lowest weight of the total collected litter was at all three sampling sites. The main identified reason for such variation is that the predominantly collected items in this period occupying the catch bag were microplastics <5 mm, which are exceptionally light.

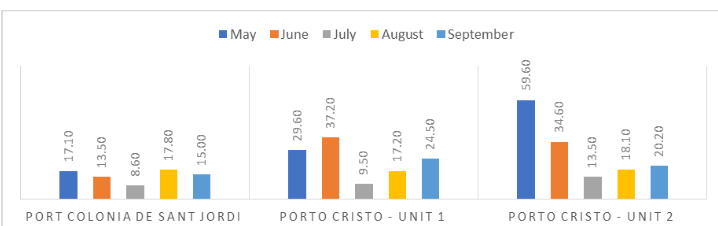

Figure 8: Weight of collected marine litter per month at each site (in kg).

The greatest total weight of marine litter was collected by the seabin device no. 2 in the Port of Cristo being 146 kg (43.5%), followed by the seabin device no. 1 in the same port with 118 kg (35.1%) and the device in the Port of Colonia de Sant Jordi with 72 kg (21.4%). The seabin device no. 2 in Port of Cristo collected the most litter by weight in May, being 59.6 kg (56.1%). Altogether, the results show that seabin device no. 2 in the Port of Cristo collected the highest number of items with the highest total weight, followed by seabin device no. 1 in the same port and the seabin device in the Port of Colonia de Sant Jordi.

The Friedman test was performed based on the data on the amount of marine litter collected in each category (Table 1), while the time series analysis was performed using the data on the weight of collected marine litter (Figure 8), the Friedman test results (Table 2) are as follows: $Q=0.27$, $df=2$, $p=0.87$, $p > 0.05$, which means that a null hypothesis should not be rejected, indicating that the differences between means of collected marine litter in different sampling location are not significantly different.

Table 2: Friedman's test results.

R2	6,918.5
k	3
n	24
Q	0.270833333
df	2
p	0.873351939
α	0.05
sig	no

Considering the Friedman test results, Table 3 presents the time series analysis in terms of seasonality, irregularity, and time trend of monthly time series data on collected marine litter.

Table 3: Monthly time series analysis of the weight of marine litter collected at each site.

Time period	Port	Month	Marine litter [kg]	CMA	S_t, I_t	S_t	De-seasonalized data	T_t
1	Port of Colonia de Sant Jordi	May	17.10			1.68	10.21	14.02
2		June	13.50			1.43	9.42	15.17
3		July	8.60	14.40	0.60	0.49	17.65	16.31
4		August	17.80	16.90	1.05	0.82	21.78	17.46
5		September	15.00	21.64	0.69	0.77	19.54	18.60
6	Port of Cristo / device 1	May	29.60	21.82	1.36	1.68	17.67	19.75
7		June	37.20	21.70	1.71	1.43	25.97	20.89
8		July	9.50	23.60	0.40	0.49	19.49	22.04
9		August	17.20	29.60	0.58	0.82	21.05	23.18
10		September	24.50	29.08	0.84	0.77	31.91	24.33
11	Port of Cristo / device 2	May	59.60	29.88	1.99	1.68	35.57	25.47
12		June	34.60	30.06	1.15	1.43	24.15	26.62
13		July	13.50	29.20	0.46	0.49	27.70	27.76
14		August	18.10			0.82	22.15	28.90
15		September	20.20			0.77	26.31	30.05

The data in Table 3 show that the seasonality and irregularity components were highest in Port of Cristo - Unit 2 in May (99% above baseline - CMA), while they were lowest in Port of Cristo - Unit 1 in July (60% below baseline – CMA). Then, the irregularity was omitted and only the seasonal component was extracted and quantified (column St). The average seasonal component is highest in May (68% above baseline), followed by June, August, September, and July (51% below baseline). At first glance, it is surprising to see that the weight of marine litter collected is higher in the low season (May and June) than in the high season (July, August, and September). The general assumption is that the weight of marine litter collected is highest in the peak season when the number of users near the test sites is significantly higher.

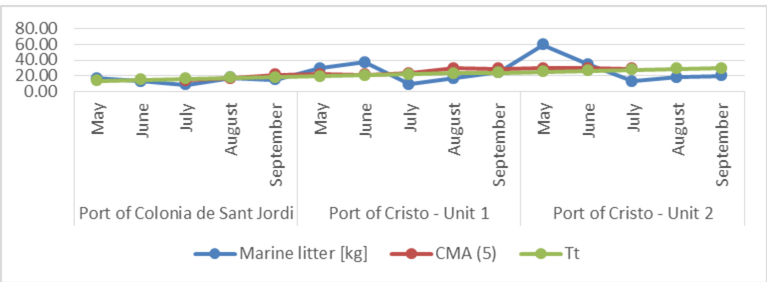

Figure 9: Monthly time series of the weight of marine litter collected at each site.

However, the results are not consistent with this assumption because COVID 19 precautions were taken at the time of technology testing and data collection, so the number of users during the high season was significantly lower than usual. Finally, the linear time trend (Tt) was calculated with an R2 of 52.25%, and presented in Figure 9, indicating the acceptable significance of the model.

Discussion and Conclusions

This paper presented a quantitative and qualitative analysis of marine litter collected by seabin devices installed in two ports on Mallorca Island in Spain.
The discussion and conclusions may be divided into two aspects: litter sampling and analysis, and the other being the pollution protection effectiveness of the seabin device.

Regarding the litter sampling procedure, the seabin proved itself a very effective device for sampling procedures and easy to handle due to its small size and limited capacity. Thanks to its innovative design and technical features, the device draws near and efficiently collects nearly anything that floats freely in its vicinity. It can collect particles from 2 mm (e.g. microplastic) to items up to approximately 40 cm long. Furthermore, the catch bag is detachable where the litter is collected, allowing easy removal, analysis, and later litter disposal.

Regarding the litter analysis, the first of this kind performed in selected ports showed the structure of the litter, which will assist the managing authorities in decision making to apply appropriate measures to improve the environmental protection. The results showed that plastic materials of different sizes comprise the most collected litter (namely microplastic, plastic bottles, utensils and food packaging). Other predominant litters include paper cups, foam and Styrofoam pieces, rope pieces and fibers. The challenge of the analysis is to prove the major litter sources for a particular litter category. For example, Styrofoam pieces may easily end up in the sea from fishing boats (Styrofoam fish containers), rope pieces and fibers may easily originate from nearby marinas or port areas with the highest concentration of boats and yachts, while food wrappings probably originate from nearby beaches.

Further research with seabin devices in port areas should be conducted to prove such a hypothesis considering the meteorological and oceanographic measurements in the observed area for a particular period. Such measurements would provide information on surface currents, i.e. the current strength, direction and duration (which could significantly differ from currents in deeper sea levels) and wind strength and duration. Furthermore, light winds or winds blowing for short periods may not influence the sea surface enough to change or start the wind-induced sea surface current.

Also, the drift direction of the floating items may not be the same for floating items that are entirely submerged and influenced by currents (e.g. some plastic materials, bags and paper) and for items that are nearly entirely above the surface and influenced mainly by winds (e.g. empty can or plastic bottle).

Such information is essential to model or assess the speed and direction of different drifting, floating items during a particular meteorological and oceanographic state. Based on that, it is recommended that the emptying of the catch bag occurs immediately when the wind and current direction significantly changes, allowing to estimate the direction of the litter source more precisely.

Regarding the seabin device aspect, the pollution protection effectiveness of the seabin device was not the primary aim of the research; hence there were no particular tests on seabin performance. However, several observations and conclusions took place, which should be emphasized. First, since all such devices are attached to a fixed installation, they should be placed in areas within the port where the floating litter accumulates the most. This information should be obtained from competent persons in a port based on their long-term observation and experience or preferably from surface current measurements and models. Secondly, there should be a person within the port managing authority designated to inspect and empty the seabin catch bag regularly, preferably on daily basis. On some occasions, a slight change of wind and/or current direction may significantly increase (or decrease) the accumulation rate of the litter. The amount of collected litter would undoubtedly be more outstanding with such dedication. Thirdly, for highly polluted areas and areas with high naturally generated debris (wood, leaves, seaweed, etc.), the seabin capacity of 20kg would be indeed too small. Therefore, multiple devices should be installed in such areas, or a different approach should be considered.

To determine the optimal number of sufficient devices to collect the marine litter from the sea surface in the port, the size of the port's water area should be considered, and the floating litter density should be measured or estimated. This can be done regularly via aerial surveillance monitoring by drones or fixed camera surveillance of the sea surface.

The results of research like this one can contribute to a better understanding of the sea pollution state and could improve the ports' management in line with sustainable blue growth. Whilst recognizing the mentioned methodological challenges, further research should investigate the residents' and tourists' environmental awareness and behavioral patterns to target appropriate measures and corrective actions to reduce marine pollution.

References

1. Cheshire a, Adler E, Barbière J, Cohen Y. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. 2009.
2. UNEP (United Nations Environment Programme) Marine Litter An Analytical. Unep. 2005; 47.
3. Strafella P, Fabi G, Spagnolo A, Grati F, Polidori P, et al. Spatial Pattern and Weight of Seabed Marine Litter in the Northern and Central Adriatic Sea. Mar. Pollut. Bull. 2015; 91: 120–127.
4. Carlson DF, Suaria G, Aliani S, Fredj E, Fortibuoni T, et al. Combining Litter Observations with a Regional Ocean Model to Identify Sources and Sinks of Floating Debris in a

Semi-Enclosed Basin: The Adriatic Sea. Front. Mar. Sci. 2017; 4: 1–16.
5. Siegfried M, Koelmans AA, Besseling E, Kroeze C. Export of Microplastics from Land to Sea. A Modelling Approach. Water Res. 2017; 127: 249–257.
6. Munari C, Corbau C, Simeoni U, Mistri M. Marine Litter on Mediterranean Shores: Analysis of Composition, Spatial Distribution and Sources in North-Western Adriatic Beaches. Waste Manag. 2016; 49: 483–490.
7. Deudero S, Alomar C. Mediterranean Marine Biodiversity under Threat: Reviewing Influence of Marine Litter on Species. Mar. Pollut. Bull. 2015; 98: 58–68.
8. Alomar C, Deudero S. Evidence of Microplastic Ingestion in the Shark Galeus Melastomus Rafinesque, 1810 in the Continental Shelf off the Western Mediterranean Sea. Environ. Pollut. 2017; 223: 223–229.
9. Anastasopoulou A, Kovač Viršek M, Bojanić Varezić D, Digka N, Fortibuoni T, et al. Assessment on Marine Litter Ingested by Fish in the Adriatic and NE Ionian Sea Macro-Region (Mediterranean). Mar. Pollut. Bull. 2018; 133: 841–851.
10. Baini M, Fossi MC, Galli M, Caliani I, Campani T, et al. Abundance and Characterization of Microplastics in the Coastal Waters of Tuscany (Italy): The Application of the MSFD Monitoring Protocol in the Mediterranean Sea. Mar. Pollut. Bull. 2018; 133: 543–552.
11. Compa M, Ventero A, Iglesias M, Deudero S. Ingestion of Microplastics and Natural Fibres in Sardina Pilchardus (Walbaum, 1792) and Engraulis Encrasicolus (Linnaeus, 1758) along the Spanish Mediterranean Coast. Mar. Pollut. Bull. 2018; 128: 89–96.
12. Abidli S, Antunes JC, Ferreira JL, Lahbib Y, Sobral P, et al. Microplastics in Sediments from the Littoral Zone of the North Tunisian Coast (Mediterranean Sea). Estuar. Coast. Shelf Sci. 2018; 205: 1–9.
13. Digka N, Tsangaris C, Torre M, Anastasopoulou A, Zeri C. Microplastics in Mussels and Fish from the Northern Ionian Sea. Mar. Pollut. Bull. 2018; 135: 30–40.
14. Pellini G, Gomiero A, Fortibuoni T, Ferrà C, Grati F, et al. Characterization of Microplastic Litter in the

Gastrointestinal Tract of Solea Solea from the Adriatic Sea. Environ. Pollut. 2018; 234: 943–952.
15. Avio CG, Cardelli LR, Gorbi S, Pellegrini D, Regoli F. Microplastics Pollution after the Removal of the Costa Concordia Wreck: First Evidences from a Biomonitoring Case Study. Environ. Pollut. 2017; 227: 207–214.
16. Alomar C, Deudero S, Compa M, Guijarro B. Exploring the Relation between Plastic Ingestion in Species and Its Presence in Seafloor Bottoms. Mar. Pollut. Bull. 2020; 160: 111641.
17. UNEP Marine Plastic Debris and Microplastics – Global Lessons and Research to Inspire Action and Guide Policy Change. United Nations Environment Programme. Nairobi. 2016.
18. Fossi MC, Pedà C, Compa M, Tsangaris C, Alomar C, et al. Bioindicators for Monitoring Marine Litter Ingestion and Its Impacts on Mediterranean Biodiversity. Environ. Pollut. 2018; 237: 1023–1040.
19. Lebreton LCM, Greer SD, Borrero JC. Numerical Modelling of Floating Debris in the World’s Oceans. Mar. Pollut. Bull. 2012; 64: 653–661.
20. Van Sebille E, Wilcox C, Lebreton L, Maximenko N, Hardesty BD, et al. A Global Inventory of Small Floating Plastic Debris. Environ. Res. Lett. 2015; 10: 124006.
21. Cózar A, Sanz-Martín M, Martí E, González-Gordillo JI, Ubeda B, et al. Plastic Accumulation in the Mediterranean Sea. PLoS One. 2015; 10: 1–12.
22. Lacombe H, Gascard JC, Cornella J, Béthoux JP. Response of the Mediterranean to the Water and Energy Fluxes across Its Surface, on Seasonal and Interannual Scales. Oceanol. Acta. 1981; 4: 247–255.
23. de Francesco MC, Carranza ML, Varricchione M, Tozzi FP, Stanisci A. Natural Protected Areas as Special Sentinels of Littering on Coastal Dune Vegetation. Sustain. 2019; 11.
24. Mazarrasa I, Puente A, Núñez P, García A, Abascal AJ, et al. Assessing the Risk of Marine Litter Accumulation in Estuarine Habitats. Mar. Pollut. Bull. 2019; 144: 117–128.
25. Alshawafi A, Analla M, Alwashali E, Aksissou M. Assessment of Marine Debris on the Coastal Wetland of

Martil in the North-East of Morocco. Mar. Pollut. Bull. 2017; 117: 302–310.
26. Campana I, Angeletti D, Crosti R, Di Miccoli V, Arcangeli A. Seasonal Patterns of Floating Macro-Litter across the Western Mediterranean Sea: A Potential Threat for Cetacean Species. Rend. Lincei. 2018; 29: 453–467.
27. Angiolillo M, Lorenzo, B di, Farcomeni A, Bo M, Bavestrello G, et al. Distribution and Assessment of Marine Debris in the Deep Tyrrhenian Sea (NW Mediterranean Sea, Italy). Mar. Pollut. Bull. 2015; 92: 149–159.
28. Consoli P, Andaloro F, Altobelli C, Battaglia P, Campagnuolo S, et al. Marine Litter in an EBSA (Ecologically or Biologically Significant Area) of the Central Mediterranean Sea: Abundance, Composition, Impact on Benthic Species and Basis for Monitoring Entanglement. Environ. Pollut. 2018; 236: 405–415.
29. Blašković A, Fastelli P, Čižmek H, Guerranti C, Renzi M. Plastic Litter in Sediments from the Croatian Marine Protected Area of the Natural Park of TelašČica Bay (Adriatic Sea). Mar. Pollut. Bull. 2017; 114: 583–586.
30. Palatinus A, Kovač Viršek M, Robič U, Grego M, Bajt O, et al. Marine Litter in the Croatian Part of the Middle Adriatic Sea: Simultaneous Assessment of Floating and Seabed Macro and Micro Litter Abundance and Composition. Mar. Pollut. Bull. 2019; 139: 427–439.
31. Asensio-Montesinos F, Ramírez MO, Aguilar-Torrelo MT, Anfuso G. Abundance and Distribution of Cigarette Butts on Coastal Environments: Examples from Southern Spain. J. Mar. Sci. Eng. 2021; 9: 1–14.
32. García-Rivera S, Lizaso JLS, Millán JMB. Spatial and Temporal Trends of Marine Litter in the Spanish Mediterranean Seafloor. Mar. Pollut. Bull. 2018; 137: 252–261.
33. Williams AT, Randerson P, Di Giacomo C, Anfuso G, Macias A, et al. Distribution of Beach Litter along the Coastline of Cádiz, Spain. Mar. Pollut. Bull. 2016; 107: 77–87.
34. Godoy V, Prata JC, Blázquez G, Almendros AI, Duarte AC, et al. Effects of Distance to the Sea and Geomorphological Characteristics on the Quantity and Distribution of

Microplastics in Beach Sediments of Granada (Spain). Sci. Total Environ. 2020; 746: 142023.
35. Martín-Lara MA, Godoy V, Quesada L, Lozano EJ, Calero M. Environmental Status of Marine Plastic Pollution in Spain. Mar. Pollut. Bull. 2021; 170: 112677.
36. Eriksen M, Lebreton LCM, Carson HS, Thiel M, Moore CJ, et al. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLoS One. 2014; 9: 1–15.
37. Mecho A, Francescangeli M, Ercilla G, Fanelli E, Estrada F, et al. Deep-Sea Litter in the Gulf of Cadiz (Northeastern Atlantic, Spain). Mar. Pollut. Bull. 2020; 153: 110969.
38. Compa M, March D, Deudero S. Spatio-Temporal Monitoring of Coastal Floating Marine Debris in the Balearic Islands from Sea-Cleaning Boats. Mar. Pollut. Bull. 2019; 141: 205–214.
39. Guerrero-Meseguer L, Veiga P, Rubal M. Spatio-Temporal Variability of Anthropogenic and Natural Wrack Accumulations along the Driftline: Marine Litter Overcomes Wrack in the Northern Sandy Beaches of Portugal. J. Mar. Sci. Eng. 2020; 8: 1–15.
40. Project Seabin The Seabin v5 - Technical Specifications Available online at: https://seabinproject.com/the-seabin-v5/technical-specs/
41. Fleet D, Vlachogianni T, Hanke G. European Commission. Joint Research Centre. Joint List of Litter Categories for Marine Macro-Litter Monitoring: Manual for the Application of the Classification System. 2021.
42. Six Sigma Study Guide Friedman Non Parametric Hypothesis Test. Available online at: https://sixsigmastudyguide.com/friedman-non-parametric-hypothesis-test/.