Title: ABUNDANCE AND SPATIAL DISTRIBUTION OF COASTAL FLOATING PLASTIC MARINE DEBRIS IN THE BALEARIC ISLANDS

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Abstract

Coastal ecosystems are continuously affected by anthropogenic threats such as urbanization, maritime activities, recreational and commercial activities, all of which have been prominent sources of plastic marine litter. During summer of July 2017, the spatial distribution of floating plastics at seven locations across the island using nearshore sea cleaning boats was assessed. One-hundred percent of the samples contained plastic items of varying sizes, ranging from macro- (> 25 mm), meso- (5-25 mm) and micro-plastics (< 5 mm), composed principally of fragments, films and filaments. Significant differences were found for the abundance and size differences of items between the sampling locations. All samples were collected within one kilometre of the coastline and both the abundance and weight was found to significantly increase closer to the coastline. Plastics smaller than 5 mm were the dominant size class and fragments composed of almost 60% of the items with the main colors being transparent and white. Low variability of polymers were found with polyethylene being the primary plastic polymer type. These preliminary results indicate there is high small scale variability of coastal marine plastic concentrations surrounding the Balearic Islands.

Key words: marine debris, plastic, conservation, Balearic Sea, sea-surface trawls.

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1. Introduction

Plastic in the marine environment is ubiquitous and is becoming a growing threat to marine diversity worldwide. Global plastic production has risen annually with over 280 million tonnes of plastic material produced with just under 30% coming from European and African nations (Plastics Europe, 2017), often surpassing waste management for most countries. This rising increase and loss of plastic into the marine environment has global plastic modelling estimates in the world's oceans reporting between 15 to 51 trillion plastic particles are currently floating on the sea surface, with remote areas such as the Artic Ocean having over 300 billion plastic fragments with the Mediterranean Sea having concentrations like those of the 5 gyres (Cózar et al., 2017; van Sebille et al., 2015).

Elevated concentrations of plastic marine debris in the Mediterranean Sea have been reported with between 0.116 – 0.40 plastic items/m^2 weighing an estimated 671.91-2020 g/km^2 (Suaria et al., 2016). In recent years, several studies have identified the high abundances of floating plastic debris and a brief bibliografic summary of a range of trawls in the Western Mediterranean Sea has been compiled to give an indication of the state of plastic trawls over the past decade (Table 1). Numerical modelling considering results from trawls surveys, coastal populations and marine traffic has weighed in and it is estimated plastic debris fluxes to be very high at 4.6 kg/km/day arriving onto the Mediterranean coastlines (Liubartseva et al., 2018). Few studies have identified plastic marine debris in the Balearic Islands in the past decade with surface trawl surveys in the Balearic Sea as an area with elevated concentrations of plastic debris (Ruiz-Orejón et al., 2018, 2016; Suaria et al., 2016). Not only are plastic debris found abundantly on the sea surfaces in the Balearic Sea but also deposited on the seafloor (Alomar et al., 2016; Pham et al., 2014). Sediment samples in coastal waters have found high concentrations of microplastics in urbanized areas while high concentrations of fragmented particles in marine protected areas (Alomar et al., 2016).

In addition to plastic particles found on the surface and the seafloor, adverse effects such as plastic ingestion in marine fauna is also a growing concern. Globally and across the Mediterranean Sea several species have been found to be threatened by marine plastic through ingestion, entanglement and colonization (Battaglia et al., 2016; Bellas et al., 2016; Deudero and Alomar, 2014; Nauendorf et al., 2016). Within the Balearic Sea, species such as *Mullus surmuletus*, *Boops boops* and *Galeus melastromus* with the number of individuals ingesting plastic between 15% and 70% of (majority microplastics less than 5 mm) in the surrounding coastal waters of the Balearic Islands (Alomar et al., 2017; Alomar and Deudero, 2017; Nadal et al., 2016). These highlight the current threat that small plastic particles are posing on coastal marine diversity, especially since the Balearic Islands harbour several endemic and endangered species.

Table 1 Trawl surfaces in the Western Mediterranean Sea from 2010 - 2017.

Study area	Sampling period	Net mesh size (μm)	Number of samples	Mean abundance	Reference
NW Mediterranean	July–Aug 2010	333	40	0.12 (±0.89) items/m^2	(Collignon et al., 2012)
Bay of Calvi (Corsica)	July–Aug 2010	200	23	0.06(±0.69) items/m^2	(Collignon et al., 2014)
W Sardinia	July 2012-July 2013	500	30	0.15 (±0.35) items/m^3	(de Lucia et al., 2014)
W Mediterranean	Sept 2011–Aug 2012	333	41	0.135 (±0.42) items/m^2	(Faure et al., 2015)
Ligurian Sea	July-Aug 2013	333	33	0.103 (±0.36) items/m^2	(Pedrotti et al., 2016)
W. Med/Adriatic	May-June 2013	200	74	0.40 (±0.74) items/m^2	(Suaria et al., 2016)
Ligurian/Sardinia Sea	June-July 2011	200	23	0.62 (±0.20) items/m^3	(Fossi et al., 2017)
Balearic Sea	July 2017	335	21	0.04 (±0.05) items/m^2	This study

Internationally there are several agreements such as the Honolulu Strategy which is a global framework for prevention and management of marine debris (NOAA, 2011). Plastic pollution has also been addressed recently at the G7 where member countries have committed to moving toward a more resource efficient and sustainable management of plastics (G7, 2018). Within the European Union there are several agreements such as the Marine Strategy Framework Directive (MFSD) which requires European Member States to develop strategies to achieve or maintain Good Environmental Status through the implementation of regional programs and the establishment of monitoring programmes for assessment (Ferreira, 2014). Finally, within the Mediterranean Basin the Barcelona Convention directly addresses the depollution of the Mediterranean Sea by the year 2020 through the Horizon 2020 initiative.

This study aims to identify the coastal plastic debris throughout the nearshore regions of the Balearic Island archipelago of Mallorca. The aims of this study are to: (i) determine the abundance of floating micro-plastics (< 5 mm) to macro-plastics (> 25 mm) along the coastline of the Balearic Islands, (ii) evaluate the spatial distribution of coastal plastics and distance to the shoreline and (iii) identify differences in size classification between sampling locations.

2. Methods

2.1. Study area

The Balearic Island archipelago is located at the centre of the Western Mediterranean Sea consisting of four inhabited islands (Mallorca, Menorca, Ibiza and Formentera) with over 1723 km of coastline. The two principal surface currents are the Algerian current in the south-eastern side of Mallorca and the Balearic Current in the north-western area. In 2017, the population of the Balearic Islands was just over 1.1 million habitants with the population of Mallorca containing 868,693 habitants, just over 75 % of the total population (www.ibestat.caib.es). The Balearic Islands are a key tourism spot in the Western Mediterranean Sea with over 2.8 million visitors having arrived to the islands during the month of July in 2017, almost tripling the population.

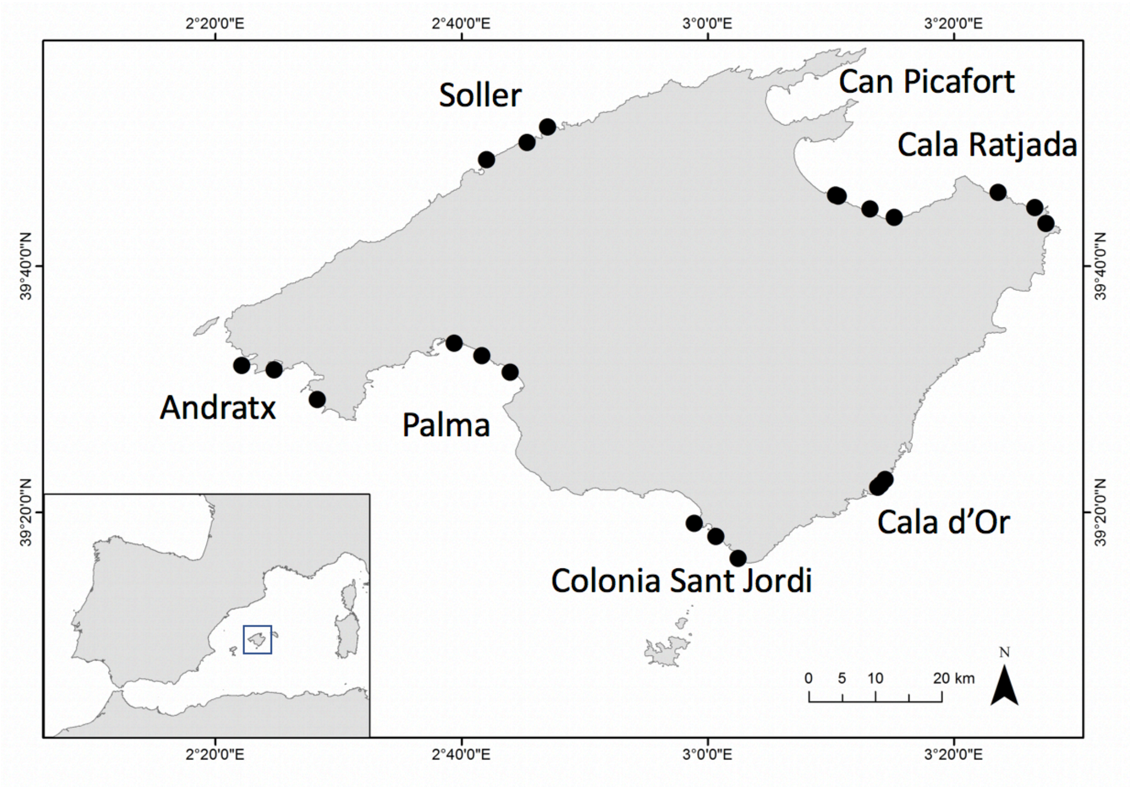

Figure 1 A map of the study area of the island of Mallorca and the sampling locations from the month of July of 2017. Inset map indicates the location of Mallorca in the Western Mediterranean Sea.

2.2. Sampling and collection methods

Sample collection was performed in 2017 in collaboration with the regional government's annual sea cleaning boats using small vessels (www.abaqua.es) as part of their Coordinació de Neteja Litoral which has been ongoing since 2005. The coastal sea cleaning and monitoring programs contains over 30 of specialized boats for surveying nearly the entire coastline of all of the Balearic Islands (Mallorca, Menorca, Ibiza, Formentera).

During the summer month of July 2017 on the island of Mallorca, samples were collected at seven distinct geographical areas between the hours of 8 and 15 (Figure 1). All samples were collected within 500 m of the shoreline. Sampling was performed using a Hydro-Bios (www.hydrobios.de) sea surface microplastic net specialized for operating in coastal areas during calm seas equipped with a mouth opening 40 x 70 cm and a cod length of 2 meters with the net size measuring 335 µm. At each station, the sea surface microplastic net was towed for an average of between 15-30 minutes when weather conditions permitted at an average speed between 1.5 and 3 nautical miles with sufficient distance to assure the sampling occurred outside of the turbulence of the wake (Kovač Viršek et al., 2016; Suaria et al., 2016). Three samples were collected at each location following the coastline and conserved in 70% ethanol for further analysis in the laboratory. Once in the laboratory, samples were carefully hand-picked and separated from organic material using a stereo-microscope (Leica) and dried at room temperature in glass petri dishes. Measurements were taken along the widest surface to the longest distance between two points of each particle using two methods: manually using the Euromex program on the stereo-microscope for particles > 5 mm and the second using the ImageJ© software (http://imagej.nih.gov/ij/; Schneider, Rasband, & Eliceiri, 2012) for the larger items (> 5mm) . Images were then used to identify the width, type, color. In addition, each particle was categorized following six categories: fragments, films, pellets, granules, filaments and foams (Kovač Viršek et al., 2016). Once samples were separated and categorized and weighted, the sea surface area trawled was calculated by multiplying the sampling distance by the width of the opening of the manta net to determine items/m^2 and g/ m^2 and further normalized per items/km^2 and g/ km^2 (Kovač Viršek et al., 2016).

2.3. Polymer characterization

To determine the polymer characterization of the particles collected, one of the three samples from each site was randomly selected. Following recommendations from the Guidance for sampling marine debris in European Seas, ten percent of each of the selected samples were separated, except for those samples with less than 20 items of which all of the items were analysed. (Ferreira, 2014). The chemical structure was identified using a Fourier Transform Infrared Spectroscopy (FT-IR) (HYPERION Series FT-IR Microscope) with the OPUS Spectroscopy Software with spectra recorded in transmittance mode. The analysis was performed with the support of the Scientific-technical Services at the Balearic Island University. The identification of polymers was performed by comparing each spectra with a library of standard spectra for different polymer types.

2.4. Distance to the coastline and wind correction

The central location for each transect was determined using ArcGIS version 3.14. The near tool from the analysis toolbox was used to determine the nearest distance to the coastline using the geodesic which considers the shortest path on a spheroid to consider the curvature of the earth. The coastline for the Balearic Island's used was freely available from the European Environmental Agency. In addition, based on surface and subsurface observations and a one-dimensional column model, it has been demonstrated that plastic concentrations measured using surface tow measurements depend on wind speed and tows in high wind conditions tend to capture fewer plastic pieces because plastic pieces are vertically distributed in the mixed layer due to wind-induced mixing (Kukulka et al., 2012). Wind and wave height data for each of the sampling days was derived from the numerical models from Puertos de Estado (www.puertos.es). The numerical data from give SIMAR data points were used with the nearest point being assigned to each location using the near tool from the toolbox in ArcGIS 10.3.4.

2.5. Data analysis

To evaluate the differences in the spatial distribution of floating plastic, a mixed linear regression model was performed to determine the relationship between the abundance (items/m^2) and the weight (g/m^2) of plastic debris and their sampling locations. Basic tests for homogeneity of the variance were used and heterogeneity was not found ($p > 0.05$). Because each location contained three samples and to assure the model considers pseudoreplication, a linear regression model was performed with the fixed factor for location and each sample was included as a random effect (Chaves, 2010). For both models, the normality of the mixed model was confirmed by visually inspecting the residuals and the fitted values. For the significant model, a pos-hoc analysis was performed to determine where the pairwise differences were found between locations for significant models. Multiple comparisons between the means were further tested using the multicomp package in R (Hothorn et al., 2008).

Next, due to the large number of particles found at each location and the variety of sizes, the relationship was analysed a generalized linear mixed model with a Gaussian distribution. The size of each particle was log(x+1) and normality was assured by inspecting the residuals of the model and following the previous model, location was included as a fixed effect and the sample as a random effect. Also prior to applying the linear regression model, heterogeneity of the variances where checked.

Apart from determining the relationships between locations, previous studies have identified the relationship between the abundance and weight in relation to the coastline (Pedrotti et al., 2016; Ruiz-Orejón et al., 2018). To test for the correlation between plastic concentration (items and weight) and the distance from the coastline, a Spearman's correlation coefficient (r_s) was used (Ruiz-Orejón et al., 2018). All data analyses was done in R version 3.4 (R Core Team, 2016).

3. Results

3.1. Plastic concentrations

Plastic marine debris was found at each of the sampling locations and in all of the 21 sea-surface trawls with an overall mean of 0.04 (±0.04) items/m^2 (mean ± standard deviation) and 0.0011 (±3.4^{-3}) g/m^2. High range in the abundance of plastics was found across Mallorca with Port d'Andratx having the lowest abundance of 0.02 (±0.01) items/m^2 and Cala d'Or had the highest mean abundance of 0.13 (±0.05) items/m^2, nearly three times as high as the other sampling areas, as well as the highest weight at 0.0057 (±8.89^{-3}) g/m^2 (Table 2).

Table 2 Summary of trawl surveys for plastics in the Western Mediterranean Sea (mean ±SD).

Location	**# of surveys**	**# items /m^2**	**# g /m^2**
Colonia San Jordi	3	0.04 (±0.04)	0.0003 (±1.97^{-4})
Cala d'Or	3	0.13 (±0.05)	0.0057 (±8.89^{-3})
Can Picafort	3	0.02 (±0.02)	0.0001 (±7.29^{-5})

Cala Ratjada	3	0.04 (±0.01)	0.0006 (±7.58^{-4})
Palma	3	0.03 (±0.02)	0.0003 (±9.67^{-5})
Port d'Andratx	3	0.01(±0.001)	0.0003 (±2.73^{-4})
Soller	3	0.03 (±0.02)	0.0002 (±1.04^{-4})
Total	**21**	**0.04 (±0.05)**	**0.0011 (±3.4^{-3})**

In an effort to compare the resulting concentrations with previous studies, the results were standardized to items/km^2 and g/km^2 (Figure 2). The average overall abundance was 42,506.91 (±44,974.45) items/ km^2 in the surrounding coastal waters of Mallorca (Figure 2a). The sampling location with the highest abundance was Cala d'Or with a maximum of 180,394.39 items/km^2 and Can Picafort with the minimum abundance of 3,829.18 items/km^2. These areas also coincided as the locations with the highest weight of the items found in Cala d'Or (15,971.74 g/km^2) and the minimum in Can Picafort with 53.61 g/km^2 and an overall mean weight of 1,078.67 (±3,427.86) g/ km^2 (Figure 2b).

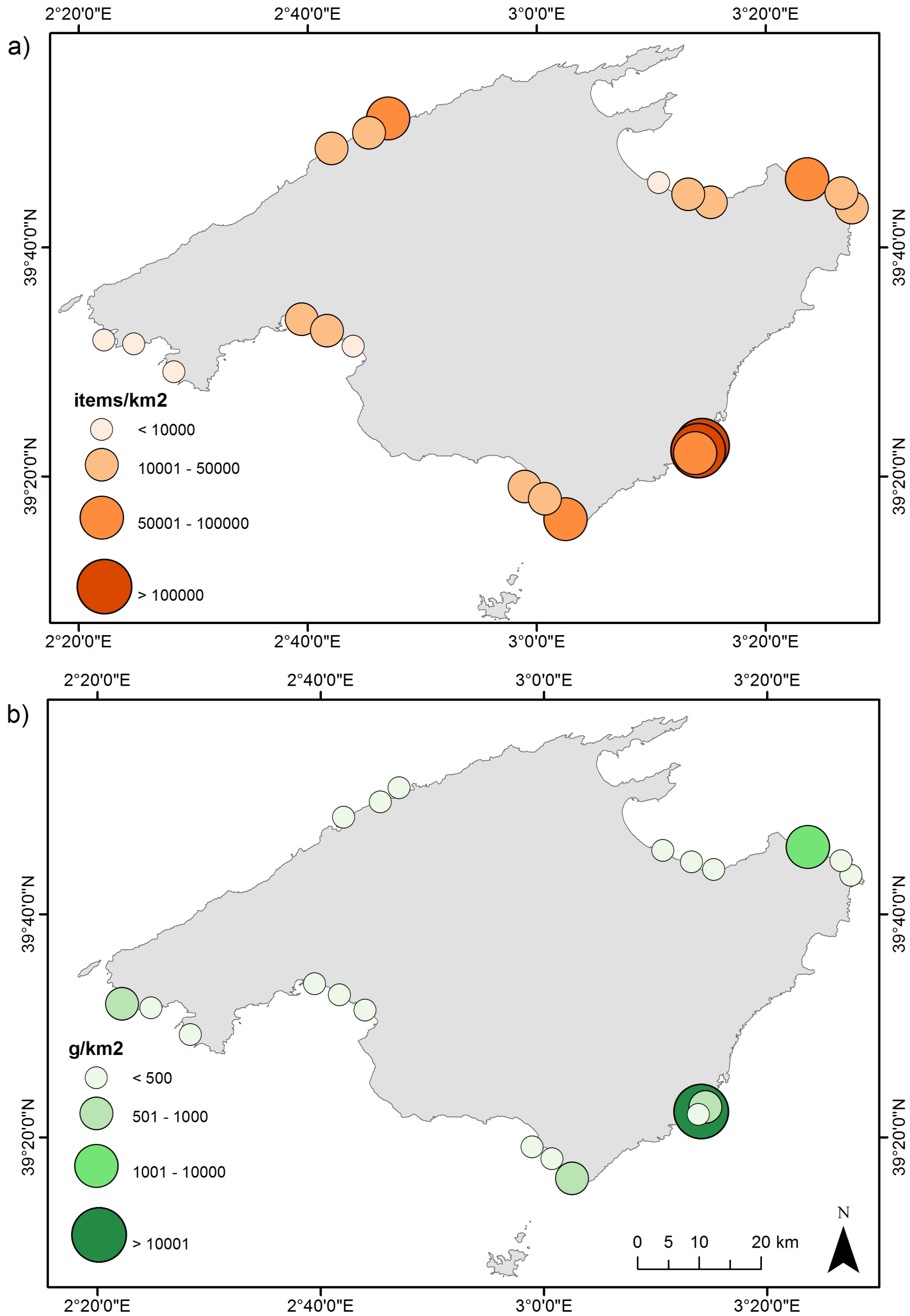

Figure 2 Spatial distribution of the plastic debris collected during the sea surface net trawls during the month of July 2017. For normalization purposes, the estimates have been extrapolated to: a) items/km^2 and b) g/km^2.

3.2. Plastic composition

A total of 920 plastic particles were collected and identified in the 21 surface trawls. Plastic items were separated by size: micro (< 5 mm), meso (5 – 25 mm) and macro (> 5mm) (Figure 3a). Items were categorized into four categories: fragment, film, filament and other (granules, pellets and foam) (Figure 3b) and then classified by colour categories (Figure 3c) (Kovač Viršek et al., 2016).

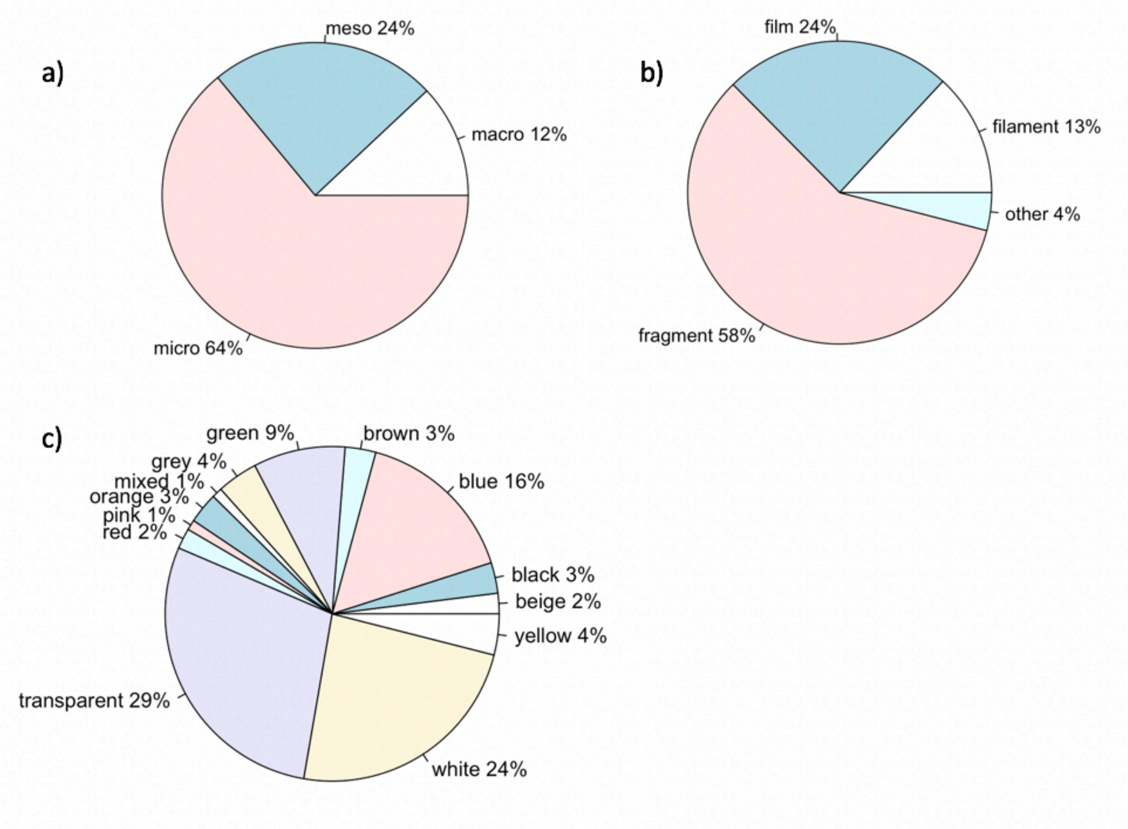

Figure 2 Summary of plastic debris found at all sample locations: a) size; b) shape of debris type; c) colour.

3.2.1. Size

Two-thirds of the plastic marine debris collected consisted of micro-plastics (< 5 mm), while 23 % consisted of meso-plastics and the least common size class found was for macro-plastics (11.9%) (Figure 3a). Despite the sea-surface trawls specialized to target small items, over a tenth of the items were larger than 25 mm. Much of these items were identified as single use items such as plastic straws and remnants of plastic packaging. Cala d'Or and Soller registered a large amount of items with the smallest size class of < 0.05 mm and coincidently particles of this size class were not found at any of the other five sampling locations (Figure 4).

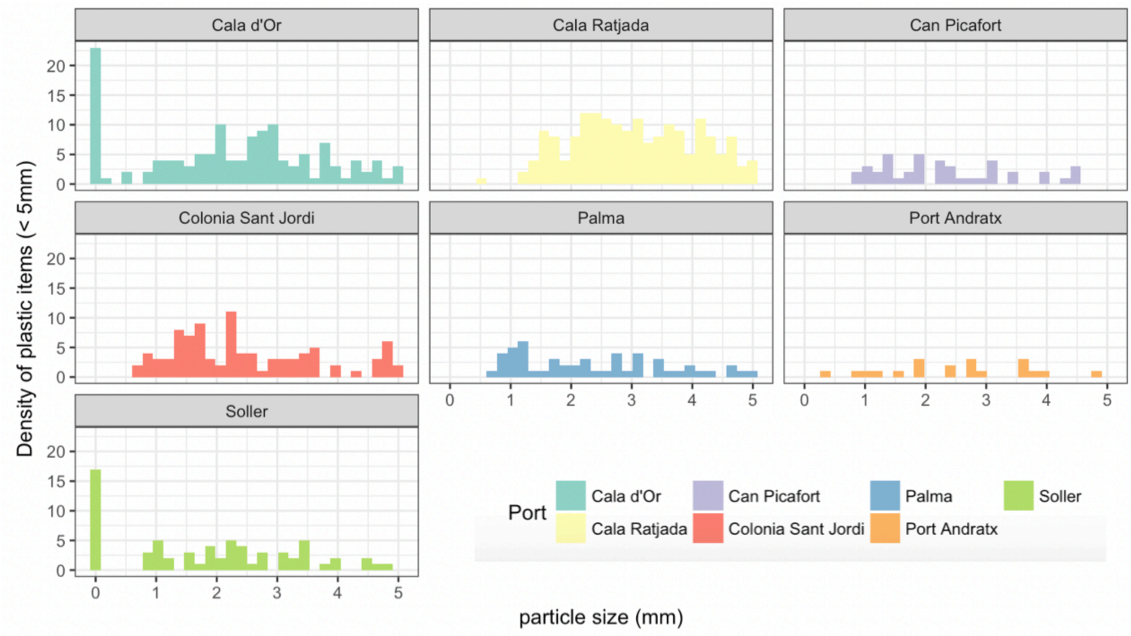

Figure 4 Density of particles less than < 5 mm for plastic debris found at each of the seven sampling locations.

3.2.2. *Shape*

Fragments were the most abundance marine debris type (57.9 %) and film was the second most abundant (25.5%) (Figure 3b). Filaments consisted of 13% and other (foam, pellets, and granules) 4% were the least amount of plastic debris found. The majority of the filaments identified were cuttings from lost fishing line. Microfibers were not considered in this study and contamination from clothing was not 100% contained during the sampling prior to the laboratory analysis. The further degradation of plastics provides us with importance information indicated fragmented pieces are more likely to continue breaking and fragmenting while pellets and granules will keep their size classes. Film and filaments on the other hand tend to stay slightly larger, most film from packaging sources and filaments resemble remnants of fishing line clippings.

3.2.3. *Color*

The dominant colors were transparent (29%), white (24%) and blue (16%) (Figure 3c). The least abundant colors were of mixed origin (items containing several colors), pink, red and beige (< 2% of the items). Overall, transparent and white colors consisted of over half of the items found throughout the area.

3.3. Polymer characterization

A total of 83 items were randomly selected from all of the trawls of which 53 were successfully characterized by their polymer type (Figure 5). Almost eighty percent of the items were identified as polyethylene with high density polyethylene being the most abundant (48%) and low density polyethylene slightly lower (29%). The least common plastic type was polystyrene and polypropylene (both 6 %). There were items that were visually identified as plastic items but results from the FT-IR analysis indicated they were of natural material, primarily chitin.

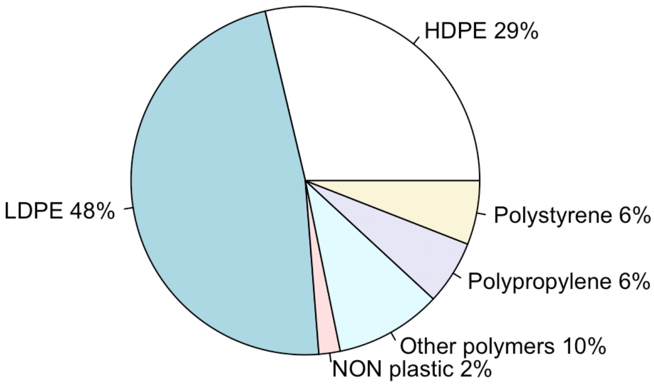

Figure 5 Representative results from the FT-IR analysis for low-density polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene, polypropylene, non-plastic and other polymers.

3.4. Data analysis

3.4.1. Abundance of marine plastic

Results from the linear regression indicated significant differences were found between locations (lme, $p < 0.01$) (Figure 6a and Table 2) and further analysis confirmed these differences were found between the location Cala d'Or and the other six sampling locations (Figure 6b). Cala d'Or was one of the locations with the highest abundance of plastic items consisting of 20% of the total plastic items. No significant differences were found between the weight of plastics and the sampling locations (lme, $p < 0.01$). In addition, no wind correction for these surveys was needed as no trawls were > 0.6 cm/s as the maximum was 0.39 cm/s and no significant linear correlation was found (lm, $p < 0.05$), giving a good indication that the survey method using nearshore sea cleaning boats allowed for the adequate calculation of the abundance of items in each surface trawl and the need to consider vertical dispersion within the sea surface water column was unnecessary.

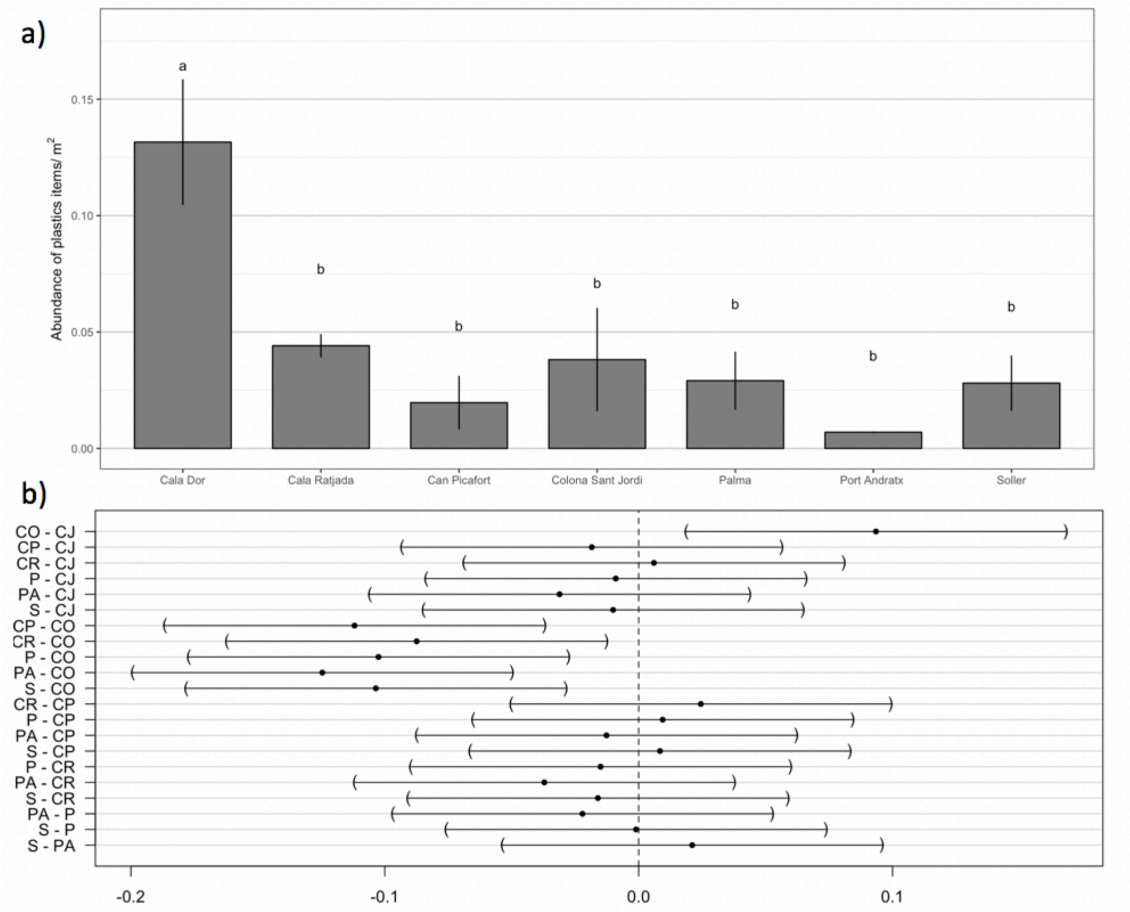

Figure 6 Bar plot means for the abundance of plastic items (items/m^2), error indicates the standard error of the mean (a) and the pairwise comparison between all locations with a 95% confidence interval from results from the linear regression model (b) at each location. Those bars with the same letter indicate they are not significantly different according to Tukey's HSD test. The x axis for plot b corresponds to: Cala d'Or (CO), Cala Ratjada (CR), Palma (P), Soller (S), Puerto d'Andratx (PA), Colonia Sant Jordi (CJ) and Can Picafort (CP).

Table 2 Summary of results from the linear regression model for the abundance of plastics (items/m^2) and each sampling location.

	Estimate	Std. Error	t value	Pr(>t)
Intercept	0.038	0.015	2.463	0.027*
Cala d'Or	0.093	0.022	4.269	0.001***
Can Picafort	-0.018	0.022	-0.844	0.413
Cala Ratjada	0.006	0.022	0.274	0.788
Palma	-0.009	0.022	-0.413	0.686
Port d'Andratx	-0.031	0.022	-1.424	0.176
Soller	-0.010	0.022	-0.461	0.652

$p <$ 0.001 ***
$p <$ 0.01 **
$p <$ 0.05 *

The results from the generalized linear mixed model indicated no significant differences for the size of the plastic items collected at each sampling location (lmer, $p > 0.05$). Despite this, it is important to note plastics found in the Bay of Palma were larger than those collected in the other locations (Figure 7) indicates the sizes class once the log transformation was applied. Sizes of plastics for Palma were larger than those collected at the other ports.

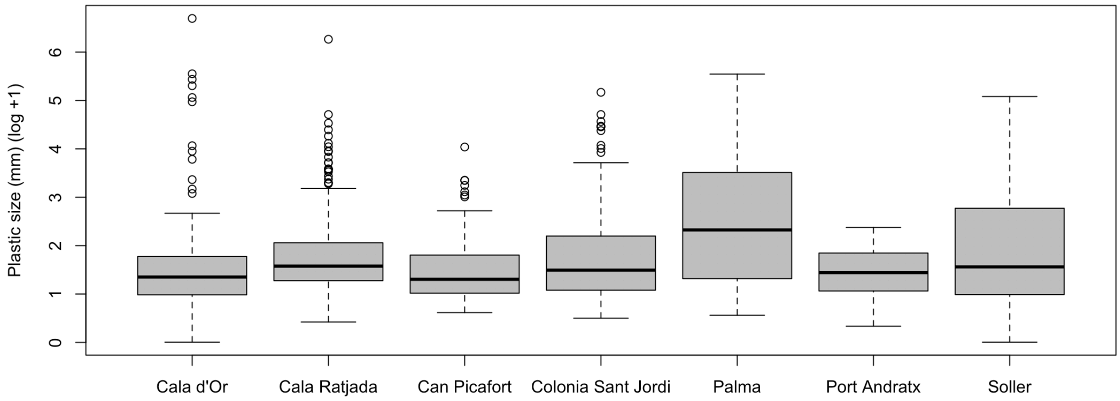

Figure 7 Boxplot summary of the abundance of sizes for the plastic particles collected at each of the seven sampling locations. The y-axis was log(x+1) transformed to consider to the range of sizes.

3.4.2. Distance

All of the samples were collected within one kilometer of the coastline with 90 % of the samples collected within the first 500 m of the coastline. A negative correlation was found for both plastic items/km^2 (r_s = -0.47, $p < 0.05$) and for the weight of plastic (r_s = -0.56, $p < 0.01$). These results highlight that plastic in terms of both abundance and weight decreases with distance from the coastline within the first kilometer of the coastline in the Balearic Islands.

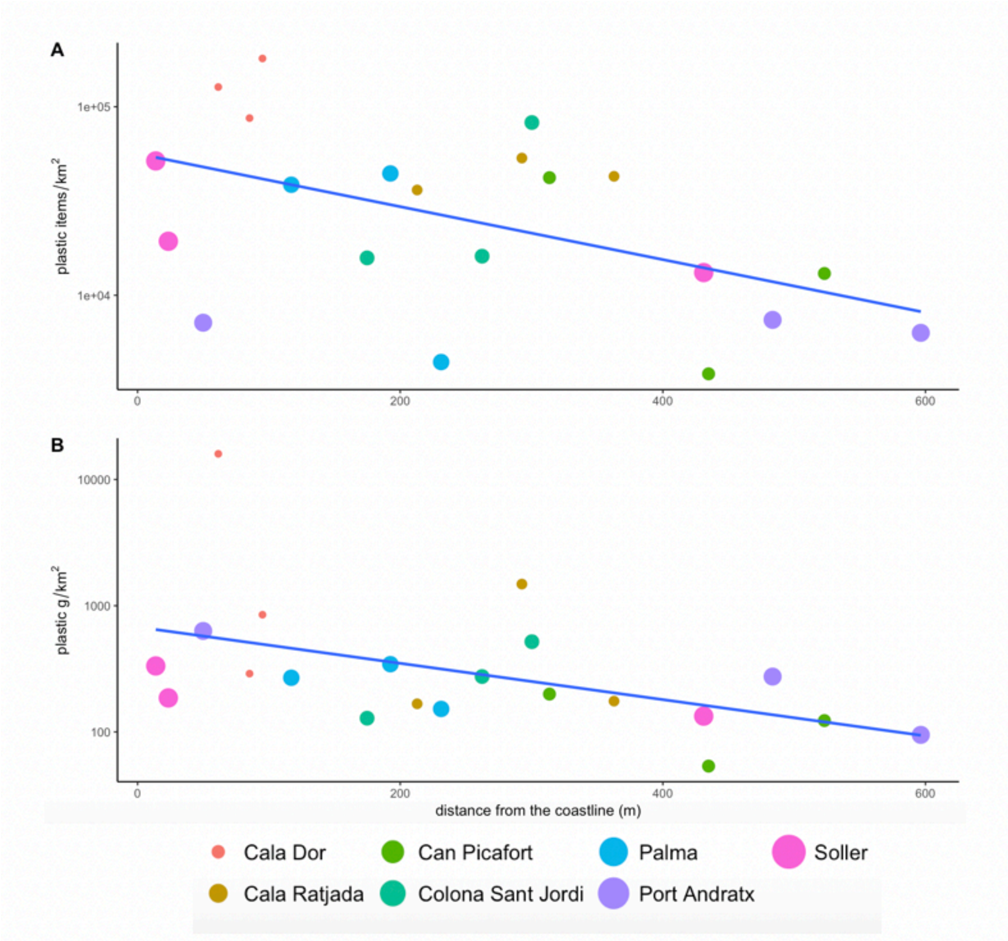

Figure 7 Distance from the coastline of plastic abundance for: a) items/km^2 and b) g/km^2. The y axis has been log10 transformed for visual representation.

4. Discussion

Plastic marine debris was found in all sampling trawls at each of the sampling locations in the nearshore area on the island of Mallorca. High small-scale variability in the abundance of plastic debris was found between locations indicating concentrations are not homogeneous in the coastal waters. The average abundance found in the coastal areas was 42,506 items/km^2 (maximum 180,394 items/km^2) and the average weight was 1078 g/km^2 (maximum 15,971 g/km^2).

The highest abundance of plastic debris was found along the eastern coastline on the south-eastern coastline of Cala d'Or which was significantly different from the other locations. Trawl samples from this area were taken within the small bays along the coastline emphasizing the accumulation and concentration of plastic debris in these areas, compared with other areas such as the Bay of Palma where lower concentrations were found despite the size of the items being much larger. These differences in sampling areas may arise due to the debris is more likely to concentration is smaller areas yielding higher densities compared to areas with extensive coastline and which are less sheltered and protected by the features of the coastline making them more easily dispersed across the sea surface.

The average abundance and weight of plastic items was less than found in previous studies of plastics net trawls on the high sea (Suaria et al., 2016) however they were quite similar to previous studies that have found similar results such as in the Bay of Corsica where a mean of 62,000 items/km^2 were collected over a one year period (Collignon et al., 2012) as well as in the Tyrrhenian sea with a mean of 69,191 items/km^2 (Baini et al., 2018) .

In terms of dry weight, there was variability between locations with Can Picafort having the minimum amount (53.61 g/km^2) and Port d'Andratx having the second least amount (94.79 g/km^2) with Cala d'Or having the highest average weight (5,703.34 ±8,897 g/km^2). The low amount of weight found in these areas may suggest the input is not local indicating the plastics may have arrived by means of hydrodynamics and regional environmental conditions. According to annual report from the regional sea cleaning service provided by the local government, these were also the areas with the least amount collected during the 2017 season (ABAQUA, 2017).Despite this variability, the overall the average weight was similar to a recent study on floating plastics in the Balearic Islands with (1,165 ±2,334.84 g/km^2) (Ruiz-Orejón et al., 2018). During the month of July, a total of 8,954.67 kg of marine debris were collected in the beach waters and coastal areas surrounding the coastline of which 3,759 kg of plastic debris were collected (ABAQUA, 2017).

The majority of plastic debris collected was micro-plastics and the least common was macro-plastics. Micro-plastics have consistently dominated the size class in the trophic trawls across the Mediterranean Sea (Suaria et al., 2016). Also, although micro-plastics were not considered on their own in this study, it is important to highlight the different pattern in size classes between 0 and 5 mm. Cala d'Or and Soller, which both contained high amount of plastic debris, there were high abundances of items 1 mm in size while the other locations sizes ranged from 1- 5 mm (Figure 4) and are areas exposed to the two major currents, the Balearic Current and the Algerian current. In addition, almost 12 % of the plastics were larger that > 25 mm, this arises concern especially due to the probability these larger items will eventually weather and becoming smaller items over time, essentially becoming more available for trophic transfer within the food chain.

Distance from the coastline was also an important highlight in this study as abundance and weight diminished further from the coastline. This coincides with Pedrotti et al., 2016 where the highest plastic concentrations were found in the first kilometre adjacent to the coastline as well as in regions distant from land. Conversely, a recent study from Baini et al., 2018 highlighted the lowest abundance was in coastal waters within the first 0.5 kilometer and increased offshore. This may describe the exceptionally high concentrations found in the offshore coastal waters of the Balearic Islands (Ruiz-Orejón et al., 2018).

Several samples did contain a large amount of organic material (foliage from terrestrial trees and seagrass) which may be an indication of coastal or nearshore origins of the plastic pollution as seagrass grows in shallow ecosystems and much of the foliage consisted of pine needles from the nearby coastal areas. Other indications of plastic debris coming from nearshore sources was in the Bay of Palma. Palma is the capitol of the Island of Mallorca and consists of the highest year-round resident population and principal tourist destination as well as being one of the most frequented ports of entry for marine traffic (cruise ships, ferries, fishing vessels and recreational boats). The larger items of marine plastic tended to be of the original item (i.e. food wrapper) with little photodegredation and biofouling, indicative of plastic debris coming from urbanized areas.

Over three-fourths of plastic marine debris was either from films or fragments. This is an indication of secondary plastics deriving from the degradation of larger plastic items. Fragmented items can pose a threat to marine debris because of ingested, they can cause obstruction or perforation of their internal organs while the ingestion of film can cause blockage of the oesophagus or other organs impeding the translocation of food items. These are only a few of the hazards the ingestion of the items can potential cause which may result in death. Items such as filaments from primarily from lost fishing gear was also common, this may be due to the closeness to ports and recreational fishing areas where snippets of fishing line or nets are often fragmented and lost at sea. The least common items were pellets and granules; these are mostly primary plastics meaning they enter the marine environment in the shape and size they were found in. Overall, the results indicated that over 95 % of the plastic marine debris items collected were secondary plastics, indicating they originally derived from larger items. A recent study has linked the breaking down of plastics into smaller items is contributing to climate change through the decomposition of the plastic items releasing greenhouse gases into the atmosphere with LDPE producing the most amount of gases (Royer et al., 2018). This is very alarming as the amount of plastic marine debris entering the marine environment is increasing, fragmentation processes could be increasing the amount of plastic found.

Although evidence of fragmentation was found throughout the survey area, there were areas of low concentrations of these plastics. In urbanized areas, such as in Port Andratx, low abundance of sea surface plastics were found coinciding with previous studies of low abundance of fragmented plastics on the seafloor in these areas (Alomar et al., 2016). This may indicate that the plastic debris does not originate from land based sources but rather arrive with the hydrodynamics of the surrounding waters and they are not settling and accumulating on the seafloor or on the sea surface in these areas. Alomar et al.,2016 found that in these areas there was a higher abundance of microfibers which have been linked to high anthropogenic impacts through point sources such as discharge from washing machines (Hartline et al., 2016; Napper and Thompson, 2016). Despite microfibers not being the objective of this study, it is important to highlight the fallout and sinks of microfibers in future studies of sea surface trawls.

Just over half of the plastic items in the samples were either white or transparent. Most the transparent items belonged to the films or fragments while the plastics with white colours were from fragments. This could hint at potential sources of what type of items these plastics could be coming from. For example, transparent film is unique to packaging and wrappers of food items commonly found in supermarkets or packaging of cigarette cartons while the harder plastics from plastic bottles, although very few items were found to be from polyethylene (77%). The white plastic fragments on the other hand can come from a range of single use items from cutlery or plastic bottles to weathered items that have become discoloured over time. Photodegredation can provide both a loss in the form of plastics as well as the loss in colour, returning the items that may have print or paint to their base colour which is often white.

The FT-IR analysis has confirmed the high-density polyethylene and low-density polyethylene were the most common marine debris items found. This has been reflected in several studies where polyethylene (both HDPE and LDPE) are consistently the most frequent particle type. All of the polymer types found fall into the category of thermoplastics, meaning that despite their longevity, there is the possibility for the material to be reheated, reshaped and frozen repeatedly (Plastics Europe, 2017). Low variability of plastic types were found in coastal areas compared to areas where samples have been found in high seas (Suaria et al., 2016) however the results from this study were comparable to a recent study in the Tyrrhenian Sea with polyethylene, polypropylene and polystyrene dominating the plastic types (Baini et al., 2018). In addition, the majority of items were correctly visually sorted to be of plastic origin (< 98%), however although less than 2% of the items were of non-plastic sources, this does highlight the importance of utilizing a polymer characterization method to assure the correct identification.

Results from this study highlight islands are being sources, temporary reservoirs or final sinks of plastic marine debris coinciding with previous studies (Monteiro et al., 2018). Due to the sensitivity of marine diversity surrounding islands, it is important for efficient management of identifying where and what these sources are and mitigating these impacts on the coastal ecosystems. Future studies would benefit to integrating sampling in the marine protected areas as differences in seafloor plastic has been observed in the Balearic Islands (Alomar et al., 2016).

Although this study focuses on small marine debris items, visual surveys carried out during the sampling effort identified single use items such as plastic bottles and plastic bags as common items found, the majority not presenting any fouling indicated the low amount of time in the water. Currently the Balearic Islands does not have a plastic bag ban nor a return system for plastic bottles. Recent studies in other countries have shown the implementation of a plastic bottle return system reduced the amount of bottles found by 30% (Willis et al., 2018). Despite this, polyethylene terephthalate (PET) the principal components of plastic bottles and was interestingly not found as a type of polymer in the samples analysed. This may be due PET being a heavier polymer and is more likely to be found on the sea floor. Plastic bans, although they are not a long-term solution, these are the first steps the Balearic Islands could take in preventing plastic items entering the marine environments during the summer and winter months.

The rising concern for marine plastic pollution has caused the development of several local, regional and global initiatives to help prevent mitigate and monitor the emerging problem (Pedrotti et al., 2016).The results from this study should be used for further management and conservation plans to make informed decisions, especially in areas with pristine conditions such as the several Marine Protected Areas found within the Balearic Islands. The present work highlights the abundance of small and large plastics in the nearshore coastal waters and aims to contribute to the development of a long-term data set to monitoring the evolution of plastic marine debris in the coastal waters in the Balearic Islands.

5. Final remarks

- The extensive regional survey indicated plastic marine debris was abundant at each survey location and 100% of the samples contained plastic debris.
- High small scale variability of floating plastic debris.
- Increased abundance and weight of plastics closer to the coastline.
- No relationship between sizes and locations.
- Two-thirds of plastics from the size class micro (< 5mm) the most abundant.
- Almost 60% of the plastic items were fragments.
- The most common colors consisted of white and transparent colours films and fragments.
- Polyethylene was the most abundant plastic debris type (< 80%).

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