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Three-dimensional evaluation of beaches of oceanic islands as reservoirs of plastic particles in the open ocean

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ABSTRACT

The quantification of plastic debris on beaches has been extensively used as an indicator of plastic pollution in the marine environment. However, most efforts have focused on surface layers, with few investigations looking deeper into the substrate, thus underestimating total standing stocks. Such information is crucial to improve our understanding of where plastic accumulates in the oceans. In this study, we investigated the three-dimensional distribution of plastic (>1 mm) in three sandy beaches located in oceanic islands of the North Atlantic (Azores and the Canary Islands) that are known to accumulate significant quantities of small plastic debris at the surface layer. On each beach, we collected a total of 16 sediment cores down to 1 m depth, from the high tide line up to the backshore following a stratified random sampling design spread across four different levels across the beach. Samples were taken every 10 cm down to 1 m into the sand. Our results revealed the presence of plastic items in the deepest layers with subsurface layers accounting for 84 % of the total plastic abundance and with a similar pattern in terms of size, shape, colour and composition. Furthermore, we found increasing plastic concentrations towards the upper levels of the beach, indicating longer term accumulation in the backshore. Collectively, this study suggests that the plastic items reaching sandy beaches of the Macaronesia are being incorporated into its deepest layers, acting as reservoirs of plastic in the open ocean.

1. Introduction

Plastic pollution is a pressing challenge for humanity, particularly due to the ongoing increase in plastic manufacturing and usage. Ineffective waste management and limited mitigation strategies have caused a substantial accumulation of plastic waste in the environment dating back to the 1950s. As a result, the marine environment has been continuously contaminated with a vast amount of plastics, and they are now present in all environmental compartments, ranging from the most remote locations in the Antarctic (Waller et al., 2017) to the deepest point on the seabed (Chiba et al., 2018).

Furthermore, the more recent discoveries of the widespread distribution of micro and nano-sized plastic particles (Peng et al., 2020) means that this pollutant affects the various levels of organization within marine ecosystems. It is interacting with marine organisms across the entire food web, with potential severe population-level effects (Kühn and van Franeker, 2020). Additionally, marine litter has been shown to cause serious socio-economic damage, impacting fishing, navigation, and tourist activities (Rodríguez et al., 2020).

Despite various global initiatives to tackle this problem, there is still a shortage of relevant information to effectively direct these actions and promote change. Understanding patterns of plastic distribution has become the focus of many researchers across the globe, particularly for solving the mass balance between the leakage and abundance measured in the marine environment (Cózar et al., 2014; van Sebille et al., 2015; Isobe and Iwasaki, 2022). Certainly, analysis of field data suggests that

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plastic abundance in the oceans is orders of magnitude lower than plastic inputs, highlighting the need for more data on plastic distribution throughout the oceans (Ryan et al., 2020).

It is well established that floating plastic debris in the marine environment is often carried over vast distances by ocean currents (van Sebille et al., 2020), eventually reaching one of the five major subtropical gyres where it can remain for extended periods (Lebreton, 2022). Oceanic insular environments are generally under the influence of such large current systems and have been proposed to act as sentinels of global ocean pollution (Barnes et al., 2018) as beaches are often reported to accumulate significant quantities of plastics from far away sources (Lavers and Bond, 2017; Monteiro et al., 2018: Pieper et al., 2019). Therefore, such beaches can be regarded as a significant storage site for oceanic plastics of major relevance for monitoring.

Coastal ecosystems are easily accessible, and as a result, much of the available data on marine plastics is obtained from beach surveys (Ryan et al., 2020). However, the bulk of research on beach litter relies on individual surveys that only report the amount and composition of litter found at specific beach locations, without providing information on changes over time (Serra-Gonçalves et al., 2019). Additionally, most studies on beach litter have focused their analysis on surface layers, which fails to accurately represent the entire standing stock of litter on the beach. Researchers that have analysed items buried deeper within the substrate have emphasized the significance of contamination within beach sediments, providing a more precise assessment compared to solely examining surface layers (e.g. Williams and Tudor, 2001; Kusui and Noda, 2003; Carson et al., 2011; Turra et al., 2014; Chubarenko et al., 2018; Duncan et al., 2018; Tavares et al., 2020). The specific methodology and depth at which the extent of buried debris is assessed varies across studies. While some authors compare the surface with a second subsurface layer ranging from 5 to 150 cm (e.g. Williams and Tudor, 2001; Kusui and Noda, 2003; Chubarenko et al., 2018; Tavares et al., 2020), few others use a multilayer selection system using cores from depths of 25 cm to 200 cm, with each layer divided into distinct segments (5 cm to 20 cm), enabling descriptions of vertical profiles (e.g. Carson et al., 2011; Turra et al., 2014; Duncan et al., 2018). However, there is a lack of research exploring the potential variations of these profiles along the beach, encompassing the water line to the backshore. Since shorelines, and especially the backshores are often recognised as an important sink for plastics (Olivelli et al., 2020; Onink et al., 2021; Isobe and Iwasaki, 2022) it is crucial to understand the amount of plastic that is being sequestrated in their body and the possibility of it being released.

Macaronesia refers to a group of four volcanic archipelagos in the North Atlantic: the Azores, Madeira, the Canary Islands, and Cape Verde, which share a common exposure and influence of a plastic soup formed by the North Atlantic subtropical gyre (Cardoso and Caldeira, 2021). Some Macaronesian beaches have been shown to accumulate large quantities of plastic fragments, occasionally exceeding 10,000 items m^{-2} (Pham et al., 2020; Álvarez-Hernández et al., 2019; González-Hernández et al., 2020; Hernández-Sánchez et al., 2021). However, previous assessments of debris in these beaches have only considered the surface layers and the abundance of plastics across different depth layers remains largely unknown.

This study aimed to determine the extent of plastic sequestration in Macaronesian beaches by examining the amounts of plastic at different depths layers (down to 1 m) and at different horizontal levels from the water line up to the backshore. Plastics were characterized by their size, shape, colour and composition to identify their potential role in burial processes.

2. Materials and methods

2.1. Study area

This study was undertaken in two archipelagos located in the North Atlantic: the Azores and the Canary Islands. The Azores is the northernmost group encompassing nine islands, located at a distance of about 1600 km from the European continent and about 3400 km from the North American continent (Fig. 1). The Canary archipelago is situated about 115 km off the West African mainland and is composed of eight islands (Fig. 1). Sandy beaches in the Azores ($n = 2$) and Canaries ($n = 1$) were selected based on previous studies revealing a chronic exposure to small plastic fragments: Porto Pim in Faial island, Milícias in São Miguel island and Playa Grande in Tenerife island (Fig. 1). Porto Pim is a sandy beach that stretches across 290 m, featuring a light slope, fine sand, and a broad surf zone nestled within a sheltered bay. In conditions where south, southwest, and southeast winds prevail, this beach has the capacity to accumulate large quantities of mesoplastics, up to 15,000 plastic items m^{-2} (Pham et al., 2020). Similarly, Milícias is another gently sloping beach spanning 268 m, which is susceptible to south winds and occasionally experiences high amounts of litter (Pham et al., unpublished data). Playa Grande is a northeast-oriented fine sandy beach, spanning approximately 107 m in length with an intertidal zone width of about 50 m. The slope in this area is gentle, reaching a depth of 20 m at a distance of 820 m from the shoreline. It is bounded by a cliff ranging from 15 to 18 m in height which promotes the formation of a climbing dune. With predominant north and northeast winds, Playa Grande has been reported to be among the beaches accumulating most plastics in the Canaries (Álvarez-Hernández et al., 2019; González-Hernández et al., 2020).

2.2. Beach sampling design

We used a stratified sampling design (Fig. 2) to determine the abundance of plastic items (>1 mm) across different depth layers (from the surface down to 1 m) and at different levels of the beach (from the water line to the backshore). Samples were collected between March 2021 and April 2021. In the Azorean beaches, two 100 m sections were delimited due to a difference in backshore extension, expected to influence plastic abundance (zones A and B, see Fig. S1). The separation of the beach into two sections was not done for Playa Grande due to its even backshore characteristics and smaller extension. In Porto Pim, section B is characterized by a steep wall with a very limited backshore, while in section A, the backshore is characterized by a dune system. Similarly, in Milícias, the dune extension on B is restricted compared to section A (Fig. S1).

In each section four different levels were identified (Fig. 2): (1) the high tideline, (2) the berm, (3) the foredune and (4) an intermediate level located halfway between the high tideline and the berm. The "high tideline" was defined as being the most recent highest tideline and could easily be identified at the interface between wet and dry sand. When various tidelines were present, the highest strandline was selected. The berm was defined as the line of accumulation located higher on the beach out of reach of ordinary waves. The foredune was located higher on the beach slope at the start of the dune. Four replicate cores were taken at a random position along each level (Fig. 2). Samples were taken as separate 10 cm intervals until a depth of 100 cm, resulting into ten distinct depth layers per core. In the level closer to the water line (high tideline), the water was occasionally reached before 100 cm, preventing to sample the full core. In zone B of Milicias beach, only three replicate cores could be collected.

The core consisted of a metal tube with handles at the top for the retraction of each 10 cm sediment sample. For beaches of the Azores, the core had a height of 120 cm and a diameter of 7 cm while the core used in Playa Grande, had the same height but with a diameter of 5 cm.

2.3. Sample processing

The samples were processed either in the laboratory or directly on site by sieving the contents through a 1 mm stainless-steel mesh. All plastic particles were counted and measured in their longest dimension

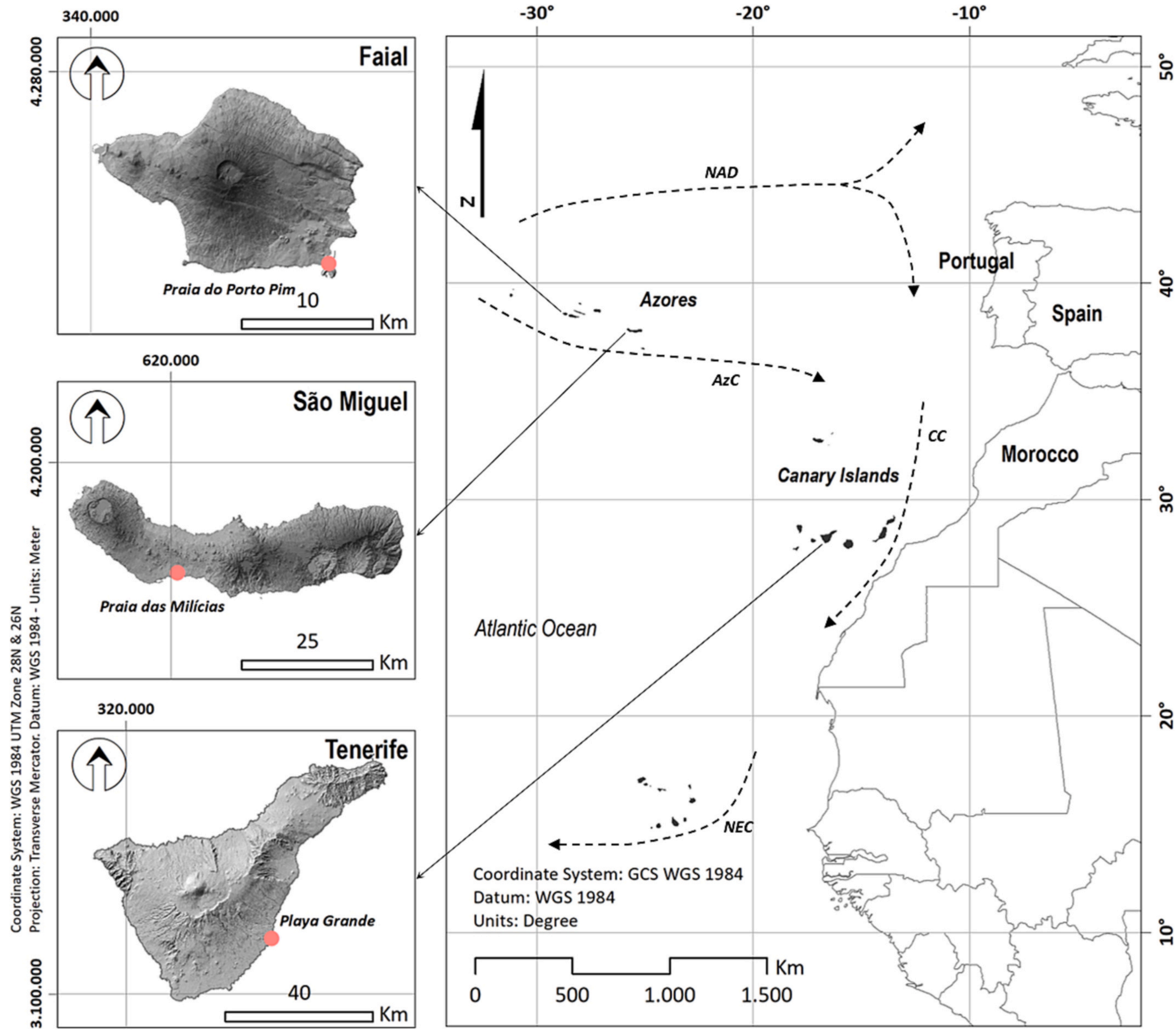

Fig. 1. Localisation of the three sandy beaches of the Macaronesia where the abundance of plastic was investigated down to 1 m depth. North Atlantic circulation at the surface: North Atlantic Drift (NAD), Azores Current (AzC), Canary Current (CC), North Atlantic Equatorial Current (NEC).

(maximum Feret's diameter) and assigned to one of the following size classes: “1–2 mm”, “2.1–3 mm”, “3.1–4 mm”, “4.1–5 mm”, “5.1–6 mm”, “6.1–7 mm”, “7.1–8 mm”, “8.1–9 mm”, “9.1–10 mm”, “10.1–15 mm”, “15.1–20 mm”, “20.1–30 mm”, “30.1–50 mm” and “>50 mm”. Shapes assigned to each item were the following: “fragment”, “pellet”, “foam”, “line” and “others”. Colours of the plastics were classified into 11 classes: “black”, “blue”, “green”, “grey”, “orange”, “pink”, “red”, “white”, “yellow”, “aged” and “other”. The volume of the collected sediment, wet and dry weight were recorded for a subset of samples (n = 120) in order to express the number of plastics per dry weight of sediment. We selected a sub-sample of the plastic items (n = 915) to determine polymer composition. For this purpose, we used a Fourier-transform infrared (FTIR) spectrometer Cary 630 equipped with a single reflection diamond Attenuated Total Reflectance (ATR) module (Agilent Technologies, California, USA), with a ZnSe beamsplitter and a 1.3 mm diameter thermoelectrically cooled deuterium triglycine sulphate (dTGS) detector. FTIR spectra were collected with 32 scans per spectrum (Happ-Genzel apodization function was applied) at a resolution of 8 cm^{-1} in the range 4000 and 650 cm^{-1}. Agilent MicroLab PC FTIR software was used to acquire and identify spectra using polymers libraries. The minimum matching for positive identification was set at quality values ≥0.70 over 1.00, which corresponds to a 70 % of positive identification. Such criteria was set following the indications of the Guidance of Marine Litter in European Seas of the European Commission (Joint Research Centre, Institute for Environment and Sustainability, 2014).

2.4. Data analysis

The concentration of plastics was expressed as number of items per unit of dry weight of sediment. We computed proportion of shapes, colour and polymer composition of plastics per beach, depth and levels. Size distribution of the items per depth and per beach were also computed and represented. Comprehensive data exploration was performed prior to the analysis following the recommendations given by Zuur et al. (2010). A generalized linear mixed-effect model (GLMM) with a negative binomial distribution and a log link function was applied due to the dependency structure of the data and because of

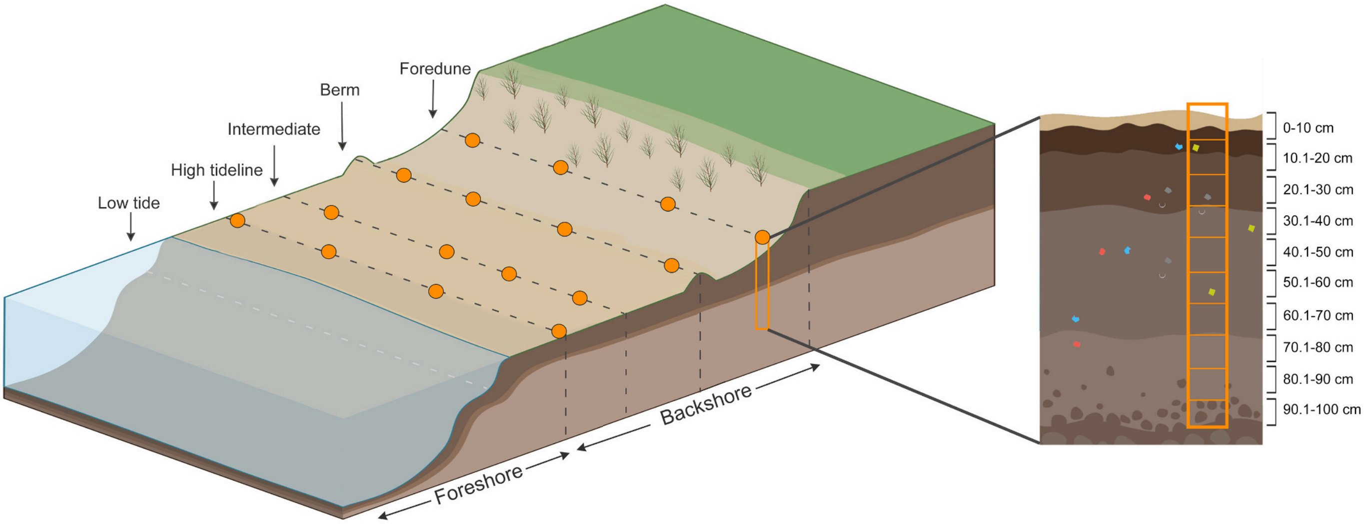

Fig. 2. Beach stratified random sampling design applied to determine plastic abundance down to 1 m depth and across four levels in three beaches of the Azores and Canaries.

overdispersion when using other distributions. The spatial dependency was included in the model as a random effect to deal with this intrinsic spatial correlation of the experimental design. The number of plastics was modelled as a function of depth (as a factor), beach, section and level as fixed effects and the core as a random effect. Sample weight was included as an offset to account for differences in the quantities of collected sediment between the two archipelagos. The glmmTMB package was used to fit the model using maximum likelihood estimation via 'TMB' (Template Model Builder). To validate the model, a residual analysis was made using DHARMa package (Hartig, 2020). ANOVA table was generated using Anova.glmmTMB. All data processing and graphical representations were performed using R software version 4.0.2. (R Core Team, 2021).

3. Results

3.1. Vertical and horizontal distribution of plastic abundance

Throughout the 3 beaches, 76 sediment cores were processed, resulting in a total of 751 separate depth strata collected from the surface down to 1 m, uncovering 6808 plastic items.

Overall, subsurface strata (depth layers from 10.1 to 100 cm) comprised 84 % of all plastic found, and in numerous core samples, the plastic content in the top layer (0–10 cm) was less than that of all deeper layers combined. However, there was a significant relationship between the number of plastics found at the surface layer (0–10 cm) and the amount of plastic buried in the entire substrate column (Fig. 3). Depth profiles were variable throughout the three different beaches, zones and four levels (Fig. 4). Results of the GLMM revealed that all factors (beach, level, zone, and depth) were important in explaining plastic counts (Table 1). Overall plastic concentrations decreased with increasing depth (Fig. 5a). Yet, in some areas, such pattern was not as pronounced, due to the low number of plastics recovered in these locations (Fig. 4).

Our analysis also revealed Playa Grande to be the beach having the overall highest plastic load compared to the other two beaches (Fig. 5b). For the two Azorean beaches, zone A had a higher plastic abundance compared to zone B (Fig. 5c; Chisq: 24.36; $p < 0.001$). The model also revealed that the quantity of plastic increased significantly when moving from the high tideline up to the foredune (Fig. 5d). As a result, most of the plastic items found on the various beaches and zones were concentrated on the backshore (consisting of the berm and foredune), accounting for 94 % of the total (90.2 ± 7 %, average, SD). Among the different zones, the foredune held the highest proportion (66 %) of plastic items. The exception was zone B of Porto Pim, where the highest concentrations were found on the berm, reflecting the limited extent of the backshore on this zone of the beach (Fig. 6).

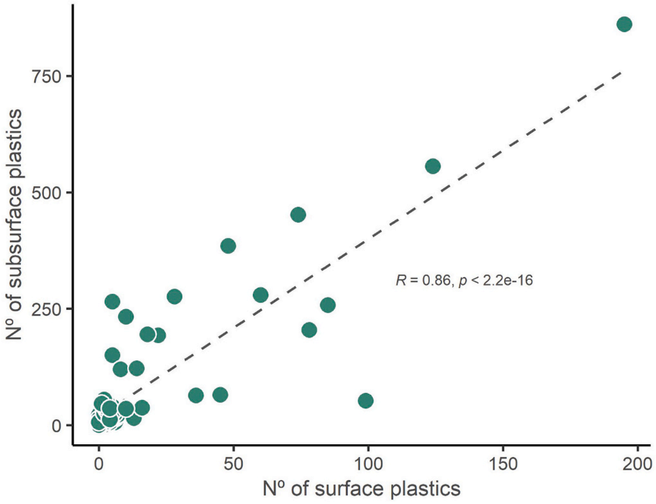

Fig. 3. Relationship between the number of plastics at the surface (0–10 cm) and the corresponding number of plastics buried (10.1–100 cm) in each core (n = 76) collected in three beaches of Macaronesia.

3.2. Shape, colour, size and polymer composition

Most plastic items recovered from the beaches were in the shape of fragments, representing 82 % of all the plastic items recovered. While both in Porto Pim and Playa Grande, fragments represented 88 % and 89 % of the items (87 ± 4 %, average, SD, respectively (Fig. 7a), in Milícias, foam was found in equal proportion to fragments, a pattern maintained throughout the depth layers (Fig. 7a). For the two other beaches, the predominance of fragments remained similar throughout the depth profiles (Fig. 7a) and also across the different levels of the shore. Pellets were present in similar proportions for all three beaches (5 %, 6 % and 6 %, for Milícias, Porto Pim and Playa Grande, respectively), and were found in the different depth layers and shore levels (Fig. 7a).

The most frequently occurring colour of plastic items found across all three beaches and depth layers was white, with blue following in second

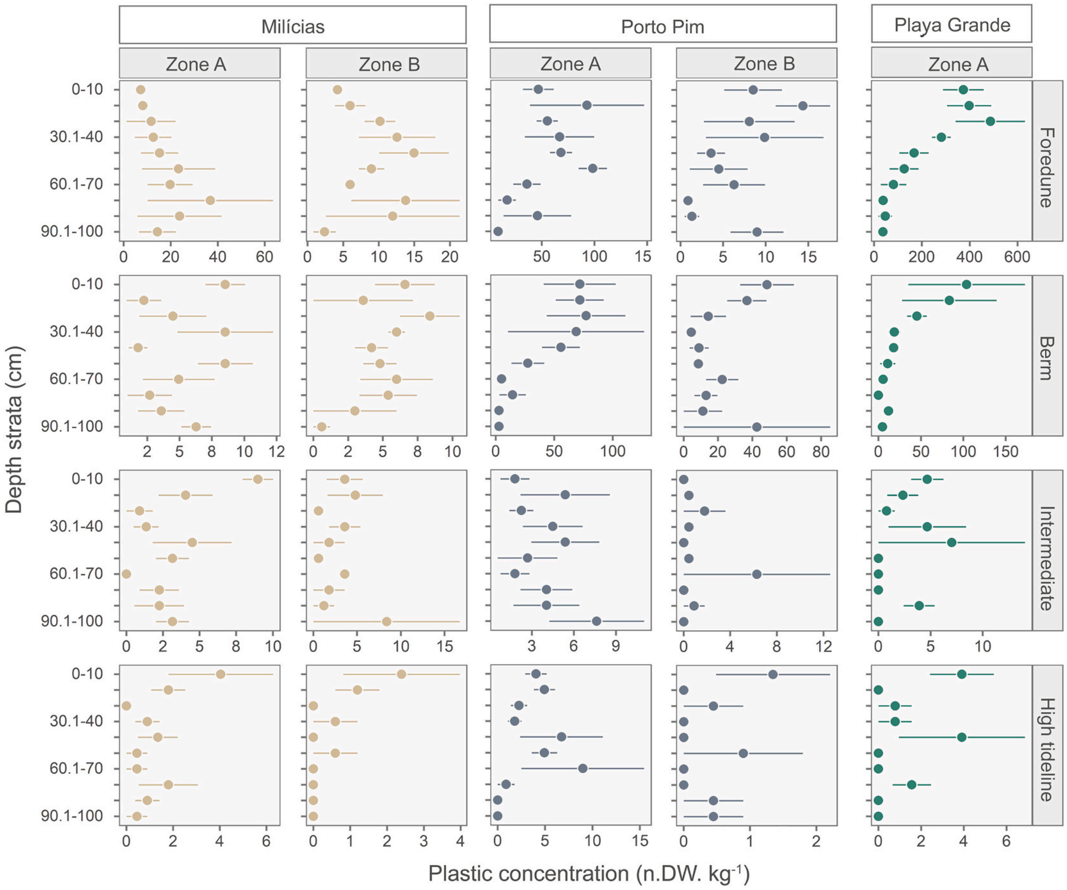

Fig. 4. Average plastic concentration (number of items DW·kg^{-1}) across different depth strata (n = 10) and across the four levels for the three studied beaches and zones of the Macaronesia. Error bar denotes the standard error.

Table 1
Analysis of deviance with Wald Chi-square tests (Chisq) of fixed categorical variables: depth (n = 10), level (n = 4), beach (n = 3) and zone (n = 3) in GLMM negative binomial of plastic counts.

Variable	Chisq	DF	*p*
Depth	145.61	9	<0.001
Level	148.34	3	<0.001
Beach	12.35	2	0.002
Zone	24.36	1	<0.001

place (Fig. 7b). Polymer composition was similar throughout the depth layers of the beaches (Fig. 7c). Polyethylene was the dominating polymer recovered, followed by polypropylene, making together 95 % of the sample analysed (Fig. 7c).

The size distribution of plastic items was consistent across all three beaches and various depth layers (Fig. 8). Overall, large microplastics (1–5 mm) and mesoplastics (5.1–25 mm) represented 99 % of the items recovered from the beach sediments, and this was the case throughout the depths and levels of all beaches. Fig. 8 shows that the size frequency distribution was very similar between depth layers and the three beaches, with the mode being found in plastics of 3–4 mm lengths.

4. Discussion

This study shows that restricting the sampling to only the surface layers of a beach does not provide an accurate measure of the overall levels of plastic contamination. The amount and type of plastic present on the surface of beaches have been analysed worldwide to gauge the extent of pollution in particular areas (Serra-Gonçalves et al., 2019).

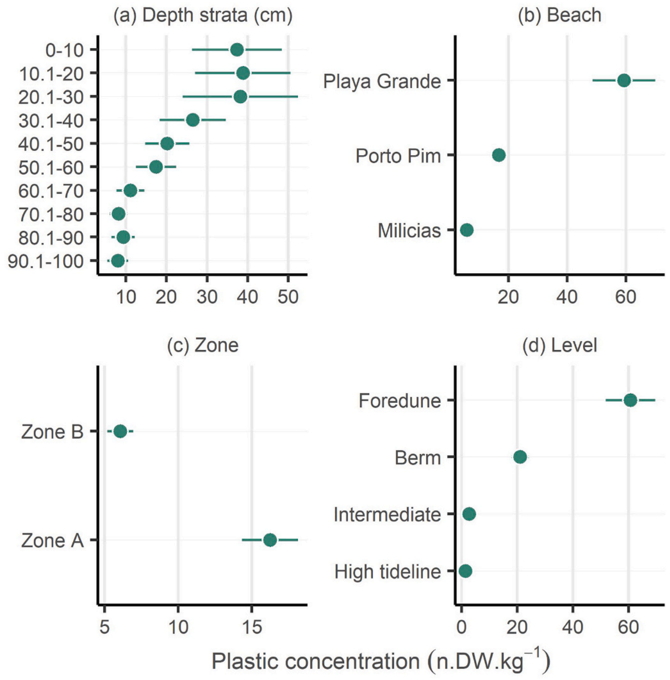

Fig. 5. Overall average plastic concentrations (number of items DW·kg^{-1}) for different (a) depth strata (n = 10), (b) beaches (n = 3), (c) zones (n = 2) and (d) horizontal levels (n = 4). Error bar denotes the standard error.

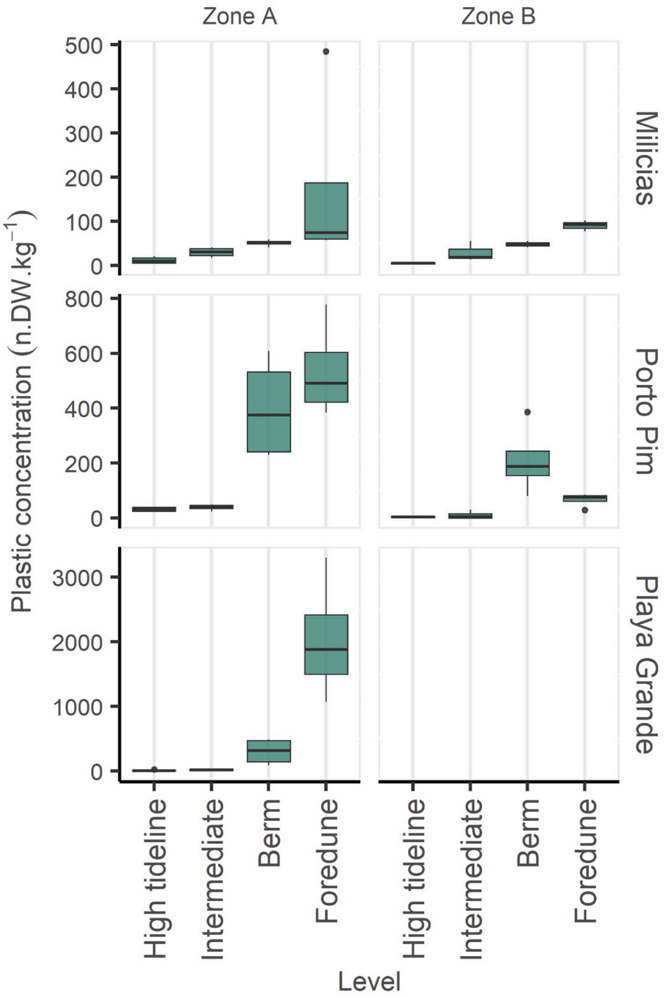

Fig. 6. Boxplot of plastic concentration (number of items DW·kg^{-1}) across levels (n = 4) and in the two zones (A and B) of the three beaches of Macaronesia. Playa Grande did not include a zone B.

However, collecting samples at varying depths is crucial to obtaining a more accurate assessment of debris levels in sandy beaches and their potential to function as a sequestration site. By adopting this method, a more comprehensive understanding of the actual quantities of debris present can be achieved. Furthermore, we showed that plastic quantities at all beaches increase significantly from the high tideline up to the foredune, confirming previous indications that the backshore is acting as an accumulation zone (Lee et al., 2015; Onink et al., 2021; Olivelli et al., 2020; Chubarenko et al., 2018). When the extent of the backshore is limited, as is the case for a side (zone A) in Porto Pim, plastic abundance is reduced because debris are being backwashed offshore by swash waves (Isobe et al., 2014). If certain sections of the beach have a broader stretch of sand, intense storms can deposit debris farther up the shoreline, exceeding the usual reach of waves and initiating a process of accumulation, especially when there is vegetation (Olivelli et al., 2020).

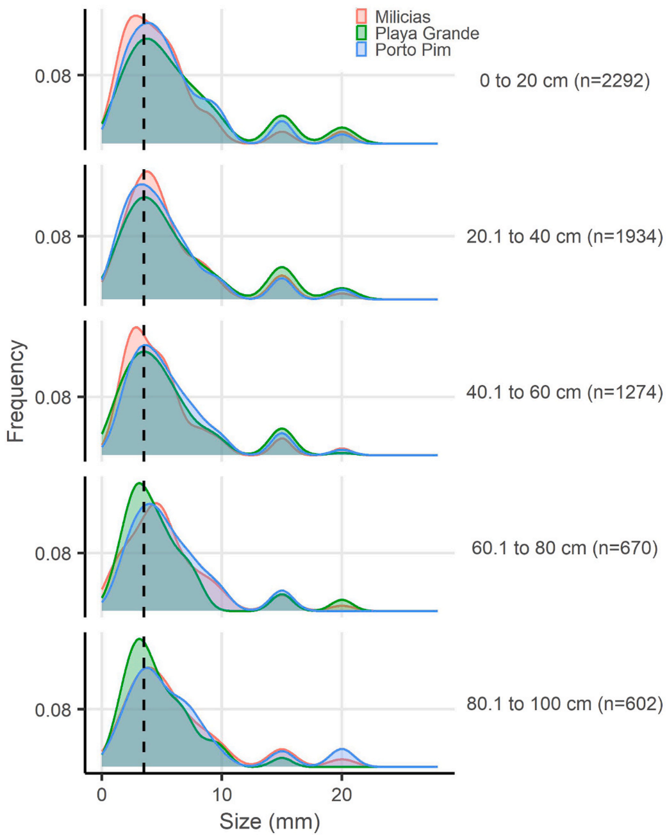

Fig. 8. A kernel density estimation of the fragment lengths at different depths layers within the three beaches of the Macaronesia. Dashed line represents the overall mode of size distribution of fragments with 3 to 4 mm.

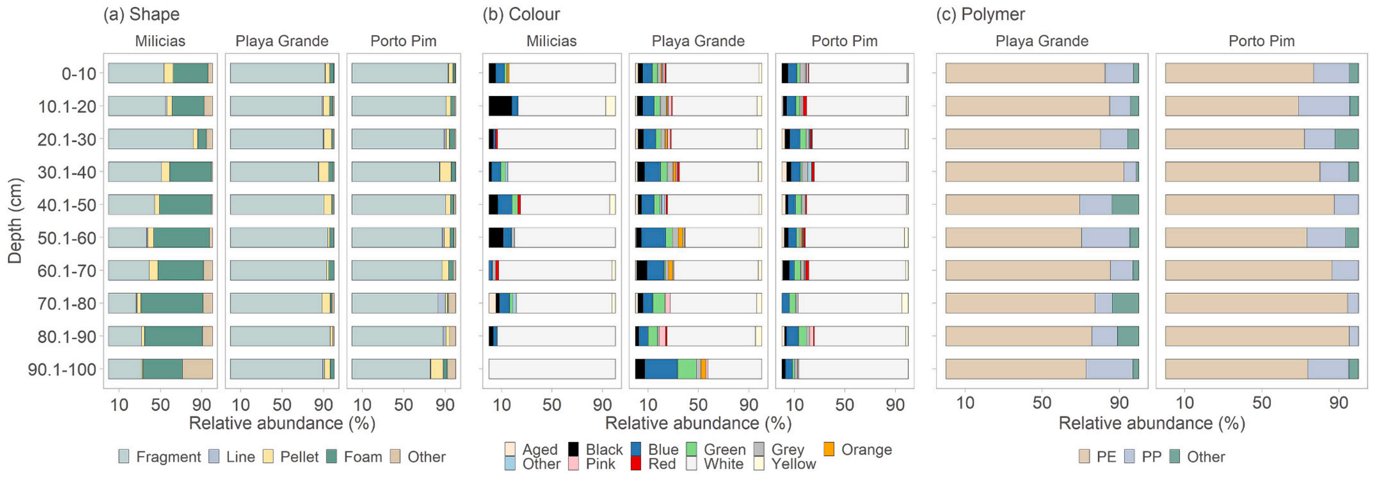

Fig. 7. (a) Shape, (b) colour and (c) polymer composition of plastic items recovered across depth layers of the three studied beaches of the Macaronesia.

Most of the other studies that have compared plastic concentration above and below the beach surface have found a greater concentration of plastic items buried in the sediment than exposed. For example, Turra et al. (2014) discovered plastic pellets in Brazilian beaches that were as deep as 2 m and surface layers accounted for <10 % of the total abundance in the sediment column. In Senegalese beaches, Tavares et al. (2020) discovered that the plastic concentration at a depth of only 10 cm was 25 times higher than that observed on the surface. Similarly, Lavers and Bond (2017) reported that the quantities of plastic at the subsurface (10 cm) of beaches of remote oceanic islands of the Pacific were 10 times greater than those found in the top layer. In contrast, Yu et al. (2016) obtained a different result in several Chinese beaches. These authors found that surface samples (up to 2 cm) had greater microplastic quantities compared to samples retrieved from deeper layers (up to 20 cm). Kusui and Noda (2003) reported mixed results, as some Japanese beaches showed a greater number of plastics than buried, while others had similar quantities. In the present study, the concentration of subsurface plastics was overall 5 times greater than that of the top 10 cm layer, but certain sediment cores exhibited subsurface plastic abundance 40 times greater than at the surface. In only four cores out of the 76, plastic quantities were higher on the surface than below. Collectively, these findings indicate that burial processes vary across different beach environments, potentially influenced by factors such as beach slope, wave energy, tidal range, sediment supply, weather patterns and plastic exposure. However, caution is warranted when making comparisons between studies due to inherent differences in the methodology applied. For instance, some studies have quantified “buried” items in the sediment column as deep as 2 m (Turra et al., 2014), while others have only examined the 5 cm subsurface layer. Moreover, some investigations have focused exclusively on plastics larger than 2 mm (e.g., Tavares et al., 2020), while others have also considered small microplastics (e.g. Yu et al., 2016).

The presence of plastic fragments down to 1 m in the beach body indicates that plastics are being transferred down in the sediment profiles, especially higher up the shore. Beaches are dynamic, high-energy environments, where sediments are being disturbed or reworked by natural and anthropogenic processes, leading to burial of parts of the plastics. Therefore, the different layers of plastic in the body of the beach does not represent chronological microplastic deposition such as identified in low-disturbance settings (e.g. lakes; Dong et al., 2020) but rather caused by mixing. It is not clear what is the residence time of these buried plastics and the role of storms in remobilizing them back into the ocean. Since approximately 80 % of the positively buoyant plastics floating at the surface is estimated to end up being deposited on beaches (Onink et al., 2021), an understanding of their rate of sequestration and potential for remobilization is necessary for comprehending the fate of plastic in the marine environment.

The concentration of plastics in subsurface layers is likely to be more stable than that at the surface due to a reduced degree of influence from wind, wave action, and tides. In contrast, superficial debris layers are more dynamic in nature. Indeed, our previous assessment of plastic densities on some of these beaches revealed high temporal variability largely guided by meteorological factors prior to sampling. For example, plastic concentration in Porto Pim was found to exceed 10,000 items m^{-2} following days of southern winds, rapidly dropping to background concentrations on the following days (Pham et al., 2020). While the present study, was effectuated on a single occasion, it is fair to assume that temporal monitoring of buried debris serves as a more stable indicator of plastic contamination levels. Furthermore, lighter items such as small threads and pieces of plastic bags that could be easily blown off the surface by winds are remained trapped when buried in the sand (Williams and Tudor, 2001), thus providing a better picture of the suite of items contaminating beaches. Kusui and Noda (2003) noted that smaller foam around 2–3 mm in size were more abundant in the subsurface layers compared to the surface. Tavares et al. (2020) also found that small plastic items were low at the beach surface but abundant below it. Studies investigating microplastics in lake sediments also reported that smaller microplastic shapes were representing a larger proportion of the total microplastics buried deeper in the sediment (Turner et al., 2019; Dong et al., 2020). Such changes in the characteristics of the plastics throughout the vertical profile of the sediment were not detected during our sampling. Shape, colour, polymer and size composition of the plastics were similar across the depth levels, reflecting the predominance of white polyethylene fragments of 3–4 mm floating in this region. These plastics were similar between the two most polluted (and most distant) beaches: Playa Grande and Porto Pim. This was not surprising considering the Azores and Canaries are both under the influence of the clockwise-circulating system of ocean currents (North Atlantic subtropical gyre) where such plastic fragments are known to be dominating (Moret-Ferguson et al., 2010; Prunier et al., 2019; Courtene-Jones et al., 2022). The North Atlantic subtropical gyre has been identified as the most conspicuous feature influencing particle distribution in Macaronesian archipelagos (Cardoso and Caldeira, 2021). Floating plastics trapped in this system are being transported to the Azores through the Gulf Stream and associated branches, being intercepted mostly by southwest orientated beaches, such as Porto Pim. On the other hand, plastic items are reaching the Canaries from the north, through the wind-driven Canary Current, resulting in the highest concentrations of microplastics reported for the beaches located on the northern side of the islands, including Playa Grande (Baztan et al., 2014; Herrera et al., 2018; González-Hernández et al., 2020; Hernández-Sánchez et al., 2021).

This paper provides a comprehensive insight into the extent of plastics contamination within the body of beaches located on isolated oceanic islands of the North Atlantic. Despite observing a general decrease in plastic concentration with sediment depth, the total abundance of buried items was found to be far greater than surface loads. Furthermore, the steady increase in plastic abundance from the water line towards the upper levels, suggest that the backshores act as an accumulation zone. Within such environments, the suggested sequestration of substantial quantities of plastic within beach sediments have relevant implications for our current understanding of the role beaches play as crucial concentration areas of plastics in the open ocean.

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CRediT authorship contribution statement

Christopher K. Pham: Conceptualization, Formal analysis, Methodology, Investigation, Resources, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition. **Sofia G. Estevez:** Formal analysis, Investigation, Data curation. **João M. Pereira:** Methodology, Investigation, Writing – review & editing. **Laura Herrera:** Methodology, Investigation. **Yasmina Rodríguez:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing. **Cristopher Domínguez-Hernández:** Methodology, Investigation, Writing – review & editing. **Cristina Villanova-Solano:** Methodology, Investigation, Writing – review & editing. **Cintia Hernández-Sánchez:** Methodology, Investigation, Writing – review & editing. **Francisco J. Díaz-Peña:** Methodology, Investigation, Writing – review & editing. **Javier Hernández-Borges:** Conceptualization, Methodology, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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