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Plastic pollution on eight beaches of Tenerife (Canary Islands, Spain): An annual study

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ABSTRACT

Stranded marine debris from eight beaches of Tenerife (Canary Islands, Spain) was analyzed.

Sampling was conducted along the high tide line every 35 m over the whole lengths in periods of 5 weeks for one year. Evaluated particles included all materials bigger than 2 mm, which were subdivided in Mesoparticles (2–10 mm) and Macroparticles ($>$ 10 mm). There was a great variability of plastic abundance regarding the locations and the sampling dates. In contrast, the occurrence of debris along the beaches showed consistency and even zones of high and low accumulation. The most polluted beach was Poris, which is indeed infrequently visited, but highly affected by the main current.

Plastic particles were principally mesoparticles and white/transparent color. This study not only confirms, that the Canary Islands are highly affected by the marine plastic pollution, but also for the first time shows, that stranded plastic accumulates in restricted areas of sandy coastlines.

1. Introduction

Since the beginning of the use of plastic, the possibilities of its application grew constantly. Today these organic polymers are present all over and it became almost impossible to live a plastic-free life. The possibility of this wide range of use and cost-effective fabrication led to a worldwide production of 335 million tons of plastic in 2016, with an upwelling trend (PlasticsEurope, 2018). But what if the plastics after its use cannot be recycled properly and end up as waste in the environment?

Until 2015 humankind produced already 6300 million metric tons of plastic waste, of which approximately only 9% were recycled (Geyer et al., 2017). Around 60% of all ever produced plastics are accumulating in landfills or in the natural environment (Geyer et al., 2017). According to Barnes et al. (2009) the major release of plastics to the environment is the result of improper human behavior, e.g. littering. The litter can originate from domestic, agricultural and industrial activities (Koutsodendris et al., 2008). Randomly disposed waste in landscape can be easily wind-blown and thus reach any water body (Barnes et al., 2009). On the other hand, synthetic fibers of clothing discharged from washing machines as well as microbeads from personal care products can enter the aquatic environment via sewage treatment plants (Browne et al., 2011; Rochman et al., 2015a).

The most frequently definition of microplastics are particles $>$ 5 mm as it was recommended by NOAA in 2008. Nevertheless a common definition for the size of plastic debris is still missing, but control of plastic emission will depend on an international agreed definition (GESAMP, 2015; Hartmann et al., 2019). Here we used the size classification for plastic debris based on the SI nomenclature as suggested by Hartmann et al. (2019).

Already since the early 70s it is known that plastic pollutes the oceans and is ingested by marine biota (Carpenter and Smith, 1972; Colton et al., 1974). At first mainly seen as an aesthetic problem and basically insignificant for research (Derraik, 2002), this subject gained relevance in recent years. Plastic is now considered the most common type of marine debris and represents a growing environmental problem (Barnes et al., 2009; Cole et al., 2011; Derraik, 2002; Moore, 2008; Thiel et al., 2013; Thompson et al., 2009) and aquatic pollution is reported from all over the world. Low density particles form garbage patches on the oceans' surface in the world's gyres (Eriksen et al., 2014, 2013; Law et al., 2010; Lebreton et al., 2018; Moore et al., 2001).Plastics with a higher density or because of fouling processes are reaching the deep sea (Van Cauwenberghe et al., 2013). Beaches of every continent have been reported to suffer plastic pollution of marine origin (Iñiguez et al., 2016; Li et al., 2016), even in the polar regions (Bergmann and Klages, 2012; Munari et al., 2017) or on remote islands

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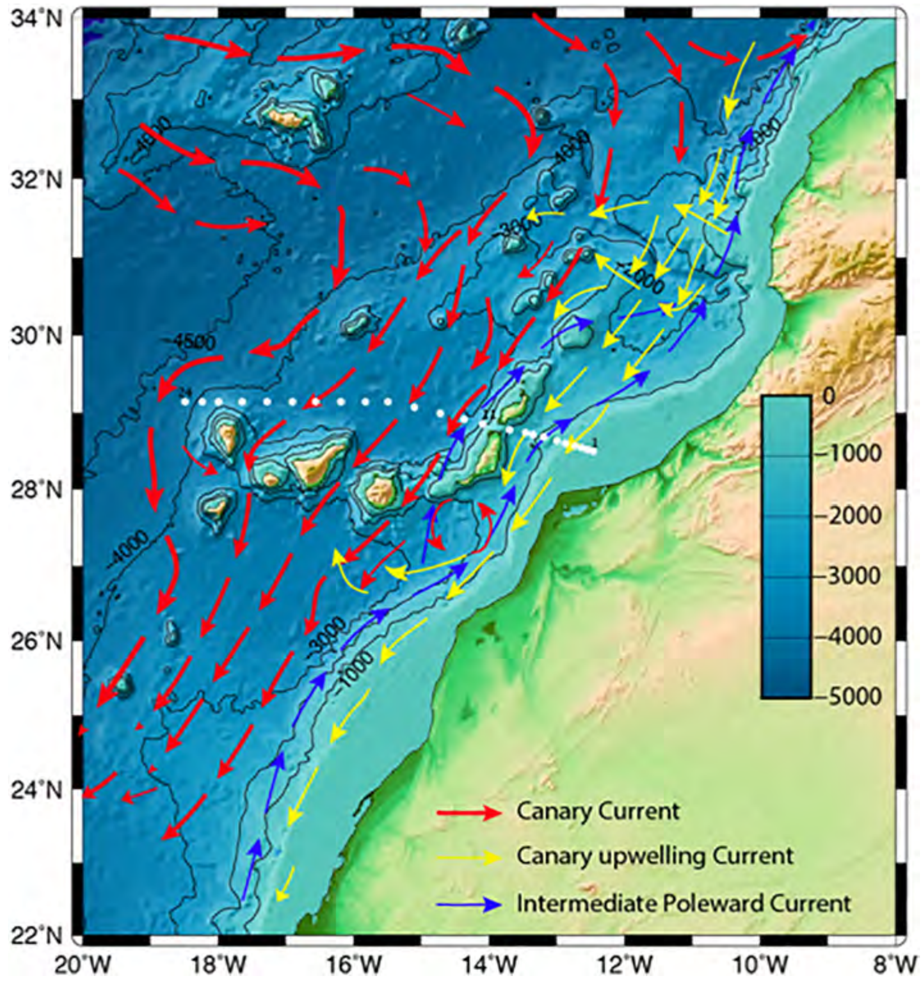

Fig. 1. Circulation scheme for the Canary Islands. Red arrows show the southward Canary Current coming from the North Atlantic Gyre. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: ICES Report on Ocean Climate 2018.

(Barnes, 2005; Monteiro et al., 2018). This shows that plastic has the potential to drift far away from the original entry point.

The North Atlantic Gyre shows a high concentration of plastic waste (Eriksen et al., 2010; Law et al., 2010) and its main current passing over the Azores and Portugal stream into the Canary stream brings plastic waste to the Canarian Archipelago (Fig. 1). This not only leads to pollution of the islands, but eventually biota, which is hitch-hiking on the plastic particles, can pose a threat as invasive species (Gregory, 2009). Another entry source is the trade winds, which can bring waste from the nearby African continent to the Canary Islands.

The Canary Islands, because of their volcanic origin, their location and the topography have a sensitive ecosystem, which among other things also includes some endemic species and can therefore easily been disturbed.

For the Canary Islands, plastic pollution has been reported along the beaches of Fuerteventura, Lanzarote and La Graciosa (Baztan et al., 2014; Edo et al., 2019; Herrera et al., 2018). For Tenerife, the largest and most visited island in the archipelago and, therefore potentially more susceptible to pollution, studies are very scarce (Álvarez-Hernández et al., 2019; Villanova Solano et al., 2018). Both studies suggested a very low occurrence of plastic particles, except for Playa Grande (Poris). Sampling was conducted only one time per beach, in February 2018 and in October, November and December 2018, respectively. While Álvarez-Hernández et al. (2019) sampled approximately every 10 m along the high tide line of every beach, Villanova Solano et al. (2018) sampled only in one spot of each beach.

This study was conducted in 2016/2017 and thus represents the first investigation about marine debris stranded on beaches of Tenerife. For the first time the evolution of plastic accumulation on eight strandlines of the island along one year was assessed. The main objective of the present study is the determination of beach pollution along the coastline of Tenerife. Therefore, the temporal variability of debris accumulation during one year was studied. Furthermore the study aimed to analyze the spatial variability, not only between sampling sites, but also alongside each beach. This information not only is necessary to establish future monitoring protocols, but also to expand the data network in Europe, which in turn is crucial to help advise policymakers in their decisions (Rochman et al., 2016). Hence it is possible to invoke positive changes to mitigate environmental accumulation of plastic (Rochman et al., 2016).

2. Materials and methods

2.1. Research area

A total of eight beaches of Tenerife were surveyed in intervals of five weeks between July 2016 and June 2017, two on the northern coastline and three on the southern and western coastline, respectively (Fig. 2). Strandlines hereafter were referred to as Almaciga, Arena, Cristianos, Gaviotas, Poris, Puertito, Socorro and Tejita. Beaches were chosen based on their accessibility, their orientation towards the main currents and their touristic pressure (Table 1).

Fig. 2. Map of Tenerife, indicating the sampling sites and total of samples taken from July 2016 to July 2017 on each location.

2.2. Sampling

Based on the methods of previous studies (Baztan et al., 2014; Galgani et al., 2013) quadrats were placed on the sand and particles within were surveyed.

Samples were consequently taken at the last high tide and quadrants were crossed by that line, to collect only the most recent deposited debris. Special care was taken, that between the accumulation of debris and the time of sampling no beach cleaning occurred.

The shorelines of every beach were sampled every 35 m by scraping the top layer of the sand from a 40 × 40 cm quadrat. This supernatant was put into a stainless steel sieve with a mesh size of 2 mm and then rinsed with clean seawater to absence the sand from the debris. Remaining particles were removed using tweezers and stored in aluminum foil for transportation to the laboratory.

Obtained samples were then oven-dried overnight at 70°, before they were classified in seven categories: Plastic, organic, mineral, metallic, paper, cigarettes and others. Plastic particles were separated into colors and further subdivided into meso- (2 mm–10 mm) and macro-particles (> 10 mm). The particles of each category were counted and weighed.

2.3. Statistical analysis

Statistical analyses and graphics were performed with R statistical software (R Core Team, 2017) and its extension, Rstudio. Data normality of plastic concentration was analyzed by the Shapiro Wilk test and the homoscedasticity was assessed graphically. Statistical differences between sampling sites and periods were tested using Kruskal-Wallis test and Conover posthoc test. The results were represented in boxplots.

3. Results

3.1. Total abundance

Overall, a total of 850 samples were obtained from eight locations throughout the months of July 2016 to July 2017. Depending on the length of every beach, most samples were taken on the strandlines of Tejita (280) and Cristianos (251), followed by Almaciga (63), Socorro (55), Gaviotas (46), Poris (44), Arena (40), and Puertito (30) (Fig. 2).

The total accumulation of plastic particles along the high tide line showed significant differences between locations (Kruskal-Wallis-Test, p-value $< 2.2e-16$) (Fig. 3). The amount of plastic particles was significantly higher in Poris than in all other beaches, except in Puertito. Puertito and Almaciga showed statistical difference to all other locations, but not among each other. The significantly lowest abundance of plastic debris was seen in Tejita.

Poris presented by far the highest plastic accumulation on the strandline regarding the mean and maximum values (Table 2). Puertito and Almaciga showed similar high average concentrations, but with Puertito reaching nearly the double amount in its highest concentration

Table 1
Summary of conditions at each sampling site.
Sources: ^{1a} Council of Santa Cruz de Tenerife; ^{1b} Council of Santiago del Teide; ^{1c} Council of Arona; ^{1d} Council of Arico; ^{1e} Council of Los Realejos; ^{1f} Council of Granadilla de Abona; ^{2} mobile app "GPS Test"; ^{3} Google Earth.

Location	Official beach name	Coordinates^{2}	Length^{3}	Orientation^{3}	Esposure^{3}	Sediment type	Hinterland	Seasonal changes	Touristic pressure	Cleaning
Almaciga	Playa de Almaciga^{1a}	28°34′19.81″N 16°11′32.43″W	220	NNW	Open to NW	Sand stone	Natural hinterland with vegetation, on the bottom of a ravine, light traffic road alongside	Less sand in winter	Low	Manual cleaning (beach)/ emptying garbage (containers) twice a week^{1a}
Arena	Playa de La Arena^{1b}	28°13′46.94″N 16°50′27.28″W	150	W	Open to W, protected to N and S	Fine sand	In the center of an touristic nucleus (La Arena)	Steady	Medium (winter), very high (summer)	Manual cleaning (beach) daily by life guards^{1b}
Cristianos	Playa Las Vistas^{1c}	28°3′7.05″N 16°43′23.86″W	850	SSW	Open to SW, protected to W and S	Fine sand	In the center of an touristic nucleus (Los Cristianos)	Steady	Medium (winter), very high (summer)	Mecanic cleaning (sand)/ emptying garbage (containers) daily^{1c}
Gaviotas	Playa de Las Gaviotas^{1a}	28°30′48.16″N 16°10′33.16″W	220	SE	Open to SE	Sand stone	Natural hinterland, on the bottom of a cliff small urbanization nearby	Less sand in winter	Low (winter), high (summer)	Manual cleaning (beach)/ emptying garbage (containers) twice a week^{1a}
Poris	Playa Grande^{1d}	28°9′8.80″N 16°25′53.78″W	150	N	Open to N, protected to NE	Fine sand	Natural hinterland, small urbanization nearby	Steady	Low (winter), medium (summer)	Manual cleaning (beach)/ emptying garbage (containers) daily^{1d}
Puertito	Playa del Puertito^{1c}	28°6′48.88″N 16°46′5.38″W	70	SW	Open to SW, protected to W and S	Fine sand stone	Natural hinterland, small urbanization nearby	Steady	Low (winter), high (summer)	Twice a month^{1c}
Socorro	Playa El Socorro^{1e}	28°23′38.58″N 16°36′10.82″W	260	NNW	Open to NW, protected to NE	Sand stone	Natural hinterland, dead end road alongside	Less sand in winter	Low (winter), high (summer)	Manual cleaning (beach) daily by life guards^{1e}
Tejita	Playa La Tejita^{1f}	28°1′54.23″N 16°33′22.32″W	1100	S	Open to S, protected to NE	Fine sand	Natural hinterland, mountain (eastern end) small urbanization nearby (western end)	Steady	Low (winter), medium (summer)	No cleaning (beach)/emptying garbage bins (sunbed zones) daily^{1f}

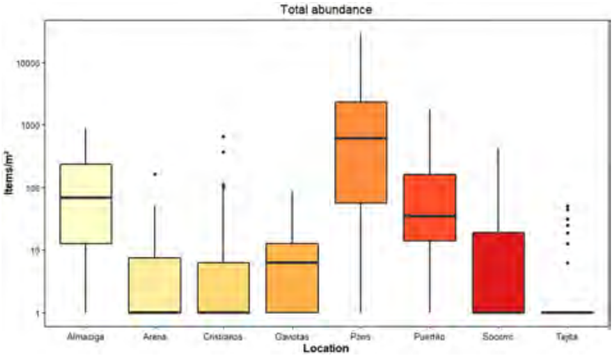

Fig. 3. Total plastic abundance in Items/m^2 by location collected from July 2016 to July 2017. The central thick line of each box designates the median, the box height shows the interquartile range; the whiskers indicate the lowest and the highest values and the circles point the values of outliers. Only for the graphical presentation in logarithmic scale values of 0 were replaced with values of 1.

compared to Almaciga. Less plastic debris was observed in the beaches of Gaviotas, Socorro, Cristianos and Arena. While Tejita indicated the lowest values in general, all beaches obtained at least one sample with no plastic particles during the year of sampling.

3.2. *Temporal variability*

There was no obvious pattern in seasonal changings for the total of all beaches. Moreover, peaks of plastic accumulation varied on every location during the sampling period.

Almaciga presented the peak mean value at 498.75 Items/m^2 (corresponding: 35.43 g/m^2) (December 2016) and the lowest mean value at 20.83 Items/m^2 (0.55 g/m^2) (April 2017) (Fig. 4a).

The maximum average accumulation in Arena was 53.13 Items/m^2 (1.07 g/m^2) in May 2017. Regarding the weight, highest values were obtained in April 2017 with 1.31 g/m^2 (20.31 Items/m^2). No plastic was found in September 2016 and June 2017. There was no significant difference between the sampling dates (Fig. 4b).

As for the beach of Cristianos, the highest mean value was 41.75 Items/m^2 (0.64 g/m^2) (May 2017), while the lowest mean value was 1.2 Items/m^2 (0.006 g/m^2) (March 2017). Plastic abundance in May 2017 and June 2017 was statistically different to the rest of the months, but not among each other (Fig. 4c).

Gaviotas showed the mean peaks at 40.63 Items/m^2 (0.43 g/m^2) in January 2017 and at 1.11 g/m^2 (15 Items/m^2) in November 2016. Only 1.25 Items/m^2 (0.003 g/m^2) in average were found in March 2017 (Fig. 4d).

The most polluted location was represented by Poris, with a maximum average of 15,135.94 Items/m^2 (411.96 g/m^2) in July 2017 and a minimum average of 18.75 Items/m^2 (0.1 g/m^2) in January 2017. In July 2016 the accumulation of plastic was statistically higher than in all other months, except for the sampling in November 2016 and March 2017. On the other hand, in January 2017 plastic abundance was significantly lower compared with the other sampling dates, except for the months February 2017 and May 2017 (Fig. 4e).

The second highest mean accumulation showed Puertito with 731.25 Items/m^2 (8.44 g/m^2) (June 2017). Even though the lowest mean value was 12.5 Items/m^2 (0.03 g/m^2) (April 2017), no statistical difference between months was observed (Fig. 4f).

As for Socorro, a high amount of plastic with an average of 155 Items/m^2 (9.63 g/m^2) was found in November 2016, while in October 2016, February 2017 and March 2017 no plastic at all was observed (Fig. 4g). This absence of plastic in these months was partially caused by seasonal changes and variations in the high tide line, which resulted in sampling spots with less sand, but rather stones or even massive rocks.

Tejita presented overall the lowest plastic abundance, with even 4 sampling dates without any plastic registered throughout the strandline. The maximum mean accumulation was 10.82 Items/m^2 (2.4 g/m^2) (August 2016) and this value was statistically highest (Fig. 4h).

3.3. *Spatial variability*

Plastic accumulation along the high tide line of each location was different, but the average amounts of the sampling positions throughout the year showed clear patterns for every beach.

The distribution of plastic across the strandline of Almaciga was mostly equal, with mean values from 160 Items/m^2 (9.84 g/m^2) (position 3) to 181.75 Items/m^2 (6.25 g/m^2) (position 6) (Fig. 5a). Only on the edges the average was lower: 110.94 Items/m^2 (4.11 g/m^2) at position 1 and 118.75 Items/m^2 (4.01 g/m^2) at position 7.

At the beach of Arena the mean accumulation of 30 Items/m^2 (0.61 g/m^2) at position 1 emerged, as the remaining positions showed all < 7 Items/m^2 (0.33 g/m^2) in average (Fig. 5b).

In general, Cristianos presented a low abundance of plastic at the representative points, except for the mean values of position 12 (120 Items/m^2, 1.42 g/m^2) (Fig. 5c). Besides, particles assembled more in the south-eastern part, whereas in the north-western part of the beach occurrence was less frequent.

Gaviotas showed average values from 16.25 Items/m^2 (0.27 g/m^2) (position 1) as a maximum to 5 Items/m^2 (0.13 g/m^2) (position 3) as a minimum (Fig. 5d). Plastic particles appeared rather on the extremes of the strandline than in the center.

The highest variation between the particular sampling positions was observed in Poris with the highest mean accumulation at 4591.88 Items/m^2 (100.31 g/m^2) (position 4) and a lowest at 85.94 Items/m^2 (1.45 g/m^2) (position 1) (Fig. 5e).

In the beaches of Poris and Puertito plastic particles assembled more in the center (Fig. 5f).

The mean amount of plastic debris at Socorro altered between the sampling points and reached the highest at position 5 with 43.13 Items/m^2 (1.49 g/m^2) (Fig. 5g).

Table 2

Mean values, standard deviation, median values and extreme values of the total plastic abundance at all sampling sites collected from July 2016 to July 2017. The results are presented as plastic particles per square meter (Items/m^2) and plastic weight per square meter (g/m^2).

Location	Values [Items/m^2]				Values [g/m^2]			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Gaviotas	11.68	17.41	0.00	87.50	0.31	0.68	0.00	3.81
Almaciga	154.66	192.70	0.00	893.75	7.06	13.54	0.00	77.44
Poris	2509.66	5078.28	0.00	28,218.75	66.87	130.29	0.00	578.08
Socorro	22.73	63.43	0.00	425.00	2.07	4.82	0.00	24.25
Tejita	1.50	5.69	0.00	50.00	0.27	2.51	0.00	38.94
Puertito	162.71	342.01	0.00	1781.25	2.71	4.50	0.00	18.02
Cristianos	12.38	49.93	0.00	650.00	0.19	0.84	0.00	9.19
Arena	10.47	27.71	0.00	162.50	0.27	0.79	0.00	3.64

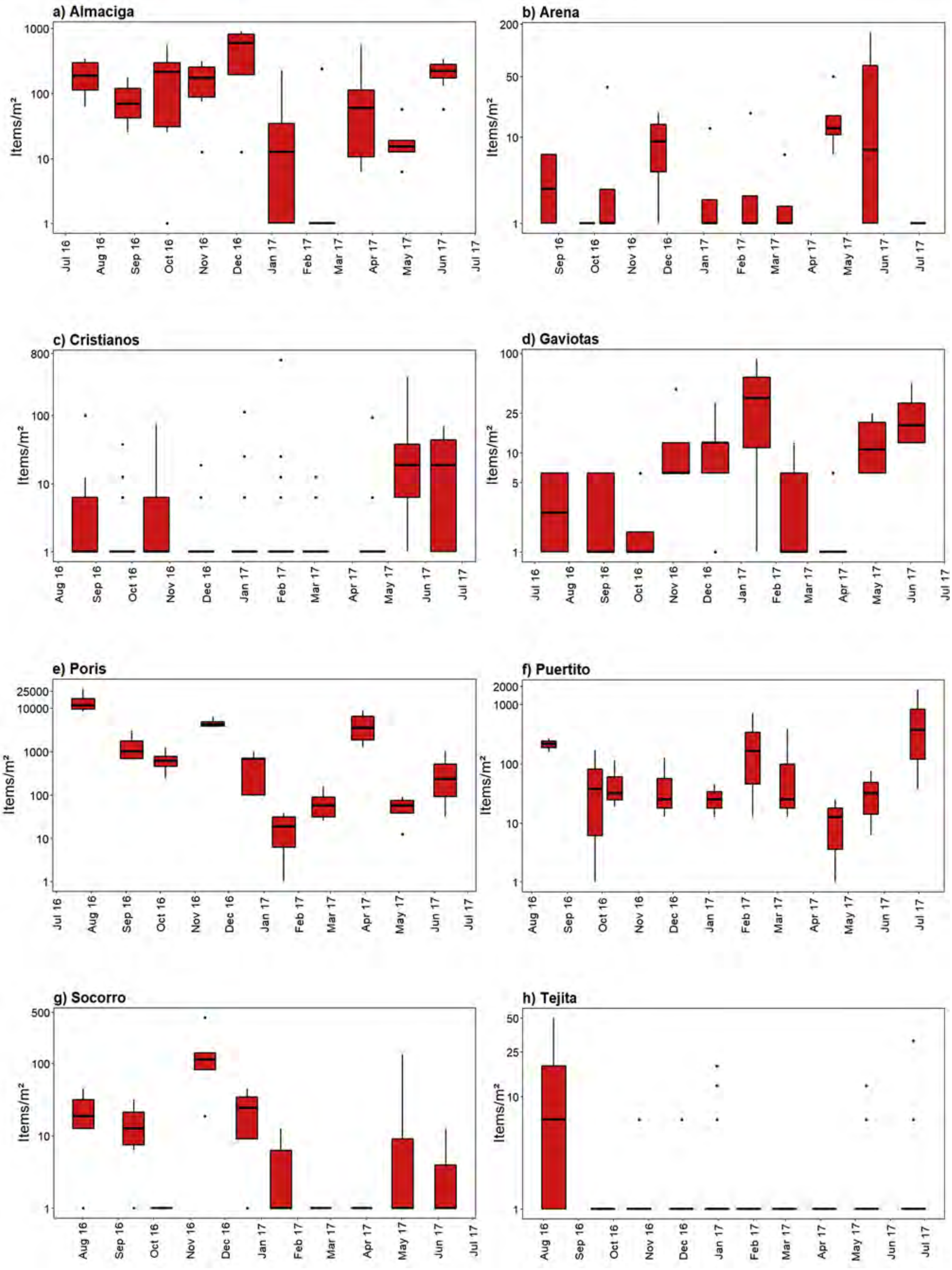

Fig. 4. Plastic abundance in Items/m^2 by sampling dates in a) Almaciga, b) Arena, c) Cristianos, d) Gaviotas, e) Poris, f) Puertito, g) Socorro and h) Tejita. The central thick line of each box designates the median, the box height shows the interquartile range; the whiskers indicate the lowest and the highest values and the circles point the values of outliers. Only for the graphical presentation in logarithmic scale values of 0 were replaced with values of 1.

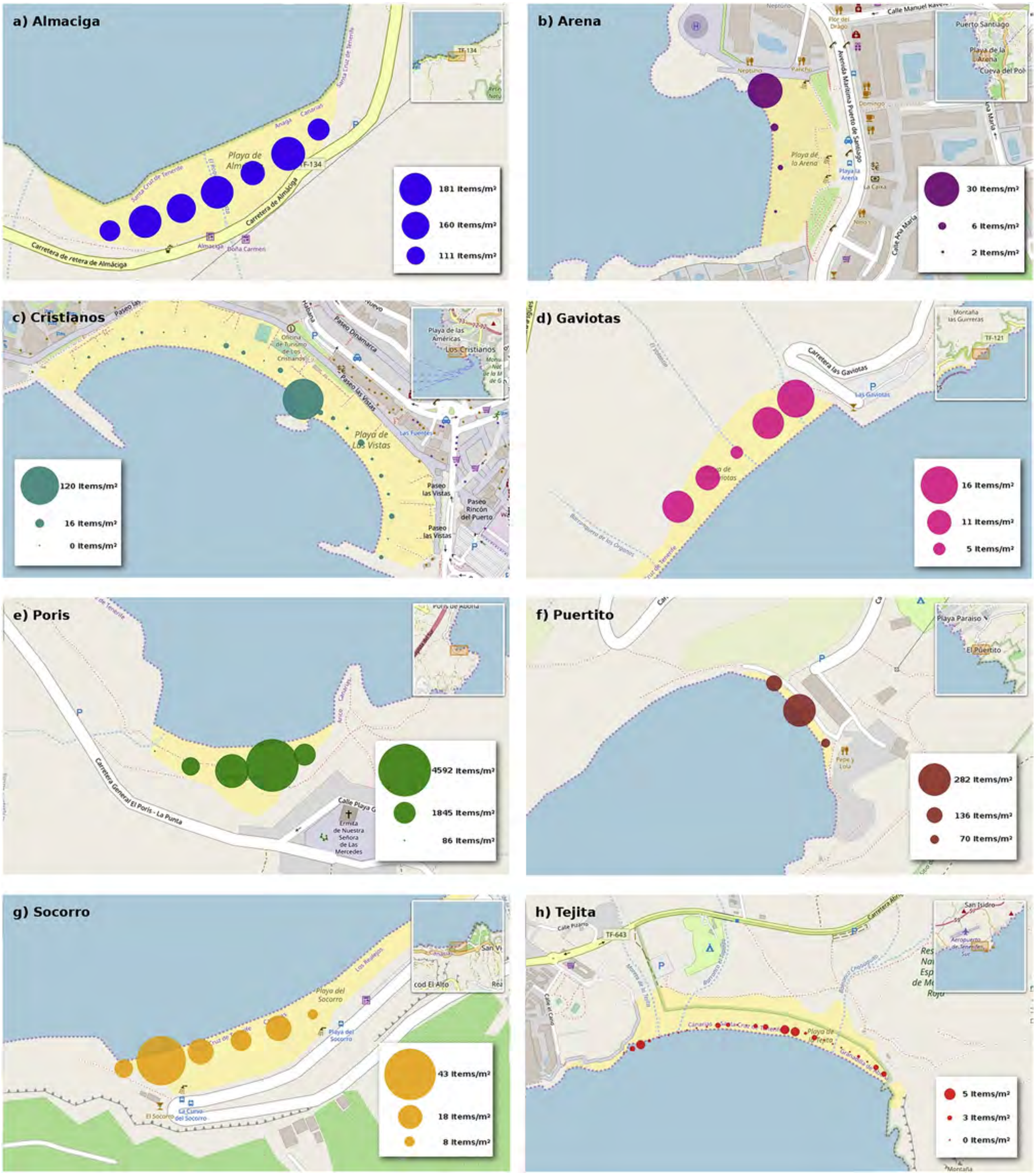

Fig. 5. Spatial variability of plastic abundance at a) Almaciga, b) Arena, c) Cristianos, d) Gaviotas, e) Poris, f) Puertito, g) Socorro and h) Tejita: Circles indicate mean abundance in Items/m^2 at each sampling point.

Particle accumulation at Tejita was very low and occurred only randomly (Fig. 5h). The highest mean value was 5 Items/m^2 (0.23 g/m^2) in the center of the strandline, but almost 25% of the representative points lacked plastic debris throughout the whole sampling period.

3.4. Types of debris and plastic colors and sizes

Overall, the most common particles throughout the sampling year were plastic debris (63%) of any color and organic materials (35%), which were mostly represented by algae, wooden pieces, seeds, leafs or other parts of plants (Fig. 6). < 0.5% was other anthropogenic debris, such as paper, cigarettes or metals. Around 2% of the debris remained undefined mostly because of the fragile material properties in dry condition. These particles were often assumed to be tar or wax, but correctness was not verified.

The 3 most abundant debris types were found on every location, whereat organics dominated on the majority of the beaches. The percentage of plastics was leading in Poris (80.48%) and Almaciga

Fig. 6. Composition of marine debris in total and at location a) Almaciga, b) Arena, c) Cristianos, d) Gaviotas, e) Poris, f) Puertito, g) Socorro and h) Tejita.

(49.71%), but in Cristianos (37.97%) and Puertito (34.03%) it was still represented with more than one-third of all debris. Less portion occurred in Socorro (15.14%), Arena (8.24%), Tejita (6.86%) and Gaviotas (5.90%). Other anthropogenic debris accounted < 2% at all locations.

The main color of the found plastic was white or transparent (64%), followed by yellow or orange particles (11%). These include pieces, that originally were white/transparent, but became yellowish or orange due to aging processes in the environment as well as yellow-dyed material (Fig. 7). The remaining categories counted with < 10% each and contained particles, which were actually dyed in the corresponding color. Although percentage of painted plastics varied among beaches, white/transparent was the dominating color at every location.

In general, mesoparticles (91%) were more abundant than macroparticles (9%), mostly represented by fragments or pellets (Fig. 8). Even though the ratio between particle size varied from beach to beach, the total amount of mesoparticles during the sampling year at each location never exceeded 24% of all plastic particles.

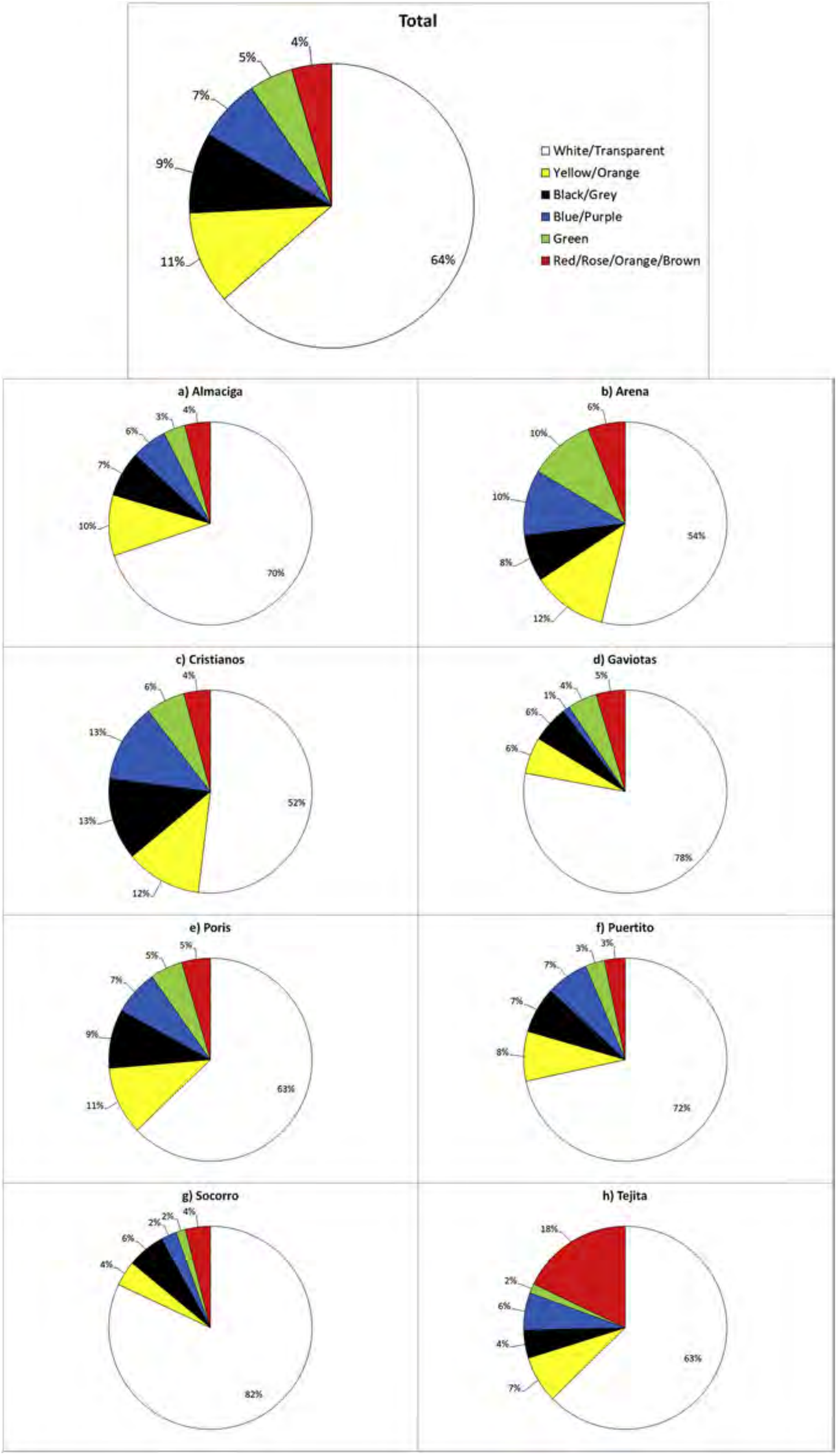

Fig. 7. Percentage of colors of plastic particles in total and at location a) Almaciga, b) Arena, c) Cristianos, d) Gaviotas, e) Poris, f) Puertito, g) Socorro and h) Tejita.

4. Discussion

The plastic pollution values found were very wide ranged, not only between locations but also between the sampling dates on every beach. Values of plastic weight mainly supported values of the amount of particles found on every location. Nevertheless they showed more variability as it can be seen in the temporal variability of Arena and Gaviotas, as well as on position 3 and 6 of Almaciga (spatial variability). This might be due to the different types of existing plastic and their densities. No evidence was found, that plastic accumulates more in areas of touristic pressure or near urban nucleus as it was assumed earlier (Ivar do Sul and Costa, 2007; Ryan et al., 2009; Thompson et al., 2009). Rather the beaches of Arena and Cristianos, which are located in tourist centers are very little affected by plastic pollution. On the other hand beaches of Poris, Puertito and Almaciga, which are very low populated and less visited showed a high accumulation of debris. This supports the suspicion that most of the stranded plastics originate from the open sea, rather than from local or population-related sources

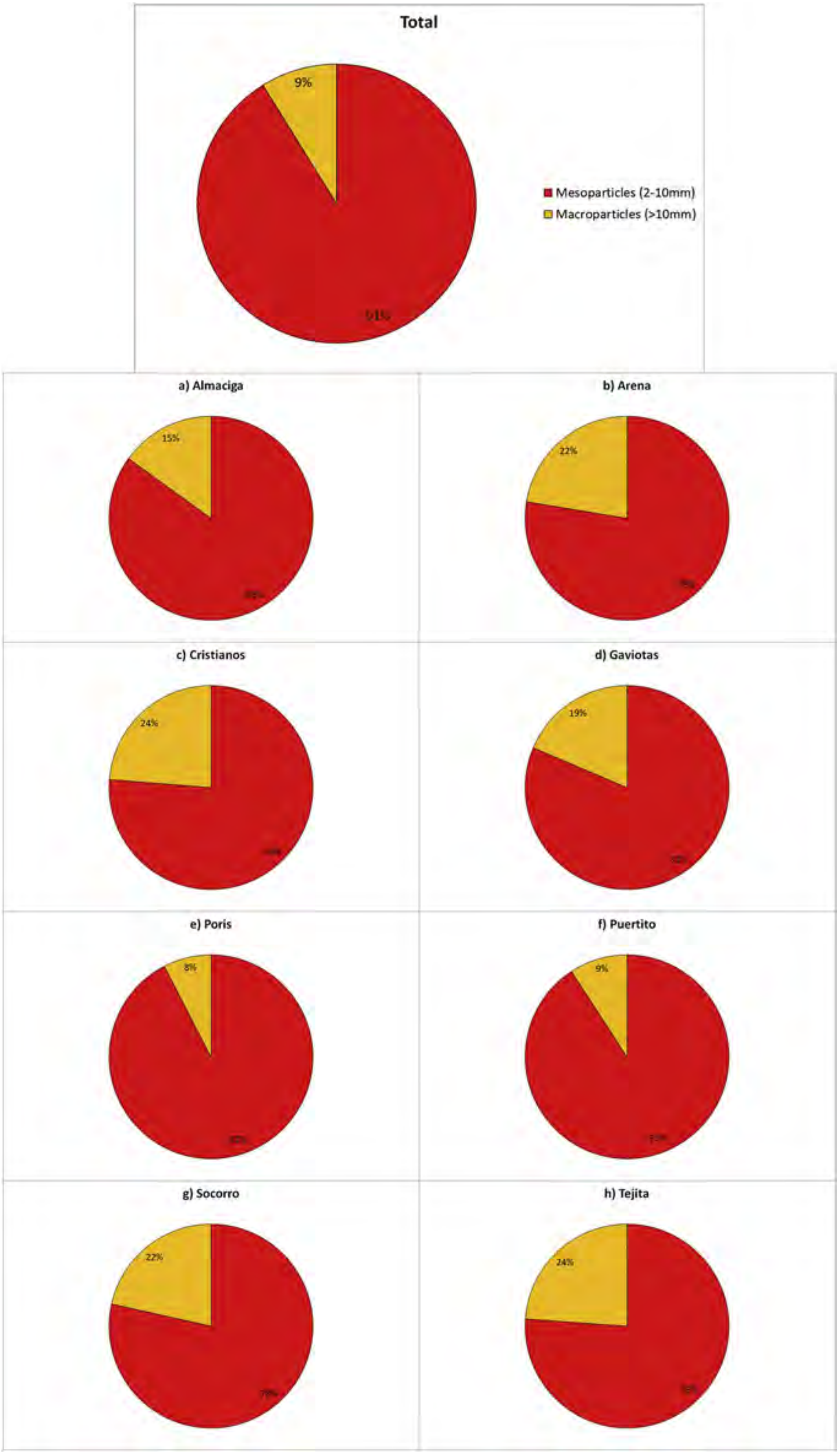

Fig. 8. Percentage of meso- and macroparticles in total and at location a) Almaciga, b) Arena, c) Cristianos, d) Gaviotas, e) Poris, f) Puertito, g) Socorro and h) Tejita.

(Baztan et al., 2014; Corcoran et al., 2009; Ivar do Sul et al., 2009). Moreover wave and wind driven origins seem to be the main priority for plastic accumulation on strandlines (Herrera et al., 2018; Ivar do Sul et al., 2009). The high pollution of Poris and Almaciga confirms this theory. Both beaches are widely open to the main currents, whereat other beaches situated on the northern and southern coastline are less exposed. The strandlines on the western side of Tenerife are all located in bays and therefore they are protected towards the main current. Nevertheless Puertito showed a high amount of debris, which might be due to two possible reasons: First, the bay represents a deeper inlet than Arona and Cristianos, which in turn can result in higher accumulation due to local currents and winds in the bay. Second, the beach receives far less attention in beach cleaning than the other two mentioned beaches. However, to determine the relation between plastic abundance on coastlines and current or wind directions more studies are needed. Also, the data showed no patterns for seasonal changes of plastic accumulation during the year, but the results of recent studies presented similar amount of plastic regarding the sampling months. The beaches of Gaviotas and Tejita demonstrated low plastic abundance in February 2018, as well as Socorro in October 2018 (Álvarez-Hernández et al., 2019; Villanova Solano et al., 2018). In contrast, on the strandline of Poris a high amount of plastic was found in October 2018 (Álvarez-Hernández et al., 2019). This coincidence might be due to the fact that in general the first two beaches are little polluted and the beach of Poris is highly polluted. As for Socorro, this study also shows low plastic abundance on days with less sand on the beach due to seasonal changes. Another explanation might be that the plastic accumulation on beaches is variable during one year, but show consistency throughout the months of every year. Further research is needed to investigate the long-term temporal variations of plastic accumulation on coastlines and its causes.

However, patterns had been seen for the distribution of plastic debris along the strandlines. The majority of the beaches accumulated particles in particular zones, which were mostly located in the center. Only Arena and Socorro accumulated at the edges. Tejita showed accumulation in the center and at one edge, which might be due the low pollution in general. For future investigations, it is therefore suggested to run preliminary sampling tests on the beaches of interest to determine zones and periods of minimum and maximum accumulation during the year. This information is essential for further diagnostics and monitoring. Besides, it can help local communities to improve their beach cleaning, as more attention can be paid to areas and periods of high accumulation.

Plastic seemed to be in general the most abundant debris on the coastline of Tenerife, but this proportioning results mostly from the high amount of particles found on Poris, Puertito and Almaciga. In case of Poris and Almaciga this high abundance can be explained by their exposed orientation towards dominant currents and winds. Furthermore, Poris is not only receiving debris from the open sea, but also from the south-eastern coastline of Tenerife, as the main current passes by closely. Therefore, the current can drag more anthropogenic debris from coastal urbanization, the capital and its harbor to this strandline. This might be an explanation for the high amount of plastic particles. Otherwise, Almaciga is exposed to the current coming from the open sea bringing all sort of debris, which results in a more balanced composition. Puertito, on the other hand, is located on the south-western side of the island and is therefore little affected by the main current. Nevertheless it is situated in a small bay, which is rarely cleaned, but is frequently visited by tourist boats and where it is common to have barbecues or celebrations on the weekends along the seafront. Local currents can be dominant and hence local debris can circulate and accumulate in the bay.

Of all plastic particles white and transparent is the most common color at all locations. These colors are commonly used for packaging like food containers, wrappers, films, bags and different kind of bottles. Packaging material is not only one of the main plastic demands, but rather is the most important market sector for the plastic production (PlasticsEurope, 2018). Furthermore particles between 2 and 10 mm were most abundant in all beaches, consisting mainly out of fragments or pellets. Pellets can be considered as primary microplastics and enter in the environment through accidental spillage during transport, inappropriate use as packing materials or direct out-flow from processing plants (Cole et al., 2011). Fragments, on the other hand, represent secondary microplastics and originate from larger plastic particles, which with time become brittle and consequently break down into smaller pieces due to degradation (e.g. biodegradation, photodegradation, thermooxidative degradation) and abrasion through wave action (Andrady, 2011; Barnes et al., 2009; Cole et al., 2011).

The fact that plastic represents one of the most found particles on the strandline reflects the magnitude of this kind of pollution in the environment. Not only that production raises continuously (PlasticsEurope, 2018), but also improper human behavior and lack of recycling leads to an ongoing contamination with plastic, which threatens environment and wildlife (Barnes et al., 2009). Plastic can contain chemical additives (e.g. colors, UV-filters, plasticizers, etc.), added at the time of manufacture and also has the property to absorb organic pollutants in aquatic environment (Bakir et al., 2014; Camacho et al., 2019; Lee et al., 2014; Moore et al., 2005; Ogata et al., 2009; Rios et al., 2010). Fragments are usually the result of a slow degradation processes, meaning that these plastic particles have been in the environment for a long time already.

This leads to two problems. First, level of sorbed organic pollutants rises in each particle with the decrease of the its size due to the increase of its surface-to-volume ratio. Plastic particles can reach a sorption equilibrium in seawater in 24 h and can desorb chemicals again in animal guts (Bakir et al., 2014; Tanaka et al., 2015; Teuten et al., 2007). Second, Invertebrates, fishes, sea birds, turtles up to marine mammals from all around the world are known to ingest plastic debris (Boerger et al., 2010; Bond et al., 2013; Bravo Rebolledo et al., 2013; Browne et al., 2008; Camedda et al., 2014; Campani et al., 2013; Choy and Drazen, 2013; Guebert-Bartholo et al., 2011; Herrera et al., 2019; Hoarau et al., 2014; Lusher et al., 2013; Mascarenhas et al., 2004; Possatto et al., 2011; Schuyler et al., 2013; Tanaka et al., 2013). In Tenerife, plastic was found in the gut contents from fledglings of Cory's shearwater (*Calonectris diomedea*) (Rodríguez et al., 2012). This shows that animals of the Canarian Islands are already affected and therefore endemic species of this sensitive ecosystem can be seriously endangered in the future. But not only wildlife is threatened by this marine debris, since plastic has been detected in various fish species and oysters sold for human consumption (Rochman et al., 2015b). However, as plastic is ingested by a wide range of animals, and pollutants can be sorbed to the tissue, these pollutants can enter into the food web (Browne et al., 2008; Rochman et al., 2013; Tanaka et al., 2013; Teuten et al., 2009), which ends in the human consumption and thus represents a serious threat for human health.

5. Conclusion

Tenerife presents plastic pollution on every studied beach. The plastic concentration was variable during the year and different for every sampling site. Furthermore, the amount of plastic showed high variability between strandlines in general, but especially on Poris, Puertito and Almaciga high levels of contamination were found. Along the year each beach presented a consistent spatial pattern of accumulation.

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.

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Author contributions

S.R. designed the experimental work, conducted the sampling, processed the samples in the laboratory, analyzed the data and wrote the manuscript. A.H. performed statistical analyzes and graphics with R. C.H. contributed to design the experimental work. All authors contributed to the acquisition of the data and edited the article.

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