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Microplastics integrating the coastal planktonic community in the inner zone of the Río de la Plata estuary (South America)☆

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ABSTRACT

This study explores in plankton samples the abundance, distribution, size, types (fibres and fragments), colours of the microplastics (MPs) and its relation with the characteristics of the plankton (size and morphology) of the Río de la Plata estuary. Water samples were collected in triplicate in freshwater-mixohaline tidal zone of the estuary, in ten sampling sites located along 150 km of coast, in two periods (September–November 2016 and April–June 2017). The results revealed the presence of MPs in all the samples analysed, with a dominance of fibres and sizes $>500 \leq 1000$ μm, and blue colour being more frequent. The MPs distribution was significantly different among sampling sites, being more abundant in the most urbanized sites, sewage discharges and near the maximum turbidity front. The mean density, in the two samplings analysed, were 164 and 114 MPs m^{-3}. The fibres amount was significantly different among sites. The MPs integrated a planktonic community dominated by pico-microphytoplankton, mainly conformed by filaments/chains and solitary forms and by micro-mesozooplankton. The comparative analysis of plankton and MPs demonstrated that a fraction of the latter showed a frequency range of size that coincides with the most common sizes of plankton (≤ 500 μm). The mean percentage of MPs items in relation to zooplankton was 0.36% (sampling 1) and 1.20% (sampling 2) and for phytoplankton was 0.0002% (sampling 1) and 0.0005% (sampling 2). The correlations between the MPs concentration and habitat quality (IHRPlata index) were statistically significant, on the contrary correlations between the MPs concentration and measured environmental variables were not found. The findings of this study emphasises the need for a better treatment of urban waste, which would contribute to reducing the entry of this pollutant into the ecosystem.

The presence of microplastics in plankton samples on the coast of the Río de la Plata estuary.

1. Introduction

Plastic debris is considered an emerging issue and a relevant environmental problem that has a negative impact on ecosystems (Eerkes-Medrano et al., 2015). Plastic is one of the most common pollutants accounting for 50–80% of debris that enter marine habitats (Barnes et al., 2009). Most of debris has land-based sources and many types of plastic debris (e.g. fishing nets, ropes, bottles and plastic bags) occur in the natural environment. Plastic debris enters aquatic ecosystems in varied sizes, in the metre to micrometre range. Within the latter are the microplastics (MPs) defined as pieces of plastic less than 5 mm (Gallagher et al., 2016) and are considered emergent pollutants. There are primary sources of MPs: particles manufactured as plastics of microscopic sizes, such as scrubbers (Gregory, 1996; Fendall and Sewell, 2009) and pellets that are raw material for the industry of plastic; and secondary sources: fragments or fibres derived from the breakdown of plastic products (Browne et al., 2011; Cole et al., 2011).

MPs have direct negative impacts on organisms in aquatic systems such as: smothering and ingestion. Also, plastics may release toxic leachates that affect the development and survival of organisms (Teuten et al., 2009). Moreover, plastic debris can adsorb organic pollutants and may cause indirect harm by acting as vectors for the entry of these substances to organisms, as well as potentially transporting invasive species long distances (Lin, 2016). Once MPs

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are introduced into aquatic ecosystems, they interact with the communities, including plankton. Because many MPs are buoyant they will be widely available to planktonic organisms because these particles can be confused as food (Land, 2015).

Records referring to MPs in aquatic ecosystems are reported mainly in marine environments, however, in freshwater environments is less frequent (Eerkes-Medrano et al., 2015; Li et al., 2016; Blettler et al., 2017), and even less frequent in estuaries (Thornton and Jackson, 1998; Browne et al., 2010; Costa et al., 2011; Pazos et al., 2017). Estuaries are one of the most diverse ecosystems worldwide. They provide different resources and ecosystems services such as drinking water, food and nurseries for commercial fish species, etc. (Costanza et al., 1997; Ronnback, 1999). Plastic debris enter estuaries either from the ocean through wind, waves and the tidal flow or by land runoff (LeRoux, 2005; Nordstorm et al., 2006) and then they will reach several habitats (Thornton and Jackson, 1998; Browne et al., 2010). Plastic pollution is increasing in estuaries because urban and industrial centres settle there, so high concentrations of plastics are associated with population size (Browne et al., 2011; Seto, 2011; Yonkos et al., 2014). On the other hand few studies have analysed the MPs contained in the plankton samples (Lima et al., 2014). Furthermore know their distribution pattern in relation with environmental gradients is relevant for a better comprehension of the consequences of this emergent pollutant in aquatic ecosystems. The spatial and temporal distribution of MPs indicates that dynamic patterns are shaped by climatic forces and coastal transport processes (Yoon et al., 2010; Ballent et al., 2013; Isobe et al., 2014; Critchell et al., 2015; Critchell and Lambrechts, 2016; Liubartseva et al., 2016; Vermeiren et al., 2016). Estuarine hydrodynamics have profound implications for MPs inputs into the marine environment, so it is necessary to asses it.

The Río de la Plata is a microtidal coastal plain estuary located on the eastern coast of South America and is the fifth largest in the world draining the second largest basin in South America (Baigún et al., 2016). This ecosystem is rich in nutrients and trophically based on phytoplankton (Nagy, 2006). Industrial and urban areas (Buenos Aires and La Plata cities) are located around it; 12.8 million people live in Buenos Aires city and its metropolitan area (INDEC, 2010). Luján and Riachuelo rivers, Sarandi and Santo Domingo channels together with the main sewage effluent of Buenos Aires city contribute with more than 80% of the total pollution load that receives the Argentinean coast (Southern Coastal Fringe) of the Río de la Plata estuary (FREPLATA, 2005).

The Río de la Plata estuary is used for several purposes like fishing, drinking water, recreational and navigational activities. The estuary also receives agricultural runoff, industrial discharges and sewage effluents. Studies performed in the freshwater tidal zone of the Argentinean coast, have documented the presence of MPs in fish of several species (Pazos et al., 2017). This evidence has led us to explore plankton samples for abundance, size, types (fibres and fragments) and colours of the MPs, their distribution and its relation with the characteristics of the plankton (size and morphology); to thereby provide information about the potential risk of this pollutant in the basal level of the food chain of this ecosystem.

2. Material and methods

2.1. Study area

The study area is located in the coast of the freshwater-mixohaline tidal zone. The estuary is characterised by a low seasonality in the river discharge; a moderate residence time (0.8 and 1.8 months) (Nagy et al., 2002) and exhibits a broad and permanent connection to the sea (Mianzan et al., 2001; Simionato et al., 2004). The inner region has a pluvial regime and is under strong tidal influence meanwhile, the outer region is mainly mixohaline. The isohaline of 0.5 (PSU) constitutes the boundary between the freshwater and mixohaline zones (Mianzan et al., 2001). The dynamics of the Río de la Plata estuary is controlled by tides and wind-driven waves and the continental runoff but are modified by topography and Coriolis force. The equilibrium between these forces is highly variable, depending on the intensity of wind stress and the freshwater discharge (Guerrero et al., 1997).

This study was carried out on the Argentinean coastline of the Río de la Plata estuary (Southern Coastal Fringe) between San Isidro and the town of Punta Indio (Fig. 1). Ten sampling sites were placed along 150 km of shoreline, influenced by different land uses (Gómez and Cochero, 2013).

The northernmost sites (San Isidro (SI) and Quilmes (QUI)) are exposed to the impact of the city of Buenos Aires, where port, navigational and recreational activities occur and where industrial and sewage effluent discharge. The Berazategui (BE) site is located close to the sewage effluent of Buenos Aires city and the Punta Colorada (PC) site is located downstream. Punta Lara (PL) site is exposed mainly to recreational and fishing activities. The Bagliardi (BAG) site is located in the surrounding area of La Plata's city sewage effluent and is located upstream from the Balandra (BAL) site. The Magdalena (MAG) site is exposed to recreational activities. The Pearson (PE) site is located in the natural reserve “El Destino” and the Punta Indio (PI) site is the closest site to the maximum turbidity front of the estuary with salinity nearby to 10 UPS (Licursi et al., 2010).

2.2. Sampling

Two samplings were performed in September–November 2016 (sampling 1) and April–June 2017 (sampling 2), before and after of the period of greatest recreational use of the coast, respectively. At each sampling site 100 L of subsurface water (depth 1 m) were collected nearby to the shore by a bucket and filtered through a plankton net of 36 μm in triplicate and then placed in bottles; 5 mL of the concentrated water were used to the analysis of the zooplankton and preserved in formalin (final concentration 4%), the rest of the filtered water was refrigerated and destined to the MPs count. Also 125 mL of subsurface water were collected in triplicate for the analysis of phytoplankton and were fixed with formalin (final concentration 2%).

Temperature, pH, turbidity, conductivity, total dissolved solids and oxygen saturation were measured in the field by triplicate, with a multiparametric sensor (Horiba U-50). The data for tide height was supplied by Argentinian Naval Hydrography Service. The wind direction and intensity data was provided by the Argentinian National Meteorological Service.

In order to evaluate the quality of the coastal habitat of the Southern Coastal Fringe of the Río de la Plata, the Habitat Index for the Río de la Plata (IHRPlata) was employed (Gómez and Cochero, 2013). To obtain the index, four descriptors are evaluated: 1) spatial succession of the coastal vegetation, 2) coastal modifications due to the introduction of infrastructures, 3) occurrence of waste on the coastline, and 4) biological indicators of oxygen deficit. The IHRPLata assumes values between 0 and 10. Five habitat qualities were established: very good (> 8–10), good (> 6–8), moderate (> 4–6), bad (> 2–4) and very bad (0–2).

2.3. Sample analysis

In order to eliminate the organic matter, the samples were oxidised with a solution of Fe (II) 0.05 M and 30% hydrogen peroxide, heated to 75 °C until no organic matter was observed

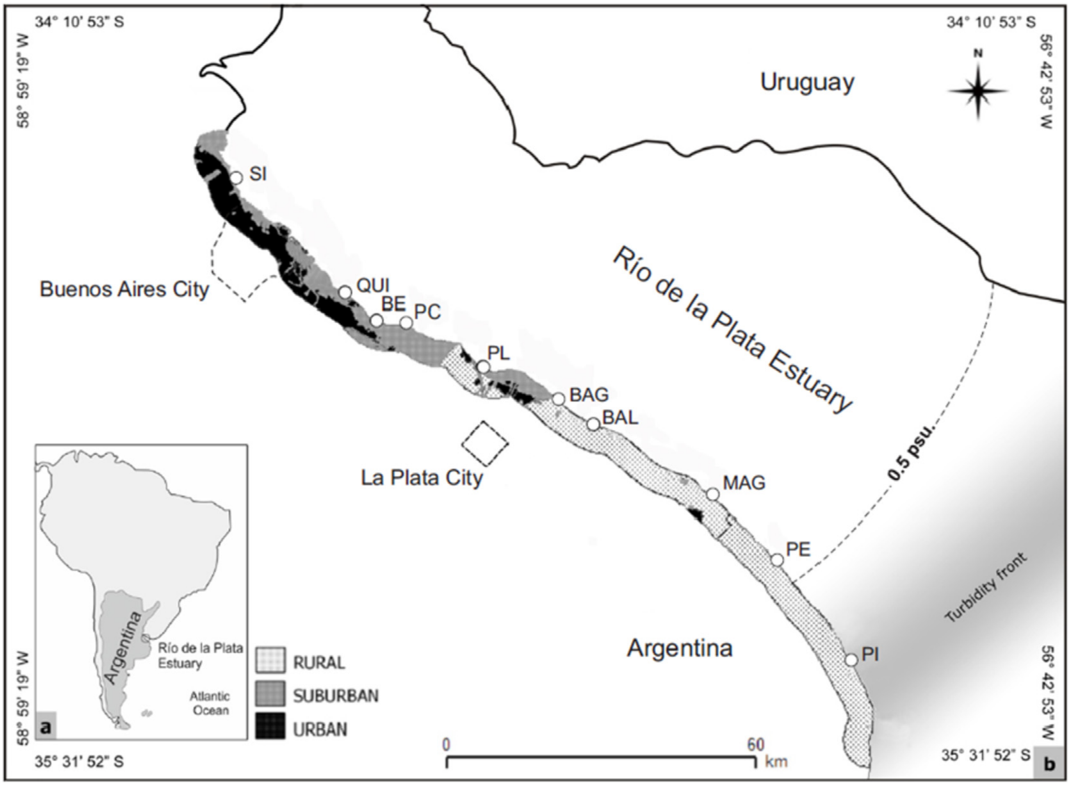

Fig. 1. Study area: location of the Río de la Plata estuary (a), sampling sites: SI (San Isidro), QUI (Quilmes), BE (Berazategui), PC (Punta Colorada), PL (Punta Lara), BAG (Bagliardi), BAL (Balandra), MAG (Magdalena), PE (Pearson) and PI (Punta Indio), and land uses of the coast (b). Shaded area corresponds to the maximum turbidity front.

following the methodology proposed by Masura et al. (2015). Then a density separation was carried out using a saturated solution of NaCl (5 M) to increase the density of the aqueous solution. Afterwards, sedimentation was carried out for a period of 24 h, the supernatant was filtered through a cellulose nitrate filter (47 mm, 0.45 μm pore). The filter was placed in a clean petri dish and dried at room temperature. In order to avoid sample contamination, glass beakers and petri dishes were cleaned with distilled water.

During digestion glass beakers were covered with watch glasses, meanwhile during storing and until visual identification, the samples were covered with foil paper. Filters were examined under stereomicroscope 5.6× (Olympus SZX7). To avoid misidentification of MPs, the criteria applied to define a plastic particle by Norén (2007), was used. MPs were counted and classified by colour, size (maximum length) and type (fibres and fragments). MPs counts for each of the categories were expressed as MPs m^{-3}.

Phytoplankton was counted in 5 mL sedimentation chambers, under an inverted microscope Olympus IX51 at 400× and 600×. The density of zooplankton was estimated using a Sedgwick–Rafter chamber (APHA, 1998).

2.4. Statistics analysis

The original data were transformed and the assumptions of normality and variance homogeneity were tested by the Barlett test. The mean number of MPs m^{-3} at each site was analysed by one-way ANOVA and differences were analysed a posteriori using the Fisher test. When the data did not follow ANOVA assumptions, they were analysed by a non-parametric test (Kruskal-Wallis). The differences between sampling 1 and sampling 2 were analysed by Rank Sum Test. The relationship between the MPs amount, environmental variables and IHRPlata index were analysed using the Spearman correlation coefficient.

3. Results

3.1. Environmental variables

The physicochemical characteristics of the water together with the tidal conditions and the winds intensity and direction are shown in Table 1. The study area shows a natural gradient that manifested particularly in the conductivity, turbidity and total dissolved solids, which increase towards the mixohaline zone of the estuary (PE and PI sites). The percentage of oxygen saturation showed the lowest concentrations in the most urbanized site (SI) and in the sewage discharges (BE and BAG). The tide values corresponded to low-water cycles, while the winds oscillated between 7 and 28 km h^{-1}, corresponding to different directions (Table 1).

3.2. Abundance, size, type, colour and distribution of microplastics

The MPs distribution was irregular along the coast (Fig. 2). The mean density of MPs in the study area for both samplings was 139 MPs m^{-3}. MPs amounts were variable among replicates and sampling periods. In sampling 1 the mean values of MPs in the study area was 164 MPs m^{-3}, being more abundant in the sites near Buenos Aires city (SI, QUI) and La Plata city (PL), followed by sewage discharges (BE, BAG) and the site located in the maximum turbidity front (PI). Meanwhile in sampling 2, the mean was 114 MPs m^{-3}, being PI site the most abundant, followed by QUI site. The mean density of MPs was significantly different ($p < 0.01$) among sites for both samplings (Table 2) but differences between sampling 1 and

Table 1
Physicochemical parameters, (mean ± standard deviation), wind intensity, direction and tidal data at each sampling site (md: missing data).

	Sites	Temp	pH	Turbidity (NTU)	Conductivity (μs cm^{-1})	Salinity (PSU)	% Dissolved Oxigen	Total Dissolved Solids (mg L^{-1})	Wind		Tides (cm)
									Intensity (km h^{-1})	Direction	
Sampling 1	SI	22.1	7.8 ± 0.1	107 ± 2	329	0.17	76.5 ± 0.9	0.2	9	SW	64
	QUI	18.7	8.2	122 ± 3	597 ± 2	0.33	131.4 ± 2.8	0.4	9	SW	37
	BE	22	8.2	210 ± 5	1042 ± 1	0.55	14.4 ± 0.1	0.9	12	SW	61
	PC	17 ± 0.1	8.9 ± 0.1	51 ± 3	606 ± 1	0.35	137 ± 8.9	0.4	12	N	53
	PL	14.4 ± 0.3	8.3 ± 0.3	97 ± 6	395 ± 9	0.24 ± 0.01	100.4 ± 2.4	0.3	10	S	md
	BAG	30.4	7.8	113 ± 3	821 ± 21	0.36 ± 0.01	81 ± 0.8	0.5	15	N	65
	BAL	25.4 ± 0.1	8.6 ± 0.1	374 ± 8	527 ± 4	0.25	125.6 ± 6.3	0.3	15	N	56
	MAG	23.6 ± 0.1	8.8 ± 0.1	180 ± 3	648 ± 171	0.33 ± 0.09	105 ± 0.2	0.5	10	md	73
	PE	21.9 ± 0.2	8.7 ± 0.2	170 ± 2	10200	7.34 ± 0.03	129 ± 3.3	6.3	10	md	64
	PI	19.9 ± 0.2	9.2 ± 0.2	130 ± 8	7330 ± 61	4.5 ± 0.02	111.7 ± 11.8	4.6	10	md	46
Sampling 2	SI	14 ± 0.3	6.8 ± 0.1	90 ± 2	338 ± 2	0.21	75.8 ± 3.6	0.2	13	NW	46
	QUI	10.8 ± 0.2	7.4 ± 0.2	51 ± 6	581 ± 3	0.39	82.2 ± 6.2	0.4	13	NW	30
	BE	11.9 ± 0.2	8.4 ± 0.1	74 ± 11	660 ± 9	0.44 ± 0.01	81.6 ± 4.2	0.4	28	N	18
	PC	17.8 ± 0.1	8.2 ± 0.1	130 ± 3	490	0.28	117.9 ± 2.8	0.3	18	S	63
	PL	17.9	8.1 ± 0.2	117 ± 6	449 ± 2	0.25	104.7 ± 1.2	0.3	18	S	6
	BAG	17.8	7.4 ± 0.1	83 ± 2	629 ± 2	0.36	73.5 ± 4.3	0.4	7	SE	42
	BAL	17.5 ± 0.2	8 ± 0.2	146 ± 4	343 ± 1	0.19 ± 0.01	101.3 ± 0.1	0.2	7	SE	39
	MAG	21.7 ± 0.3	8.5 ± 0.1	800	583 ± 19	0.3 ± 0.01	98.5 ± 0.8	0.4	20	NE	76
	PE	21.3 ± 0.3	8.5 ± 0.1	286 ± 8	3753 ± 15	2.15 ± 0.01	96.5 ± 4.8	2.4	20	NE	66
	PI	21 ± 0.2	8 ± 0.1	366 ± 24	12900 ± 100	8.09 ± 0.04	106.2 ± 4.7	8 ± 0.1	20	NE	46

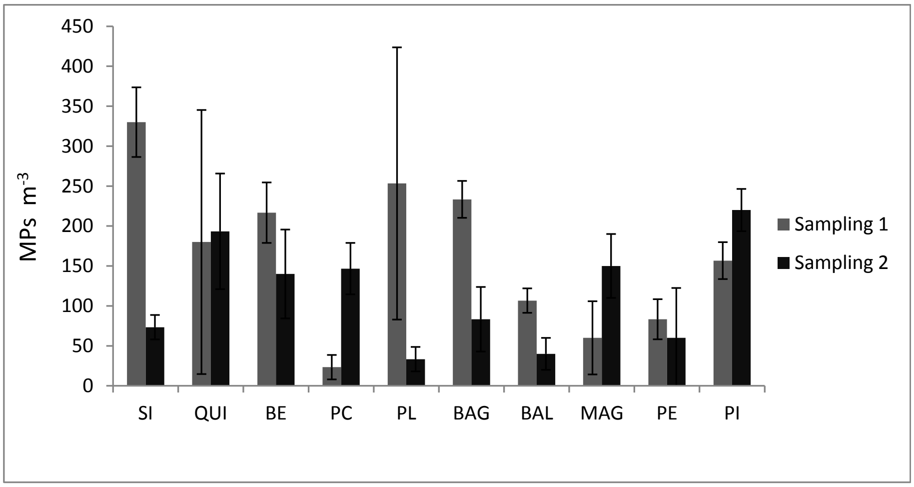

Fig. 2. Microplastics distribution (mean density) in the study area for both samplings.

Table 2
Result of one-way ANOVA (SS: sum of squares; DF: degree freedom; MS: mean squares; F and p values) comparing MPs m^{-3} among sites.

	SS	DF	MS	F	p
Sites (Sampling 1)	3.5	9	0.4	7.6	<0.01
Sites (Sampling 2)	2.5	9	0.3	5.4	<0.01

sampling 2 were not significant. No statistically significant correlations between the MPs concentration and environmental variables were found.

The most frequent MPs sizes were >500 ≤ 1000 μm (Fig. 3 a), with a higher fibres concentration in both samplings, being more abundant at SI, BAG and BE sites (sampling 1) and at PI, QUI and PC sites (sampling 2) (Fig. 3 b). The Kruskal-Wallis test performed between the mean densities of fibres was significantly different ($p < 0.05$) among sites; meanwhile differences of mean densities of fragments were not significant. The colours found were blue (34%), black (14.8%), red (14.2%), transparent (8.9%), green (7.4%), light blue (7.1%), white (5.4%), grey (3.5%), pink (2.4%), yellow (1%), brown, orange, violet and yellowish (< 1%).

3.3. *Habitat quality vs MPs*

According to the values of IHRPlata index, four of the analysed sites (SI, QUI, BE and BAG) presented a very bad habitat quality; two sites (PL and PI) presented bad quality; two sites (PC and MAG) presented moderate quality, while one site presented good quality (BAL) and only one presented very good (PE) (Fig. 4). The relationship between the MPs concentration and the IHRPlata index was significant ($p < 0.01$; Spearman's rho = −0.4566).

3.4. *Plankton community*

The phytoplankton analysed was mainly represented by diatoms in boths samplings (Fig. 5 a and b), whose dominant morphology were chains of the genera *Skeletonema* and *Aulacoseria* and cylindrical solitary cells of *Actinocyclus normanii, Thalassiosira*

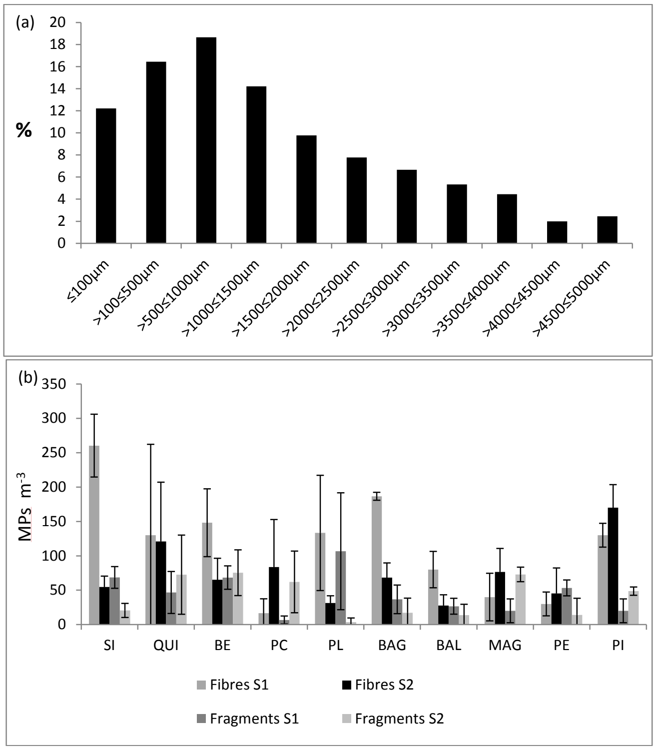

Fig. 3. Percentage of microplastics (MPs) sizes (a) and mean density of fibres and fragments in the sampling sites (S 1: sampling 1 and S 2: sampling 2) (b).

rudolfii and *Cyclotella meneghiniana*. Also cenobial and filamentous forms belonging to chlorophytes (e.g. *Dictyosphaerium pulchellum, Scenedesmus* spp.) and cyanobacteria (e.g. *Komvophoron constrictum*, *Microcystis aeruginosa, Raphidiopsis mediterranea)* were observed. The percentages of main morphological groups of the phytoplankton for both samplings are shown in Fig. 6, being more abundant filaments and solitary forms. The size of the phytoplankton fluctuated between 2 µm and 500 µm, dominating the pico-microplankton being more frequent the specimens with sizes less than 100 µm. In sampling 1 the average concentrations of phytoplankton fluctuated between 2.3 10^6 ind m^{-3} (SI) and 5.5 10^9 ind m^{-3} (QUI) and in sampling 2 between 4.4 10^6 ind m^{-3} (SI) and 5.3 10^9 ind m^{-3} (PC).

The zooplankton analysed was represented mainly by ciliates (e.g. *Codonella cratera, Tintinopsis rioplatensis, Tintinidium fluviatile*), rotifers (e.g. *Filinia longiseta, Brachionus calyciflorus, Lecane* sp.) and copepods, cyclopoida and nauplius larvae (Fig. 7 a and b). The concentrations fluctuated between 8.5 10^3 ind m^{-3} (PE) and 4.1 10^5 ind m^{-3} (PC) in sampling 1, meanwhile in sampling 2 the fluctuation was between 2 10^3 ind m^{-3} (PI) and 4.2 10^6 ind m^{-3} (BE).

The morphology of the zooplankton was varied, predominating ellipsoid, spherical and conical forms with regular and irregular contours.

The most frequent size of zooplankton was between 50 and 1000 µm, with the most frequent being those smaller than 100 µm, corresponding mainly to the micro-mesozooplankton.

3.5. *MPs vs plankton*

The sizes of the most frequent specimens of plankton and MPs are shown in Table 3. The most frequent MPs sizes were >500 ≤ 1000 µm. However the comparative analysis of plankton and MPs demonstrated that a fraction of the latter showed a frequency range of size that coincide with the most common sizes of plankton (≤500 µm).

The mean percentage of MPs in relation to zooplankton was 0.36% in sampling 1 and 1.20% in sampling 2. On the other hand, the mean percentage of MPs in relation to phytoplankton density was lower 0.0002% in sampling 1 and 0.0005% in sampling 2.

4. Discussion

The presence of MPs in freshwater has been reported mainly for Europe, North America, and Asia, and suggests that the presence of MPs are equally as far reaching as observed in marine systems (Eerkes-Medrano et al., 2015). This study constitutes the southernmost record in South America that warns of the presence of this pollutant, integrating the planktonic community of the freshwater sector of an estuary that drains into the Atlantic Ocean.

The results revealed the presence of MPs in all the samples analysed, with a predominance of sizes >500 ≤ 1000 µm and fibres, and the blue colour being more frequent.

These MPs integrated a planktonic community dominated by pico-microphytoplankton, mainly conformed by chains/filaments and solitary forms, frequent morphologies in the freshwater tidal

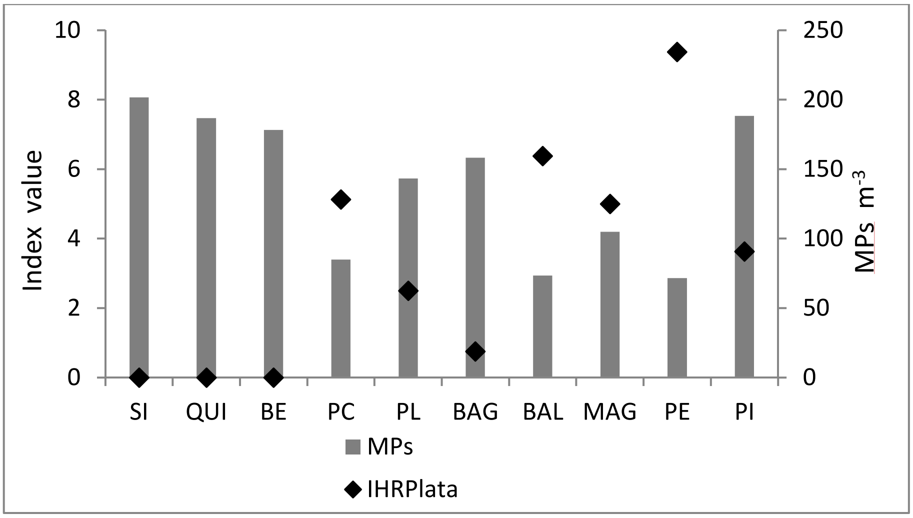

Fig. 4. Relationship between the microplastics (MPs) concentration and the Habitat Index for the Río de la Plata (IHRPlata).

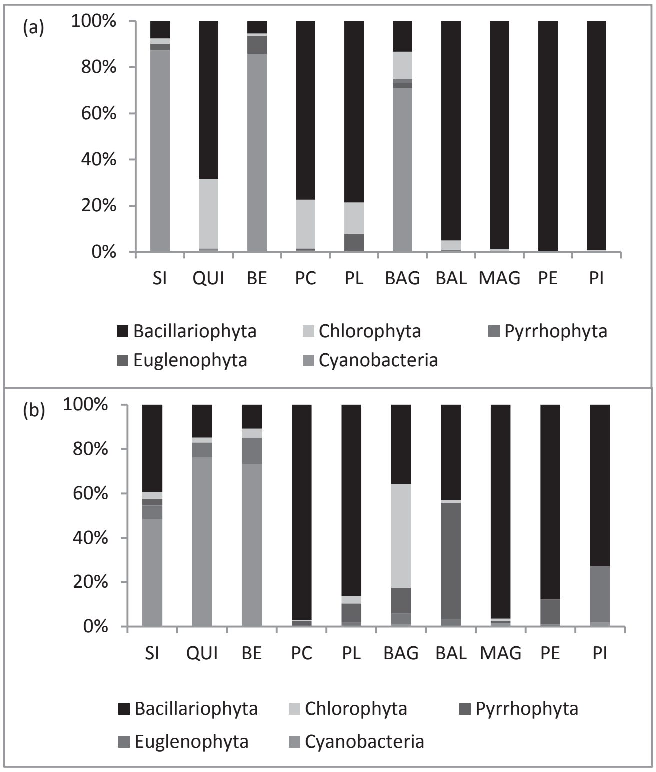

Fig. 5. Phytoplankton composition in sampling 1 (a) and in sampling 2 (b) in the study area.

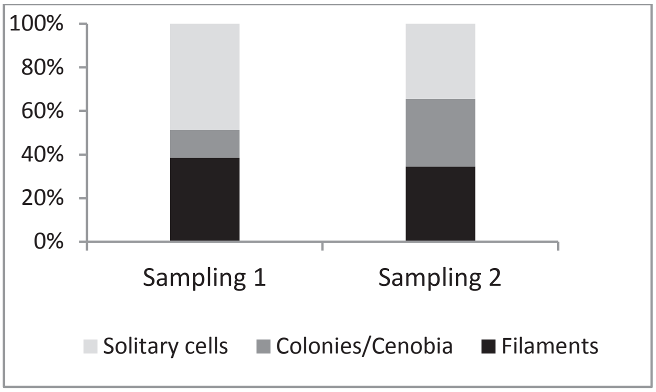

Fig. 6. Percentage of phytoplankton morphological groups.

zone of the Río de la Plata estuary (Gómez, 2014) and by a micro-mesozooplankton.

The MPs concentration showed an unequal distribution among the sampling sites and between replicates. Global reports suggest that MPs vary considerably spatially and temporally (Barnes et al., 2009; Goldstein et al., 2013). However in our study no significant differences were observed between the samplings analysed.

The MPs concentration found in the study area positions the coastal sector of the Río de la Plata estuary in an intermediate situation between the minimum reported for the Tamar estuary and the maximum for Yangtze Estuary (Table 4). It should be mentioned that in our study and in Zhao et al. (2014) the size pore employed was similar (32–36 μm), meanwhile in the rest of the studies 300 μm size pore was employed.

Several factors that affect the MPs concentration in aquatic ecosystems have been suggested, such as the proximity of the aquatic environment to human population density, water residence time, the type of waste management used, and amount of sewage overflow (Moore et al., 2011; Zbyszewski and Corcoran, 2011; Eriksen et al., 2013; Free et al., 2014; Eerkes-Medrano et al., 2015). In our study, the deterioration of the coastal habitat quality, assessed through the habitat index (IHRPlata), showed a significant relationship with the MPs concentrations. The proximity to the megalopolis of Buenos Aires and other urban centres and a poor treatment of wastewater and a null control of plastic accumulation on the coast (Gómez and Cochero, 2013), together with inherent characteristics of the dynamics of the estuary, (e.g. the front of maximum turbidity), are factors linked to the highest MPs concentrations in the coastal waters of the study area.

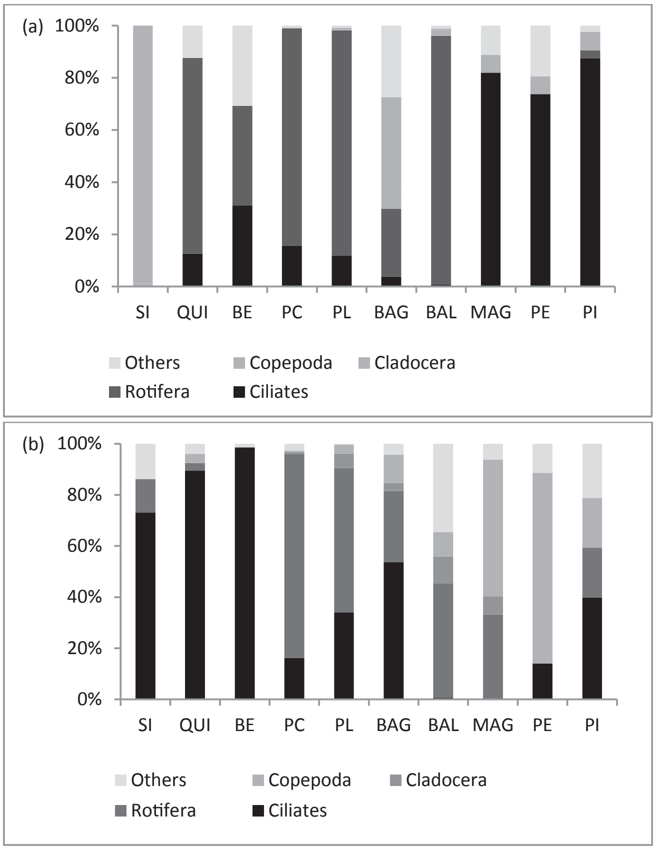

Fig. 7. Zooplankton composition in sampling 1 (a) and in sampling 2 (b) in the study area.

The flocculation and particle sedimentation of MPs, tend to increase when the salinity and turbulence interact with particle density, size, and charge (Kranck, 1975; Olsen et al., 1982; Eisma and Cadeé, 1991). In the Río de la Plata estuary, Acha et al. (2003) observed that in the maximum turbidity front the main sources of human debris were plastics (74%). This area is the ecotone between the tidal river and the estuary, where relevant ecological processes take place. This area is the principal reproductive habitat for two of the most abundant fish species in the estuary. Furthermore, high concentrations of copepods and bacteria have been recorded in this region (Mianzan et al., 2001).

Moore et al. (2002) observed in California's coastal waters that strong winds and wave action create a vertical mixing within the water column that resuspends plastics to increase the amount of MPs in the water. In our study, no significant differences were observed between the height of the tide and the winds with the

Table 3
Most frequent sizes of plankton and microplastics found in this study.

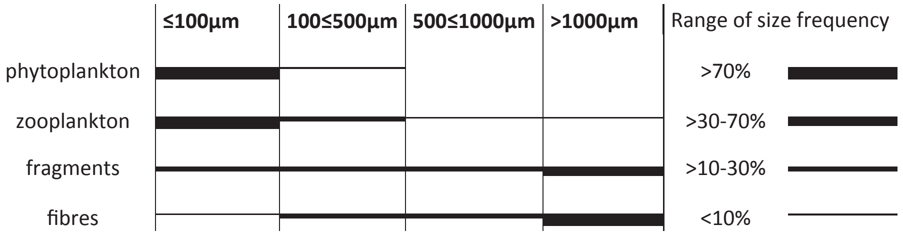

Table 4
Studies detecting microplastics in the water column of estuaries.

Sites	Mean abundance	Authors
Tamar estuary, UK, Europe	0.028 particles m^{-3}	Sadri and Thompson, 2014
Goiana Estuary, Brazil, South America	0.26 particles m^{-3}	Lima et al., 2014
iLovu, South Africa, Africa	1.02 particles m^{-3}	Naidoo et al., 2015
Mdloti, South Africa, Africa	1.1 particles m^{-3}	Naidoo et al., 2015
uMgeni, South Africa, Africa	2.5 particles m^{-3}	Naidoo et al., 2015
Isipingo, South Africa, Africa	3.1 particles m^{-3}	Naidoo et al., 2015
Durban harbour, South Africa, Africa	7.3 particles m^{-3}	Naidoo et al., 2015
Río de la Plata estuary, Argentina, South America	**139 particles m^{-3}**	**This study**
Oujiang, China, Asia	680 particles m^{-3}	Zhao et al., 2015
Jiaojiang, China, Asia	955.6 particles m^{-3}	Zhao et al., 2015
Minjiang, China, Asia	1245.8 particles m^{-3}	Zhao et al., 2015
Yangtze Estuary, China, Asia	4137.3 particles m^{-3}	Zhao et al., 2014

MPs concentration, probably because the samples were extracted during low tide cycles and with low wind intensities. However, it is not ruled out that these factors contribute to the MPs accumulation since there is evidence that the accumulation of phytoplankton on the coast of the Río de la Plata was greater with SE wind, speeds >20 km h^{-1} and high tide (Sathicq et al., 2014). Therefore, it is feasible that the MPs that integrate the planktonic community are also influenced by these factors.

The most abundant types of MPs are the fibres concentrated in the most urbanized sites and particularly in sewage effluents. The mean density of fibres in our study exceeded those reported by Castro et al. (2016) and Ivar do Sul (2013) for equatorial and subequatorial waters of the southern Atlantic. Meanwhile, Zhao et al. (2015) and Gallagher et al. (2016) found that the fibres were the predominant type of MPs in three urban estuaries of China and in Solent estuarine complex. There are several studies showing that fibres are the most frequent type of MPs found in aquatic ecosystems (Thompson et al., 2004; Ng and Obbard, 2006; Fendall and Sewell, 2009; Frias et al., 2010; Andrady, 2011; Claessens et al., 2011; Zhao et al., 2015; Gago et al., 2018). Browne et al. (2011) showed that a single synthetic clothing garment can release > 1900 MPs fibres per wash suggesting that a large proportion of MPs fibres found in the marine environment may enter the ecosystem mainly via wastewater discharge.

The most frequent and abundant MPs size were similar to reported by Browne et al. (2010), who points out that in Tamar estuary fragments of sizes below 1 mm are more abundant than larger items, so this increases the chance of ingestion by organisms with diverse feeding habits. On the other hand, the predominance of fibres of sizes <5 mm but with a high relation length/radius makes them available for biota in different trophic levels (Gago et al., 2018). The comparison between the characteristics of the MPs found in the samples of the present study shows fibres resemble the chains-filaments forms of phytoplankton and that more than 50% of the analysed plankton gather specimens whose most frequent sizes are below 500 µm, they constitute observations that warn about the dangerousness of this pollutant. When MPs enter the coastal system they begin to form part of the plankton and constitute a food supply for the first links of the trophic chain. Acording to Brillant and MacDonald (2000) due to the similarity between some MPs and algae, plastics could be prey for planktivores and may be ingested in a similar way.

The results about the percentage of MPs in the estuarine planktonic community of the Río de la Plata, particularly in relation to zooplankton, showed to be greater than the reported by Lima et al. (2014) for the Goiana Estuary in South America.

Although in our study the ingestion of MPs by zooplankton was not analysed, there is evidence in the bibliography about that many planktivores lack selectivity between particles and take anything of proper size (Moore, 2008). Furthermore, higher trophic planktonic organisms could passively ingest MPs during normal feeding activity or prey misidentification may occur (Wright et al., 2013). Studies realised by Christaki et al. (1998) about the ingestion of picoplankton-size particles and MPs demonstrated the scarce selection by the particles by marine ciliates. In our study among the most abundant and frequent zooplankton specimens found in the samples of Río de la Plata estuary, there are the Tintinniidae ciliates, that according to Rives (1997), feed on detritus, bacteria, flagellates and diatoms, which are consumed by copepods, cladocerans and fish larvae.

Of the colours of analysed MPs in this study, blue was dominant. Gago et al. (2018) highlight that this colour is the most abundant in seawater and sediment, probably due to two factors; it is a common colour worldwide (jeans, shirts, etc.) and is not attractive for ingestion. Besides, others potential sources of blue MPs are fishing nets, ropes used extensively in fishing (Dantas et al., 2012). Furthermore, blue was dominant in gut contents of 87 captured fish in the coast of Río de la Plata estuary, belonging to 11 species and four feeding habits: detritivore, planktivore, omnivore and ichthyophagous (Pazos et al., 2017), probably because MPs enter with the food as well as passively through the water that contains them.

Finally, the predominance of fibres increases their possible toxicity due to the nature of the material that constitutes them (Cole et al., 2016), and therefore increase the danger of this pollutant in water quality and biota of the Río de la Plata estuary. Their finding in highly productive areas of the estuary and the evidence on their presence in coastal fish emphasises the need for a better treatment of both liquid and solid urban waste, which contribute to reducing the entry of this pollutant into the ecosystem.

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