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Marine debris in beaches of the Southwestern Atlantic: An assessment of their abundance and mass at different spatial scales in northern coastal Argentina

Maria Eugenia Becherucci[a,*], Alan Federico Rosenthal[b,c], Juan Pablo Seco Pon[d]

[a] Grupo Ecología, Instituto de Investigaciones Marinas y Costeras, Consejo Nacional de Investigaciones Científicas y Técnicas, Universidad Nacional de Mar del Plata. Funes 3250, B7602AYJ Mar del Plata, Argentina
[b] Asociación Naturalistas Geselinos, Villa Gesell, Buenos Aires, Argentina
[c] Programa Regional de Conservación e Investigación de Tortugas Marinas de la Argentina (PRICTMA), Argentina
[d] Grupo Vertebrados, Instituto de Investigaciones Marinas y Costeras, Consejo Nacional de Investigaciones Científicas y Técnicas, Universidad Nacional de Mar del Plata, Funes 3250, B7602AYJ Mar del Plata, Argentina

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ABSTRACT

Argentina is currently undergoing an intensive development of coastal-oriented tourism due to the temperate climate and coastal sceneries of the Southwestern Atlantic and particularly its wide ocean-open sandy beaches, which may turn into an important contributor of marine debris to the beaches. This study was designed to assess at four spatial scales (*i*) the variation of the abundance and mass of marine debris and (*ii*) the composition and sources of these items in sandy-tourist beaches of coastal zones of the province of Buenos Aires, in northern Argentina. The abundance and mass of marine debris shifted between sampling localities (separated by $\sim 1.5 \times 10^5$ m) and beaches ($\sim 3 \times 10^4$ m). Debris was primarily from recreational and fishing activities and over 20 mm in size. Tackling the complications associated with marine debris in northern Argentina may include intensive educational and advertising campaigns oriented chiefly to beach users and fisherman.

1. Introduction

There is a well-established consensus about marine debris being an increasing environmental issue globally (Macfayden et al., 2009; Bergmann et al., 2015). Marine debris, also often termed marine or beach litter, may include any item showing on beaches or at sea (including the open oceans and coastal regions), mainly due to human activities (Walker et al., 2006; Bergmann et al., 2015). This debris can be broadly categorized according to material type and assigned to four main sources: recreational litter, fishing debris, sewage-related debris and shipping waste (Somerville et al., 2003; Storrier et al., 2007). Other sources may include storm water and urban runoff, and riverine input (Cheshire et al., 2009). Regardless of its source, debris is introduced into the marine ecosystem given that its management and disposal are improperly accomplished, and by accidental loss and natural catastrophes (Zhou et al., 2011). Moreover, there is evidence indicating an impact of marine debris on coastal economic activity (Walker et al., 2006). This debris also threatens marine biota through entanglement, ghost fishing and ingestion of marine debris (Macfayden et al., 2009; Kühn et al., 2015). A recent study indicated that within upper vertebrates, all marine turtle species, almost 50% of overall marine mammal species and a fifth part of all seabird species are affected by marine debris (Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel–GEF, 2012). Marine debris may also affect the structure and composition of the benthos communities developing on soft and hard substrata (Richards and Beger, 2011).

The environmental areas that are most affected by marine debris include the open oceans and coastal regions (Corcoran et al., 2009; Cózar et al., 2014). Sand beaches represent very valuable ecosystems used for outdoor recreation worldwide, among other human activities (Araújo and da Costa, 2007; Cervantes and Espejel, 2008). Not surprisingly, the majority of the studies of marine debris was conducted on beaches (Law, 2011; Williams et al., 2013), and studies of the ocean floor are relatively scarce (Galgani et al., 2000; Van Cauwenberghe et al., 2013). Beach surveys are a widely used method for measuring potentially harmful marine and land derived debris accumulating in a specific area at a given time (Walker et al., 2006; Storrier et al., 2007; Rosevelt et al., 2013). However, the accumulation of debris on beaches are affected by natural processes such as erosion, local tides and winds

* Corresponding author.
E-mail address: mebecherucci@gmail.com (M.E. Becherucci).

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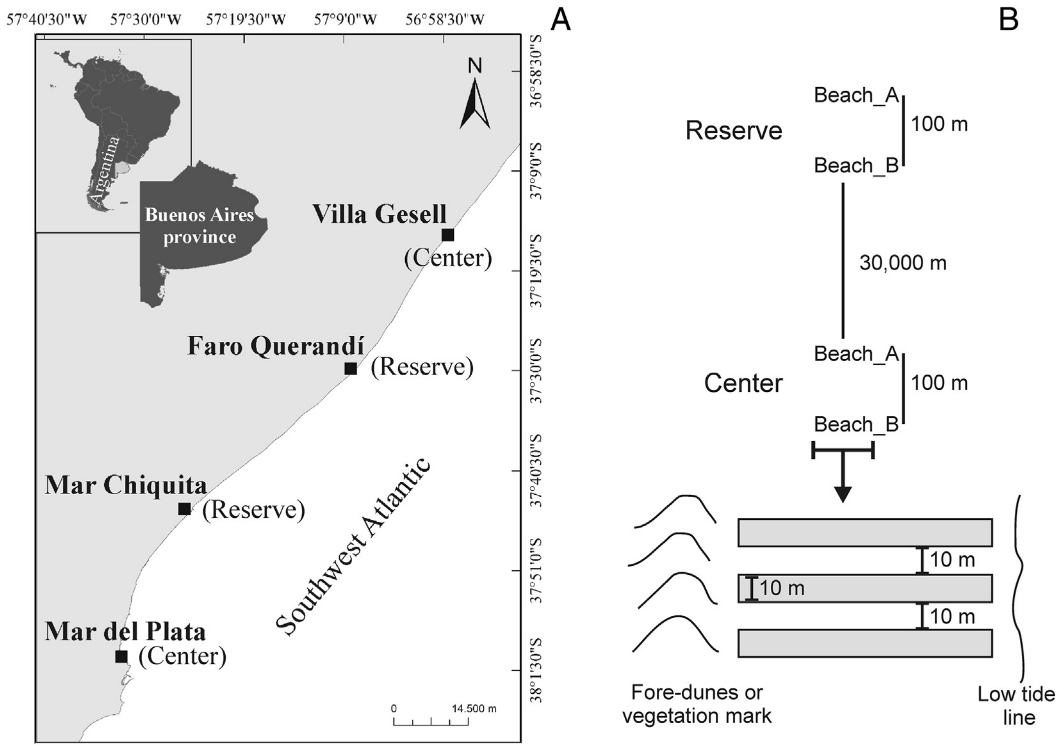

Fig. 1. Map of Buenos Aires province, Argentina showing the distribution of sampled localities (Mar del Plata – Villa Gesell) and sectors (center – reserve) (A) and detail of the transect orientation respect to sampled beaches (B).

and by anthropogenic factors like littering behavior (Ribic et al., 2010, 2012). Hence, it is expected that marine debris deposited on the beach may vary spatially and temporally (Rees and Pond, 1995; Edyvane et al., 2004; Smith and Markic, 2013; Browne et al., 2015). Furthermore, the amount of marine debris is considered to be inversely related to its geographical distance to a population center and directly to the number of users (Gabrielides et al., 1991; Frosten and Cullen, 1997; Leite et al., 2014). Other factors affecting the types and amounts of marine debris include topography, environmental variables (e.g. currents and storms) and extent of beach user (Storrier et al., 2007), among others. Still, a number of methods are employed to assess marine debris, turning the comparison of works difficult (Velander and Mocogni, 1999; Tudor et al., 2002). Besides, a significant amount of literature is dedicated to marine debris types, distribution and temporal variations on beaches in the Northern Hemisphere, including Europe (Velander and Mocogni, 1999; Somerville et al., 2003; Martinez-Ribes et al., 2007; Frias et al., 2011; among others) and North America (Ribic et al., 2010; Carson et al., 2013; Rosevelt et al., 2013; among others), with an important asymmetry of what is known for other regions like southern South America (but see Gregory and Ryan, 1997; Ivar do Sul and Costa, 2007 and references therein).

In southern South America countries like (southern) Brazil, Uruguay and (northern) Argentina are currently undergoing an intensive development of coastal-oriented tourism due to the temperate climate and coastal sceneries of the Southwest Atlantic Ocean (which bathe the coasts of the above referred countries) and particularly their wide ocean-open sandy beaches, which may turn into an important contributor of marine debris to the beaches (Lemay, 1998; López and Marcomini, 2011). Two National Coastal Contamination Censuses were performed in Argentine beaches in 1995 and in 2007 over almost 2110 km of the coastline (Esteves et al., 1997; Colombini et al., 2008). However, in Argentina studies on marine debris are scarce. Moreover, these are usually limited to a few localities (Lucero, 2011; Denuncio and Bastida, 2014), but have included the Argentine seafloor (Acha et al., 2003; Giangiobbe et al., 2012). As a result, the impact of marine debris in Argentine beaches is poorly understood. Moreover, all of the studies previously conducted were performed in coastal zones of the province of Buenos Aires, most likely because the latter is considered to be the largest and most populated province of the country, where many activities are located and consequently where most conflicts occur (Isla and Lasta, 2006; López and Marcomini, 2011). Besides, a large sector of its central and southeastern coastal zone (including a great number of cities and villages) is home to a massive tourism based on "beach and sun" activities chiefly during the summer months (e.g. December–-March) due to the extent of its open sandy beaches, as well as certain features such as visitors´ accommodation capacity, diversity of services, relative proximity to the city of Buenos Aires, among other factors (Mantero et al., 1999; Juárez and Mantobani, 2006; Furlan et al., 2012).

It is in this context and attending the scope of this issue that our study was designed 1) to evaluate the variability of abundance and mass of marine debris at different spatial scales, 2) to determine the category and source of marine debris and 3) to establish the size of debris, particularly plastic in sandy beaches of the southeastern sector of the Buenos Aires Province, Argentina.

2. Materials and methods

2.1. Study area

The study area (northern coastal Argentina) is comprised by sandy open beaches with sand dunes which alternate with extended intertidal limo-loessoides rocks (Isla, 2006) and is under the indirect influence of the warm-temperate Brazil/Malvinas Confluence. The tidal regime is semidiurnal with tidal amplitude ranging from approximately 0.8 m to 1.6 m during exceptional tides. Sea surface temperature shows a great seasonal variation (9.3 °C in winter and 20 °C in summer) (Guerrero and Piola, 1997). Samplings were conducted in sandy beaches of the coastal cities of Mar del Plata and Villa Gesell (Fig. 1A). The former is the largest coastal city of Argentina holding > 619.000 inhabitants throughout the year, also receiving c. 3 millions of tourists during the summer (EMTUR, 2016), while the latter is a smaller city located to the north of Mar del Plata which holds a 31.730 of permanent residents and receiving around 1.7 million tourists during the summer months. Several studies provide detailed information about the history and development of the selected localities (see Juárez and Mantobani, 2006; Ordoqui and Hernández, 2009; Furlan et al., 2012).

2.2. Sampling scheme

Beach sampling was performed at the end of February 2015. This month is close to the end of the tourist season. Changes in total abundance and mass of marine debris were analyzed at 4 spatial scales: localities ($\sim 1.5 \times 10^5$ m), beaches ($\sim 3 \times 10^4$ m), sectors (~100 m) and replicate levels (~1 to 10 m) (Fig. 1). For the largest scale, i.e. localities, we selected the coastal cities of Mar del Plata and Villa Gesell separated each by 150 km. The beaches were chosen based on two main features: (1) very popular beach with high presence of users and (2) quiet beach with low presence of users including natural reserves. The beaches selected in Mar del Plata included one locally known as "Popular" (hereinafter refereed as Center), neighboring the city´ central business district thus being a high visited beach, and another located at 32 km to the north and placed in the vicinity of the mouth of the Mar Chiquita Lagoon in the coastal village of Mar Chiquita (hereinafter referred as to Reserve), included within the MAB-UNESCO Man and Biosphere Reserve Parque Atlántico Mar Chiquito (Iribarne, 2001). The beaches selected in Villa Gesell comprised the beach "Paseo" (considered herein as Centro), facing the town' center, and a quite beach located at 30 km to the south within the vicinity of the Faro Querandí Natural Municipal Reserve. Two sectors separated each 100 m were selected on each beach. Three transects aligned perpendicular to the coastline were placed in each sector. These transects (10-m width) extended from the coastline during low tide to the beginning of the fore-dunes or the vegetation mark, thus the length of each transect varied with the width of the beach (see Fig. 1B). Transect arrangement and width is in line with previous published methodology (Frosten and Cullen, 1997; Velander and Mocogni, 1999; Bravo et al., 2009; among others). In this study, each transect represented a sampling unit, being n = 24 the sampling size of our survey (3 transects @ 2 sectors @ 2 beaches @ 2 localities).

Visually identifiable marine debris was hand-collected at each sampling unit and placed in separate plastic bags. Following guidelines outlined by the United Nation Environment Programme/ Intergovernmental Oceanographic Commission (Cheshire et al., 2009) with some modifications, debris was classified in the laboratory into 8 categories: plastics, papers, cigarette butt, cloth, glass, metal, organic and others (including construction debris, pruning activities debris, etc.). Cigarette butts were considered as a separate category due to its great abundance during the surveys (see Results). The number and weight (assessed with a digital scale and measured to the nearest gram) of each category units were measured for each sampling unit. The fraction comprising papers was only weighted due to difficulties in counting them separately during the survey. Moreover, we classified the marine debris collected according to its sources in packaging, fisheries related and recreational litter (including both coastal and leisure activities) (Somerville et al., 2003; Storrier et al., 2007). Particularly, plastics were further divided based on their size into three categories: meso-debris (5–20 mm in length), macro-debris (> 20 mm) and mega-debris (> 100 mm) (Ryan et al., 2009; Thompson et al., 2009). The classification of the plastic fraction was performed only with the data gathered in Mar del Plata as logistic constrains prevented us from collecting related data in Villa Gesell.

2.3. Data analysis

The total abundance and mass of marine debris were analyzed separately at different spatial scales using a nested Analysis of Variance (ANOVA) model. For this, we selected the following factors: Factor 1 included locality (fixed, crossed) with 2 levels (Mar del Plata and Villa Gesell), Factor 2 comprised beach (fixed, nested in Locality) with 2 levels (Center and Reserve); and Factor 3 encompassed sector (random, nested in Locality and Beach) with 2 levels (sector A and B). To stabilize variances only mass data was fourth-root transformed.

The composition of marine debris (abundance and mass) considering its categories and its relationship with the locality and beach was analyzed separately with a Correspondence Analysis (CA).

The prevalence of any source of marine debris within each beach and locality was analyzed with one-way ANOVA test. Likewise, a one-way ANOVA test was used to establish the prevalence of the size of plastics in beaches of Mar del Plata.

In all cases of ANOVA tests, homogeneity of variances was verified with the Levene's-test. Despite some cases data could not be transformed to meet homogeneity of variance (abundance and mass of fisheries debris), ANOVA was still used because it is a robust analysis than other non-parametric analyses (Underwood, 1997). However, the results were interpreted with caution by a more conservative significance level ($\alpha = 0.01$). Whenever a difference was established in the ANOVA tests, multiple comparisons were performed by Tukey HSD test method at the appropriate alpha level to determine differences between means.

Statistical univariate and multivariate analysis of the data was performed using STATISTICA©, Version 8 and PC-ORD software, Version 6.0 (McCune and Mefford, 2011) respectively.

3. Results

3.1. Spatial scale analysis

The total abundance of marine debris (9620 items) varied significantly at the scales of locality and beach (Table 1). Almost 77% of this debris (7394 items) was counted in Mar del Plata; the remainder 23% (2226 items) in Villa Gesell. In both localities, the overall abundance of marine debris was significantly higher in the center beaches [Mar del Plata, mean abundance (MA) = 1061.16 items; Villa Gesell, MA = 281.66 items] than in the reserve beaches (Mar del Plata, MA = 171.16 items; Villa Gesell, MA = 91.8 items).

The total mass of marine debris (54,356.5 g) varied significantly at the scales of locality and beach (Table 1). Almost 85% (46,203 g) of this debris was weighted in Villa Gesell, while the remainder 15% (8153.4 g) in Mar del Plata. The overall mass of marine debris was higher in the reserve beaches of Villa Gesell (MA = 6105.66 g) than in the center beaches of the same locality (MA = 1593.33 g). While in Mar del Plata, marine debris in the center beaches (MA = 1178.92 g) were heavier than in the reserve beaches (MA = 181.5 g).

Given that there was no significant effect at the scale of sector on both total abundance and mass of marine debris (Table 1), the

Table 1
Nested ANOVA results and paired comparisons Tukey tests of overall abundance and mass of marine debris registered at center (Ce) and reserve (Re) beaches of Mar del Plata (MdP) and Villa Gesell (VG). Significant $P < 0.01$.

	df	*F*	*P*	Paired comparison Tukey test	*P*
Abundance					
Locality	2	156.558	0.000		
Beach (locality)	4	174.959	0.000	Ce (MdP) - Re (MdP)	0.000
				Ce (VG) - Re (VG)	0.006
Sector [beach (locality)]	16	3.733	0.025		
Mass					
Locality	2	21.056	0.000		
Beach (Locality)	4	8.868	0.003	Ce (MdP) - Re (MdP)	0.036
				Ce (VG) - Re (VG)	0.043
Sector [beach (locality)]	16	2.703	0.068		

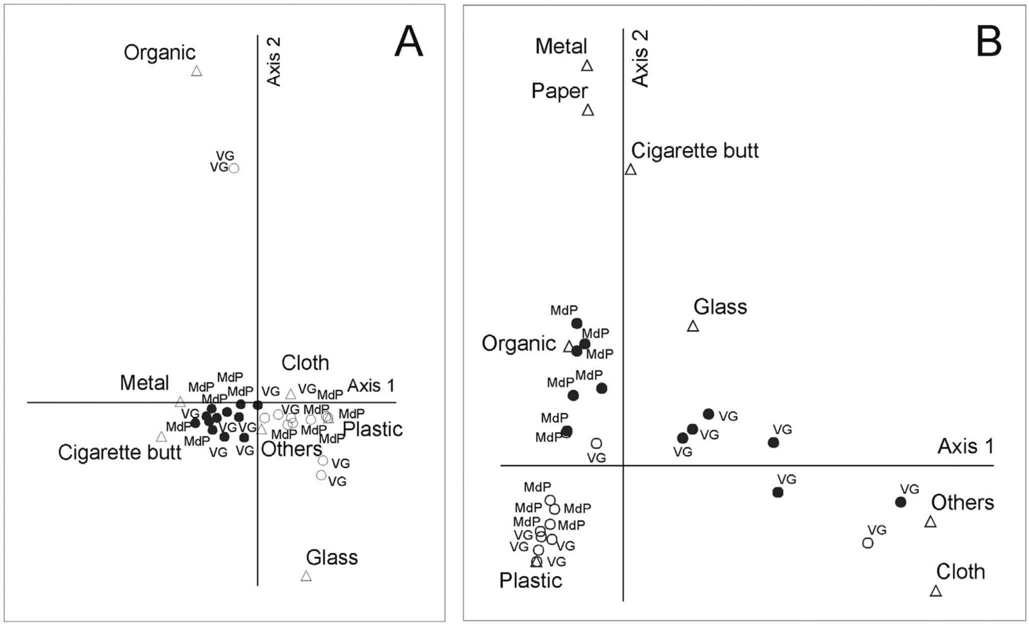

Fig. 2. Ordination plots of Correspondence Analysis between the composition of marine debris and sampling units for both beaches (center and reserve) of Mar del Plata and Villa Gesell regarding to their abundance (A) and mass (B). Empty circles represent reserve beaches and full dark circles center beaches. MdP: Mar del Plata, VG: Villa Gesell.

following analyses only include both locality and beach scales.

3.2. Composition of marine debris

Cigarette butts and plastics dominated the fraction of marine debris found both in Mar del Plata (4322 and 2539 items respectively) and Villa Gesell (800 and 762 items respectively) regardless of the type of beach. The first two axes of the correspondence analysis between the abundance of categories of marine debris and the unit samples represented 72.88% of the total variance ($\lambda_1 = 45.82\%$ and $\lambda_2 = 27.06\%$ respectively). Overall, in the ordination plot, a spatial gradient was observed in the horizontal axis. The center beaches were grouped separately from the reserve beaches in axes one (Fig. 2A). According to the ordination plot the abundance of cigarette butts and metals corresponded to the center beaches and the abundance of plastics and glass to the reserve beaches. The analysis prevented from distinguishing between localities (Mar del Plata and Villa Gesell).

According to mass, plastics (4156.5 g), papers (1496.5 g) and cigarette butts (939.5 g) dominated the marine debris fraction registered in Mar del Plata, while in Villa Gesell plastics (27,506 g), others (13,408 g) and cloth (2389 g) where the dominant marine debris. The first two axes of the correspondence analyses between the mass of categories of marine debris and the unit samples represented 77.31% of the total variance ($\lambda_1 = 53.19\%$ and $\lambda_2 = 24.12\%$ respectively). Overall, in the ordination plot, a spatial gradient was observed in both axes. The localities were grouped separately in axes one, though, this was only observed in samples from center beaches. While the center beaches were grouped separately from the reserve beaches in axes two. Considering only the center beaches, the mass of metals, papers and organics corresponded to Mar del Plata and the mass of glass and others to Villa Gesell (Fig. 2B).

3.3. Sources of marine debris

The main source of marine debris based on its abundance included chiefly recreational (MA = 284.83 items), followed by packaging (MA = 74.37 items) and fisheries (MA = 3.66), regardless of locality and beach. Recreational debris were significantly higher in the center beaches of Mar del Plata when compared to the reserve beaches of the same locality and both types of beaches of Villa Gesell (Fisher $F_{3,20} = 119.94$, $P < 0.001$). Likewise, the same pattern was found for packaging debris (Fisher $F_{3,20} = 20.05$, $P < 0.001$). On the contrary, fisheries debris were significantly higher in the reserve beaches than in the center beaches of either Mar del Plata or Villa Gesell (Fisher $F_{3,20} = 4.908$, $P = 0.010$) (Fig. 3A).

With respect to mass, the main source of marine debris included primarily fisheries (MA = 812.77 g), followed by recreational (MA = 369.68 g) and packaging (MA = 284.54) (overall localities and beaches combined). Fisheries debris were significantly heavier in the reserve beaches of Villa Gesell when compared to the center beaches of the same locality and both types of beaches of Mar del Plata (Fisher $F_{3,20} = 4.922$, $P = 0.010$). The same pattern was found for packaging debris (Fisher $F_{3,20} = 5.555$, $P = 0.006$). The mass of recreational debris was relatively similar between localities and beaches (Fisher $F_{3,20} = 2.657$, $P = 0.076$) (Fig. 3B).

3.4. Size of plastic debris in Mar del Plata

The main size of plastics registered in the locality of Mar del Plata included chiefly mega-debris (MA = 114.83 items), followed by macro- (MA = 92.00 items) and meso-debris (MA = 7.33), regardless of the type of beach. When considering the type of beach (Center vs. Reserve), the mean abundance of both macro- (Fisher $F_{3,20} = 5.026$, $P = 0.025$) and mega-debris (Fisher $F_{1,\ 10} = 14.874$, $P = 0.003$) were significantly higher in the Center beach than in the Reserve beach. The abundance of meso-debris was relatively similar between beaches (Fisher $F_{1,10} = 0.907$, $P = 0.363$) (Fig. 4).

4. Discussion

This is the first study to compare the abundance and distribution of marine debris at different spatial scales in Argentine beaches, both in terms of their abundance and mass. Moreover, we present updated information regarding the categories and sources of marine debris, and sizes of plastics, the latter being an important component of marine debris in local sandy beaches, including in Mar del Plata, the largest coastal city of Argentina. Despite few studies focusing on stranded (Lucero, 2011) and buried debris (Denuncio and Bastida, 2014) and two others on the ocean floor (including "submerged" debris) (Acha et al., 2003; Giangiobbe et al., 2012) on the effect of human activities on

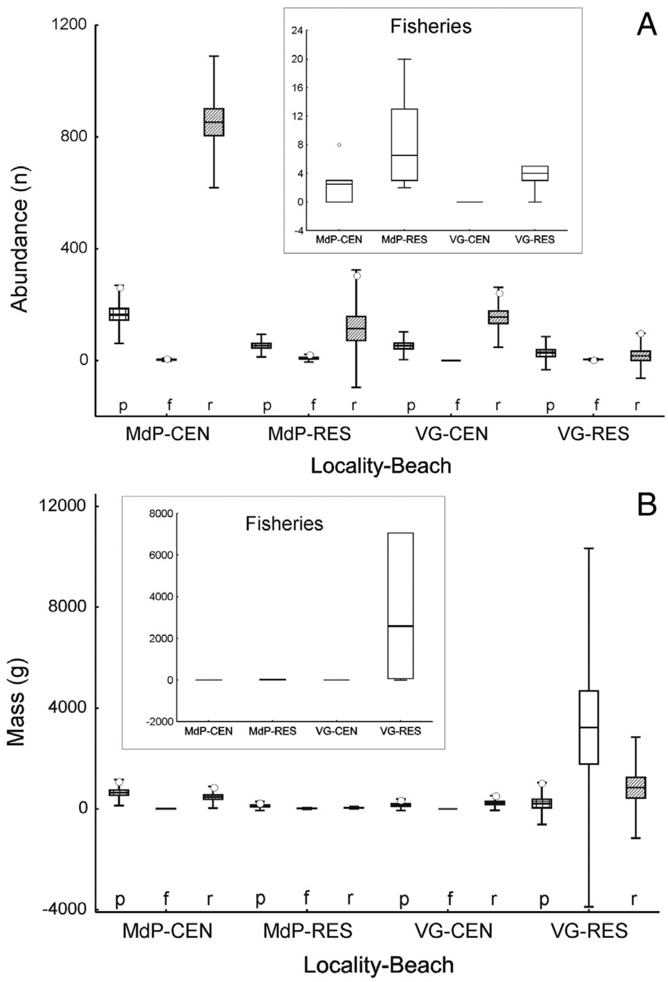

Fig. 3. Box plots representing the total abundance (A) and mass (B) of marine debris according their source: recreational (r), packaging (p) and fisheries (f) in center and reserve beaches of Mar del Plata (MdP-CEN and MdP-RES, respectively) and Villa Gesell (VG-CEN and VG-RES respectively). Box: Mean ± SE; Whisker: Mean ± 2*SD; Empty circles: outliers.

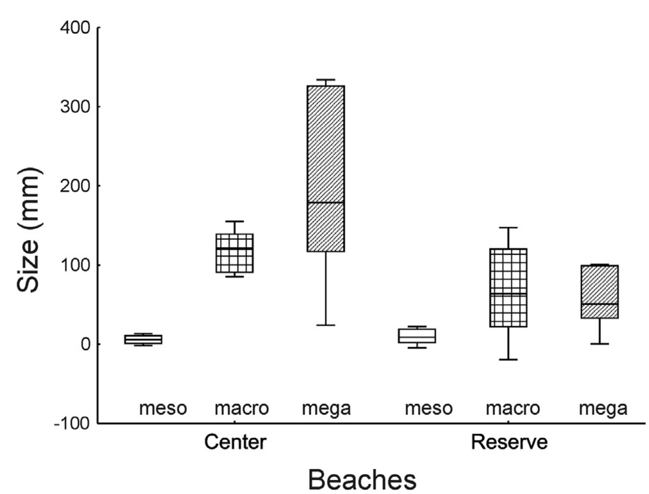

Fig. 4. Box plot representing the size of plastic debris: meso- (5–20 mm in length), macro- (> 20 mm) and mega-debris (> 100 mm) in the center and reserve beach of Mar del Plata. Box: Mean ± SE; Whisker: Mean ± 2*SD.

beaches there has been no exhausted evaluation of the growing issue of marine debris in the province of Buenos Aires in northern Patagonia.

4.1. Amounts and weights of marine debris at different spatial scales

The bulk of the marine debris (in terms of abundance) recorded in our study were found in the locality of Mar del Plata. This was expected as this is considered the most inhabited coastal city of Argentina. Other important coastal cities are among the most impacted by marine debris both in Northern (Ribic, 1998; Ross et al., 1991; Ariza et al., 2008; Rosevelt et al., 2013; among others) and Southern America (Bravo et al., 2009; Silva-Cavalcanti et al., 2009; Leite et al., 2014; Lozoya et al., 2015), including the Wider Caribbean Region (Corbin and Singh, 1993; Ivar do Sul and Costa, 2007). The city of Mar del Plata receives between 2 and 3 million of visitors particularly during the austral summer (Bouvet et al., 2005) and between 6 and 8 million tourists throughout the year (EMTUR, 2016). In addition, the coastal waters of Mar del Plata are affected by the city's harbor; a very busy site as it is the most important harbor in the country both in terms of numbers and diversity of fishing fleets (Lasta et al., 2001). Thus, this area supports a great variety of industries (e.g. ship designing and construction, ship lift, mooring and pilotage, floating dock, trailer, stowage, fueling, and diversion fish market among others) (CPR, 2016). The significant amounts of users and industries in the area may well be the main source of abundant debris in the area throughout the year (Lucero, 2011; Seco Pon and Becherucci, 2012; Denuncio and Bastida, 2014; Seco Pon, 2016). Not surprisingly, in areas with high intensive beach usage and industries including ports, there is evidence that direct inputs by beach users and maritime-related industries can significantly contribute to the deterioration of coastal environments (Willoughby, 1986; Ross et al., 1991; among others). However, the appearance and amounts of debris on a beach is dependent upon several factors, including its source, ocean currents, wind patterns and physiographic features (Walker et al., 2006; Bauer et al., 2008). Considering both localities, the greatest amount of debris was counted at the Center beach, an area facing the central business districts of the selected localities. The urban areas nearby those center beaches differ greatly in the visitors´ accommodation capacity, diversity of services, among others. However, they are characterized by a mix of daytime and nightlife activities (e.g. food and beverage shops, coffee shops, pedestrian streets, etc.), the former prevailing in the form of "beach and sun" activities (Brandani, 1987; Juárez and Mantobani, 2006; Furlan et al., 2012). These areas are also close to the most frequented sites used by users and visitors regardless of the localities, which in turn include the most littered streets, including in Mar del Plata (Seco Pon and Becherucci, 2012) and Villa Gesell (authors. comm. pers.).

In terms of mass, the majority of the marine debris was accounted in Villa Gesell. This is novel information considering the lower number of inhabitants and visitors annually and the level and extent of commercial and industrial development of this locality compared to Mar del Plata (Juárez and Mantobani, 2006; Marcomini and López, 2008). Remote areas, even if relatively away from coastal urban areas, may be affected by marine debris (Shimizu et al., 2008; Santos et al., 2009). In Mar del Plata, the bulk of the debris as per their mass were registered at the Center beach (in accordance with the abundance parameter), while in Villa Gesell was registered at the Reserve beach. This could be due to a less regular or reduced cleaning activities in beaches away of the center areas of Villa Gesell when compared to Mar del Plata. Interestingly, the selected remote beach in the locality of Villa Gesell was (still is) a quiet beach within the vicinity of the Faro Querandi Natural Municipal Reserve, an area relatively far away from Villa Gesell (Marcomini and López, 2008). However, this reserve is used by a great and diverse number of users (e.g. schools, fisherman, visitors, etc.) which may reach the area using the paved road infrastructure provided by the city council. Nonetheless, there is an important traffic due to off road vehicles transiting the sandy shore line linked to diverse activities (sport fishing, kayaking, surfing, sky-wing, etc.) including a competition for motorcycles and ATVs which has taken place each February in the area during the past 20 years (*Copa Enduro del Verano Gesell*; Municipalidad de Villa Gesell, 2016). This finding emphasizes the need of considering remote areas away from urbanization such as reserves, sanctuaries, national parks among other areas in marine debris studies (Benton, 1995; Walker et al., 1997; Edyvane et al., 2004; among others).

4.2. Composition and sources of marine debris

Following the global tendencies, cigarette butts and plastics comprised the dominant fraction of the marine debris both in terms of abundance and mass when combining the two studied localities. This is in line with earlier studies conducted in other coastal areas (Claereboudt, 2004; McDermid and McMullen, 2004; among others), including sandy beaches of the southern cone of South America, both in the Pacific (Bravo et al., 2009; Thiel et al., 2011) and in the Atlantic, including Brazil (Araújo and da Costa, 2007; Santos et al., 2005; Widmer and Hennemann, 2010; among others), Uruguay (Lozoya et al., 2015) and Argentina (Lucero, 2011; Denuncio and Bastida, 2014). This predominance of cigarette butts and plastics is partly due to the high persistence and low density of the latter mentioned items (Laist, 1987; Derraik, 2002; Sheavly and Register, 2007). Once introduced to the environment, cigarette butts, an item commonly made of cellulose acetate, degrade very slowly (Ach, 1993; Haynes et al., 1999) and only disintegrate under severe circumstances, including submersion in sewage (Novotny et al., 2009; Puls et al., 2011). According to the performed Correspondence Analysis, the center and reserve beaches of both localities were clearly distinguished on the abundances of certain categories of marine debris. Cigarette butts and metals prevailed in the center beaches while plastics and glass in the reserve beaches. Plastics virtually dominate the terrestrial- and marine-based debris globally (Derraik, 2002; Storrier et al., 2007; Jambeck et al., 2015), though cigarette butts are also considered a common and ubiquitous type of debris on the globe (Novotny and Zhao, 1999; Rath et al., 2012). Moreover, these items along with papers were the most common litter items recorded on the streets of the city of Mar del Plata linked to day- and nightlife activities (Seco Pon and Becherucci, 2012; Becherucci and Seco Pon, 2014). According to mass, cigarette butts and plastic comprised the main marine debris in the center and reserve beaches of both localities respectively. Moreover, and considering the center beaches, it was possible to distinguish between both selected localities in terms of their marine debris composition. In those beaches, categories including organic, metal and paper prevailed in Mar del Plata, while glass dominated in Villa Gesell. In the reserve beaches, plastic prevailed in both localities. The great amount and mass of plastic debris found in selected beaches of both localities may be due to the diversity of types and sizes of plastics and their versatility in manufacturing large (heavy) items which in turn may became a variable source of debris.

Recreational debris followed by packaging prevailed as the main sources of debris based on their abundance at the sampled beaches and localities, chiefly in the center beaches of Mar del Plata. This in line with previous studies conducted in other sandy beaches of Mar del Plata (Denuncio and Bastida, 2014). The most likely explanation to our findings may be linked to the prevailing "beach and sun" activity surrounding the sandy beaches of both localities, thus being areas with high intensive beach usage mainly during the summer months (Brandani, 1987; Juárez and Mantobani, 2006; Furlan et al., 2012). In the case of fisheries debris, this was mainly found in the reserve beaches of both localities. This pattern could be partially explained by a differential use by leisure and sport fisherman whom select remote areas to practice their sport (Lucifora, 2001). On the other hand, the mass related data showed that fisheries followed by recreational were the main sources of debris at selected beaches and localities, primarily in the reserve beaches of Villa Gesell. This could be explained by the dimensions and densities of debris, which included plastic cubes, safety plastic helmets and bouts, and parts of vehicles (i.e. tires, parts of refrigerators, etc.). This results suggest that fisheries related debris are linked to activities occurring primarily in the high seas, particularly fisheries and urbanization in coastal areas, which are washed ashore chiefly by local environmental conditions such as currents and storm winds. This is particularly true given the strong local littoral current flowing from south to north (Isla, 2006), and frequent storms from the southeast quadrant which constantly affect the coast (Manolidis and Alvarez, 1994).

4.3. Sizes of plastics in Mar del Plata

Though confined to Mar del Plata, this study showed that mega- and macro-plastic debris prevailed in beaches of this locality, with higher amounts of both sized-plastics on the center beaches when compared to the reserve beaches. The variation observed in the size of plastics may indicate that in the center beaches users utilize a diverse range of products made upon plastics, particularly frequently used (large) items such as nylon bags and straws, among others. This finding is of particular interest given that cleaning efforts led by both the city council and private sector takes place in sandy beaches of Mar del Plata during the summer months, thus indicating some ineffectiveness in the cleaning procedure (Boschi, 2004). Moreover, a smaller fraction of plastics (e.g. meso-debris) were found in similar proportions on both center and reserve beaches, indicating to some extent a long-lasting stranding period in marine areas such as the studied beaches (Powers, 1953). On the other hand, physical processes such as erosion and fragmentation of larger pieces may in turn increase the amounts of smaller fractions of plastics. Biological processes may also enhance the accumulation of smaller pieces of plastics, such as the activity of burrowing crabs (Iribarne et al., 2000).

5. Conclusions

We are aware of the fact the survey methods might bias the amounts and weights of any specific type of debris registered as we excluded the buried fraction. Furthermore, given that our study was based on a limited temporal scale it is not clear whether the samples represent debris deposited over known or unknown time intervals. However, it is clear that Mar del Plata, apart from being the largest coastal city of Argentina, can also accommodate a larger number of visitors during the summer months when compared to Villa Gesell. Still, at both localities, the beach facing the cities´ central business districts are heavily affected by a mix of daytime and nightlife activities. The diversity and "around-the-clock" behavior of these activities may result in adjacent beaches being heavily numbered by chiefly land-based debris. In Villa Gesell, and primarily in the Reserve beach, debris of marine-related origin prevailed, thus accounting for heavier items. This emphasizes the need for including areas away from urbanized coastal centers in marine debris studies. Addressing the problems associated with marine debris in coastal localities in northern Argentina may include intensive educational and advertising campaigns oriented chiefly to beach users, fisherman and owners of adjacent commercial and public facilities to create greater awareness of the debris problem in the area, particularly in regards to cigarette butts and plastics. Further research should include a larger number of beaches and surveys along with an ampler spatial coverage for more representative analysis, also evaluating different features of the community perception to environmental issues (including marine debris) such as educational level, age, gender, type of residence, income, marital status, and type of city user, among other factors on the impact of marine debris. Future surveys should also asses the buried fraction.

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