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Spatial and temporal variations of urban litter in Mar del Plata, the major coastal city of Argentina

Juan Pablo Seco Pon *, Maria Eugenia Becherucci

14 de julio 1425 PA (B7600GMI), Mar del Plata, Argentina

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ABSTRACT

Urban littering is considered an important environmental and public issue globally. This problem is growing considerably within coastal communities of the southern region of South America. The goals of this study were to assess (1) the abundance and composition of urban litter; (2) the spatial and temporal variations of its abundance; and (3) the relationship between the abundance of litter and three anthropogenic variables (i.e. abundance of pedestrians, of parked vehicles, and of trash bins) in Mar del Plata, the most populated coastal city in Argentina. Eighty-eight transects, each covering 1425 m^2, were sampled along four sites from April 2008 to March 2009. Results showed 20,336 items (ca. 14 items per m^2) of which cigarette butts (33%), papers (31%), and plastics (22%) were the most commonly littered items. Higher amounts of litter were found in an industrial area (city's harbor), while the abundance of litter appeared relatively even throughout the year. Redundancy analysis techniques indicated a high abundance of all three anthropogenic variables associated with the central business district area of the city and an area in close proximity to a major seaside resort, where cigarette butts and papers dominated. This is the first study that has examined spatial and temporal variations of urban litter in a high-density coastal city in Argentina. Our results showed that addressing the problems associated with urban litter must include intensive educational and advertising campaigns directed at pedestrians and owners of parked vehicles, but waste reduction, clean-up operations and law enforcement should be also considered.

1. Introduction

In this paper we refer to "littering" as throwing waste products (including cigarette butts, papers, plastics, metals, glass, and among others) on the public streets as opposed to disposing of them properly. In urban high-density areas, litter has become an increasingly obvious and pervasive problem (Chapman and Risley, 1974; Arafat et al., 2007). The accumulation of urban litter, defined as visible solid waste emanating from the urban environment (Armitage and Rooseboom, 2000) and hereafter called simply "litter", is a persistent and expensive problem affecting the economies and inhabitants of mainland, coastal or waterside communities worldwide (Stein and Syrek, 2005; Arafat et al., 2007). To clarify the current dimensions of this problem in the marine environment, the first National Coastal Contamination Census took placed in argentine beaches in 1995 throughout almost 2110 km of coastline (Esteves et al., 1997). Twelve years latter, a second census revealed that the marine environments of the majority of the coastal cities still have unresolved environmental problems (i.e. urban and fishery open dumps in close proximity to the coast, increased fishing, oiling transportation, etc.) mostly due to the significant increase in the number of inhabitants (Colombini et al., 2008). Accordingly, the increment in the number of inhabitants will generate not only benefits for the local economy but will significantly enhance the generation of surplus solid litter and sewage sludge (Araújo and Costa, 2004). Despite there being a consensus on the necessity of monitoring litter pollution in the marine environment, particularly in the southern region of South America (see Araújo and Costa, 2003, 2004, 2006; Weztel et al., 2004; Santos et al., 2005; Bravo et al., 2009), very little attention is currently being paid to the amount of litter in coastal cities of Argentina.

These days, littering is considered an environmental crime in many countries (e.g. Australia, United Kingdom, and United States), because it creates a danger to public health and safety (Stein and Syrek, 2005). Lists of litter in national cities are sparse in the literature and have limitations. However, it was possible to distinguish some major sub-categories of litter by their nature and how people acquired the items, namely: (1) paper (e.g. packaging materials and

* Corresponding author. Present addresses: Laboratorio de Vertebrados, Instituto de Investigaciones Marinas y Costeras (IIMyC), Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Funes 3250 (B7602AYJ), Mar del Plata, Argentina; Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Av. Rivadavia 1917 (C1033AAJ), Ciudad Autónoma de Buenos Aires, Argentina. Tel.: +54 223 4752426x466.

E-mail addresses: secopon@yahoo.com.ar, secopon@mdp.edu.ar (J.P. Seco Pon).

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disposables such as advertising flyers and newspapers); (2) plastic (e.g. containers, bottles, shopping bags, candy, lollipop wraps etc.); (3) cardboard; (4) glass (e.g. bottles, broken pieces); (5) aluminum (e.g. cans, tear-off closures, etc.); (6) wood; (7) cloth remains; (8) cable; and product remains such as (9) cigarette butts, and (10) others. This study aimed to assess the abundance of litter in Mar del Plata city, the most populated coastal city in Argentina (CIEM, 2010). Our research focused on three aspects (i) the abundance and composition of litter; (ii) the spatial and temporal variations of its abundance, diversity, richness and evenness within the study area; and (iii) the relationship between the abundance of litter and the abundance of pedestrians, parked vehicles, and trash bins.

2. Materials and methods

2.1. Study area, sampling methodology and classification of litter

Mar del Plata city (38°00′S, 57°33′W) (hereafter MDP) encompasses ca. 7950 ha and holds more than half a million inhabitants (366.6 habitants per km^2), thus being the most populated coastal city in Argentina (CIEM, 2010). Mar del Plata city is truly multifunctional as it supports a wide range of industries, including tourism, fishing, cereal, and sport industries. Moreover, MDP is considered the oldest and most popular seaside resort in the country (Juárez and Mantobani, 2006), having an overall lodging capacity for more than 325,000 visitors (including hotels, hostels, camping-sites and apartments). Interestingly, the city receives between 2 and 3 million tourists during summer months (December–March) (Bouvet et al., 2005).

Four urban areas (Center, Chauvin, Harbor, and Perl) were selected at MDP for sampling of urban litter (Fig. 1). The choice of the locations was based on the different dynamic characteristics of the city, the frequency and density of city users, the level of urban occupation and industrialization. Site Center (83 ha) is located in the central business district area of the city, which is heavily frequented by locals and visitors due to the easy access and proximity to commercial and public facilities (e.g. cathedral, judicial palace, public beaches, shops, theatres, walkways, etc.). Site Harbor (84 ha) is the area surrounding the city's harbor; a very busy site as it is the most important harbor in the country (Errazti and Bertolotti, 1998; Lasta et al., 2001). Thus, it 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, 2011). Site Perl (96 ha) is an area in close proximity to a major seaside resort to the north of the city, being intensively visited by locals and visitors due to the easy access and proximity to public facilities (e.g. public beaches, a faculty of law and a science museum). Site Chauvin (77 ha) has opposite characteristics; it is a very quiet residential high-income housing area. The area has relatively no tall buildings and is away from commercial and industrialized zones and away from the site Harbor, but relatively close to sites Center and Perl (Fig. 1).

We surveyed randomly two transects in each area monthly from April 2008 to March 2009. Each transect or sampling unit was about 1425 m^2, comprising three blocks long (87 m each and the 12 m in between) and the sidewalk (4 m) plus 1 m of curb wide (Fig. 2). Each transect was covered once to count and classify all visible litter. Litter was not collected or weighted. Litter was classified in ten groups according to its composition: cable, cardboard, cigarette butts, cloth, glass, metal, paper, plastic, wood, and other articles. The plastic litter category included (1) PET fizzy drink and mineral water bottles; (2) lids and caps of food stuff containers; (3) candy and lollipop wraps; (3), slash bags; (4) biscuit, pop-corn and crisps packs; (5) paint buckets; (6) cellophane; (7) cups, plates and cutlery and other disposable utensils; (8) nylon ropes; (9) nets; (10) others, including parts of computer and electrical appliances, etc.

Items, such as leaves, branches and remains of pruning activities were not counted as litter.

During each survey we also recorded the number of pedestrians, parked vehicles and public trash bins (hereafter simply called anthropogenic variables). People walking into or along the transects were considered pedestrians; those walking away from it were excluded. Vehicles parked on the curb were counted; those double parking or in transit (from in and out the transects) were excluded. Public trash bins included (1) 50 lts plastic containers (ca. 395 × 250 × 650 mm) generally set on a pedestal or (2) 110 lts metal containers (ca. 540 × 320 × 670 mm) usually sitting on the ground on the sidewalk. Each transect was covered in about 10 ± 2.7 min (n = 88).

2.2. Statistical analysis

Litter abundance (A), richness (S, total number of items), diversity Shannon (H') (Shannon and Weaver, 1963) and evenness (J') (Pielou, 1969) indices were calculated for each sampling site.

We used a two-way ANOVA to test our hypotheses concerning the effects of sampling site and season on the mean abundance

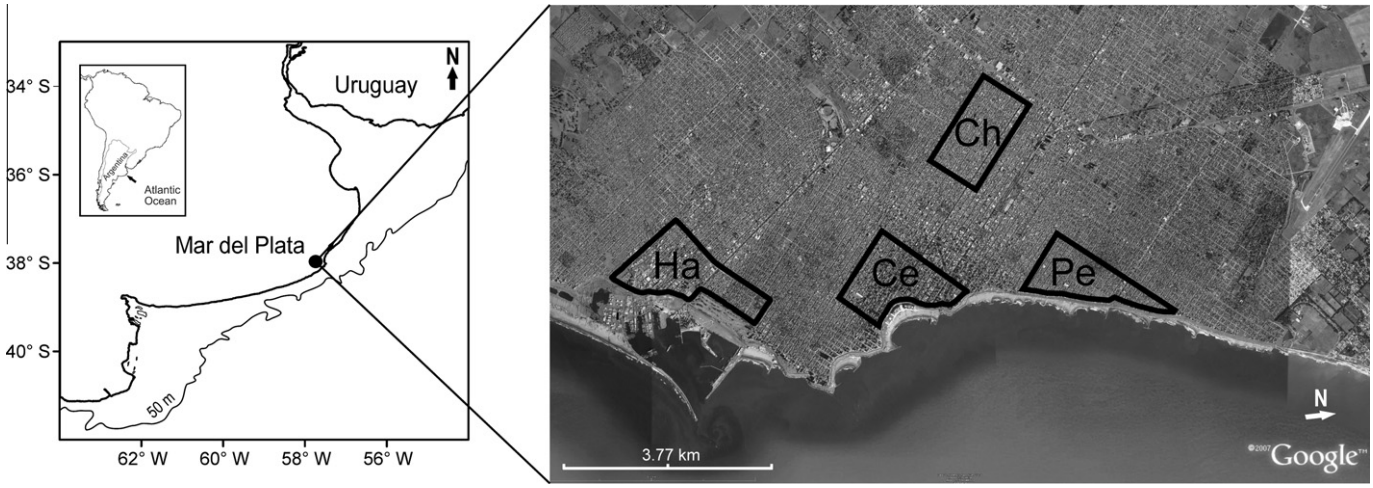

Fig. 1. Map showing the location of the four study sites (Ce: Center, Ch: Cauvin, Pe: Perl, and Ha: Harbor) in the southeast of Argentina. The inset shows the location of Mar del Plata city. Image taken from Google Earth™.

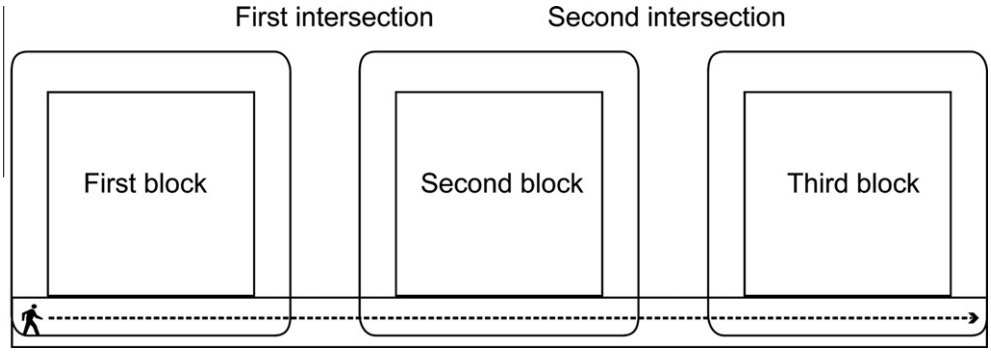

Fig. 2. Survey design. The total area of each transect was approximately 1425 m^2, as each one was 5 m wide and extended for three blocks (87 m (street length) plus 12 m (intersection length)). See Section 2 for reference.

of litter and the mean litter "community parameters" (S, H', and J'). Comparisons among means were performed using *a posteriori* Tukey test (Zar, 1999). The relationships among the average abundance of the most commonly littered items (e.g. cigarette butts, papers and plastics; see Section 3) and three anthropogenic variables (abundance of pedestrians, of parked vehicles, and of trash bins) were analyzed with an analysis of redundancy (RDA). RDA is the canonical form of principal component analysis, a form of direct gradient analysis (ter Braak, 1995). The pattern of abundance of each selected litter item among the sampling sites can be inferred in exactly the same way as in a principal component analysis biplot, and so may the direction of variation of each anthropogenic variable.

To run the ANOVA, litter "community parameters" (S, H', and J') data were transformed using fourth root (x) to accomplish assumptions of normality and variance homoscedasticity (Zar, 1999). Statistical analysis of the data was performed using R software, Version 2.5.1. (R Development Core Team, 2004). RDA biplot and singular value decomposition was obtained using the subroutine Biplot of the Excel Windows©.

In all cases, differences were considered significant where P was <0.05. Unless sated otherwise, all reported values are means ± SD.

3. Results and discussion

3.1. Overall abundance and composition of litter

We counted 20,336 items (14.27 items per m^2) over the study period; these were classified into the ten groups of litter (Table 1). 6717 items accounted for cigarette butts (33%), 6340 accounted for papers (31%), and 4533 accounted for plastics (22%). Based on our results cigarette butt, paper, and plastic litter should be considered an important environmental and public issue in MDP since they comprise 86% of the total litter surveyed in this study. This situation of cigarette butts–papers–plastics dominated litter was found to be common in other cities of the Northern Hemisphere (see Keep America Beautiful, 2009), in part because of the high persistence (time integration effect) (except for papers) and low density of the abovementioned items which accumulates in the streets. For example, cigarette butts – which most commonly contain cellulose acetate – may persist under normal environmental conditions for 18 months or more (Ach, 1993). Cigarette butts are the most common and ubiquitous type of litter on earth (Register, 2000), with at least 4.5 trillion filter-tipped cigarettes butts deposited annually in the world (Novotny and Zhao, 1999). Plastics may persist for centuries (Ryan, 1987; Goldberg, 1997), while glass may take million years to biodegrade. Although glass litter occurred in around 5% of the surveys, it is still of some concern given that glass bottles and broken pieces can seriously injure both animals and humans (Al-Khatib, 2009). For example, a high incidence of injuries caused by street glass was reported among children in Karachi, Pakistan (Rizvi et al., 2006), and in the Nablus district, Palestina (Al-Khatib, 2009). If not properly and safely removed, street litter can be transported by wind or storms into the drainage system, which in turn may transport these items to the beaches or other coastal environments (Armitage and Rooseboom, 2000; Al-Khatib et al., 2009; Widmer and Reis, 2010). Part of the litter recorded in the present study may be one of the sources of litter found on beaches or along the coastline. For example, plastics followed by papers were the most common man-made debris found in beaches of MDP (Colombini et al., 2008), while plastics where the main source of human debris in the aquatic environment of the Río de la Plata and its surroundings (Acha et al., 2003). Clearly, linking litter to their sources is a key issue to effectively minimize the problem in coastal and oceanic areas (Earll et al., 1997).

3.2. Spatial and temporal variations of litter abundance and litter community parameters

Using two-way ANOVA, we found no significant interaction between sampling sites and seasons for abundance of litter (two-way ANOVA $F_{3,88} = 0.438$, $P = 0.909$) and for overall litter "community parameters" (two-way ANOVA, all $P > 0.151$).

Still, there were significant spatial differences in the abundance of litter in MDP (one-way ANOVA $F_{3,88} = 11.805$, $P < 0.001$), with greatest amounts of litter found at Harbor site (7520 objects, 37%), followed by Center (5356 objects, 26%) and Perl sites (4866 objects, 24%). Tukey *post hoc* comparisons revealed that at the Chauvin site the amounts of litter (2594 objects, 13%) were significantly lower than from the other sites (Tukey *post hoc* comparisons $P < 0.05$). With respect to litter "community parameters", we found significantly lower richness of litter at the Chauvin site (one-way ANOVA $F_{3,88} = 5.199$; $P = 0.01$; Tukey *post hoc* comparison $P < 0.026$), whereas diversity of litter were significantly lower only at the Chauvin site than from the Port site (one-way ANOVA $F_{3,88} = 2.797$, $P = 0.045$; Tukey *post hoc* comparisons $P = 0.032$). Eventually, evenness of litter was not affected by sampling site (one-way ANOVA $F_{3,88} = 1.328$, $P = 0.27$).

The city's harbor was the most heavily littered area in MDP, where plastic dominated the litter fraction. The preponderance of plastics was similar to that reported in others harbors globally (e.g. Ross et al., 1991). Waste appears to enter harbor surroundings via numerous pathways, both from land and offshore (ABP Research, 1999). The harbor of MDP (and its surroundings) are subject to multiple uses: they provide the maritime access to the majority of the national coastal and high-seas commercial fishing fleet (Lasta et al., 2001; Cousseau and Perrotta, 2004), but also support cereal (storing), fuel supply (diesel and unleaded gasoline),

Table 1
Relative abundance, proportion of total litter counted, mean (±SD) count per site, maximum (max.) count among all surveys ($n = 88$ transects), and incidence of occurrence for litter recorded at four sites in Mar del Plata city, Argentina, April 2008–March 2009.

Sampling site/ item	Relative abundance	% Total	Mean (SD)	Maximum	% Occurrence
Chauvin site (n = 23)					
Cable	0	0	0	0	0
Cardboard	151	5.82	6.29 (5.59)	24	91.2
Cigarette butt	820	31.61	34.17 (44.47)	185	87.5
Cloth	7	0.27	0.29 (0.81)	3	12.5
Glass	33	1.27	1.43 (1.75)	5	58.3
Metal	24	0.93	1.04 (2.60)	12	29.2
Paper	836	32.23	34.83 (25.89)	105	95.8
Plastic	683	26.33	28.46 (20.68)	73	95.8
Wood	17	0.65	0.74 (1.18)	4	41.2
Other*	23	0.89	0.96	5	37.5
Total	2594				
Center site (n = 22)					
Cable	5	0.09	0.21 (0.59)	2	12.5
Cardboard	233	4.37	9.71 (8.53)	25	79.2
Cigarette butt	2029	37.88	84.54 (63.69)	244	91.7
Cloth	28	0.52	1.17 (1.40)	5	54.2
Glass	66	1.23	2.75 (3.07)	14	83.3
Metal	157	2.93	6.83 (8.79)	33	62.5
Paper	1727	32.24	71.96 (51.65)	206	91.2
Plastic	949	17.72	35.54 (32.11)	129	91.2
Wood	64	1.19	2.67 (3.23)	12	66.7
Other*	98	1.83	4.08 (4.06)	11	75
Total	5356				
Harbor site (n = 23)					
Cable	32	0.43	1.33 (2.44)	10	37.5
Cardboard	433	5.76	18.04 (14.43)	46	95.8
Cigarette butt	2241	29.8	93.38 (86.76)	390	95.8
Cloth	71	0.94	2.96 (5.41)	20	50
Glass	54	0.72	2.25 (2.36)	8	70.8
Metal	180	2.39	7.50 (7.87)	24	66.7
Paper	2330	30.98	97.08 (50.80)	184	95.8
Plastic	1909	25.39	79.54 (52.05)	269	95.8
Wood	108	1.44	4.50 (5.56)	19	66.7
Other*	162	2.15	6.75 (7.01)	25	75
Total	7520				
Perl site (n = 20)					
Cable	16	0.34	0.67 (1.24)	5	29.2
Cardboard	291	5.98	12.13 (15.95)	57	75
Cigarette butt	1627	33.44	67.79 (50.36)	156	83.3
Cloth	27	0.55	1.13 (2.13)	10	45.8
Glass	118	2.42	4.92 (4.60)	13	75
Metal	170	3.49	7.39 (10.16)	30	54.2
Paper	1447	29.74	60.29 (48.30)	173	83.3
Plastic	992	20.39	41.33 (34.21)	110	83.3
Wood	89	1.83	3.71 (5.38)	18	62.5
Other*	89	1.83	3.71 (4.81)	17	58.3
Total	4866				

* Other included parts of computational appliances, pieces of foam, mattresses, etc. The items are listed alphabetically.

military (an Atlantic Naval Base which holds the National Maritime Patrol Division and the Command of the Force of Submarines combined), sport (walking, running, cycling, ATV riding, fishing and kayaking), and tourism (mainly public and private open beaches use, but also wildlife watching (chiefly a male South American sea lions *Otaria flavescens* colony within the port) industries, among others) (CPR, 2011). As a result, the various industries based in and around the local harbor may in themselves be waste producers. A study on Halifax Harbor in Canada, for example, showed that 62% of the total litter in the harbor originated from recreational and land-based sources activities (Ross et al., 1991). Accordingly, the areas in which people drop litter obviously affect people's littering behavior. Dirtiness of the streets might encourage people to throw litter in a particular area or site (Arafat et al., 2007; Al-Khatib, 2009), and this may hold true for Harbor site.

Interestingly, we found no significant seasonal variation in the abundance of litter along MDP throughout the year (one-way ANOVA $F_{3,88} = 3.070$; $P = 0.05$) (Table 2). However, there were significantly lower richness (one-way ANOVA $F_{3,88} = 7.825$; $P = 0.01$; Tukey *post hoc* comparison $P < 0.04$) and diversity of litter (one-way ANOVA $F = {}_{3,88} = 4.787$, $P = 0.01$; Tukey *post hoc* comparisons $P = 0.01$) during summer than from the rest of the seasons. Finally, evenness of litter was not affected by season (one-way ANOVA $F_{3,88} = 2.207$, $P = 0.09$) (Table 2).

The significant lower diversity and richness of litter during summer was unexpected given that the city usually undergoes a highly marked peak visitor season during the late December–February summer holidays (see Bouvet et al., 2005). The most likely explanation for the lowered drop in both community parameters (diversity and richness of litter) during summer is the fact that the sampling areas we choose were less popular than ocean-front beaches. Another cause may be a major frequency of street sweeping or an enhanced informal sector partnership in solid waste management during summer, among other factors. Massive beach tourism prevails as one of the main economic industries in most of the national littoral districts, and MDP is not an exception (Dadon and Mateucci, 2006). In the last years the beaches of MDP received around two million visitors during summer (Bouvet et al., 2005). Accordingly, such environment ranked as the second most littered coastal district within the Buenos Aires Province in 2007 (Second National Coastal Contamination Census) (Colombini et al., 2008). Given the high recreational value offered by the beaches of MDP and the fact that beaches are susceptible to the accumulation of litter originating from diverse sources (Araújo and Costa, 2006; Elías et al., 2006; Araújo and Costa, 2007; Colombini et al., 2008) additional research is needed to quantify the significance of land and marine-based sources of litter in the contamination of local beaches.

3.3. Relationship between abundance of litter and anthropogenic variables

Axis I of the RDA performed with the most commonly littered items (i.e. cigarette butts, papers and plastics) and all anthropogenic variables (Fig. 3) explained 92% of the variance, while axis II explained 7%, from a total variance of 99%. A high abundance of pedestrians, of parked vehicles and of trash bins were associated

Table 2
Mean abundance (A), richness (S), diversity (H'), and evenness (J') of all litter items counted at Mar del Plata city throughout a year ($n = 88$ transects).

Season	A	S	H'	J'
Autumn	211.83	7.50	0.56	0.68
Winter	248.10	7.13	0.52	0.67
Spring	236.58	8.38	0.64	0.72
Summer	150.92	5.50*	0.49*	0.71

* Indicates significant differences among seasons ($P < 0.05$).

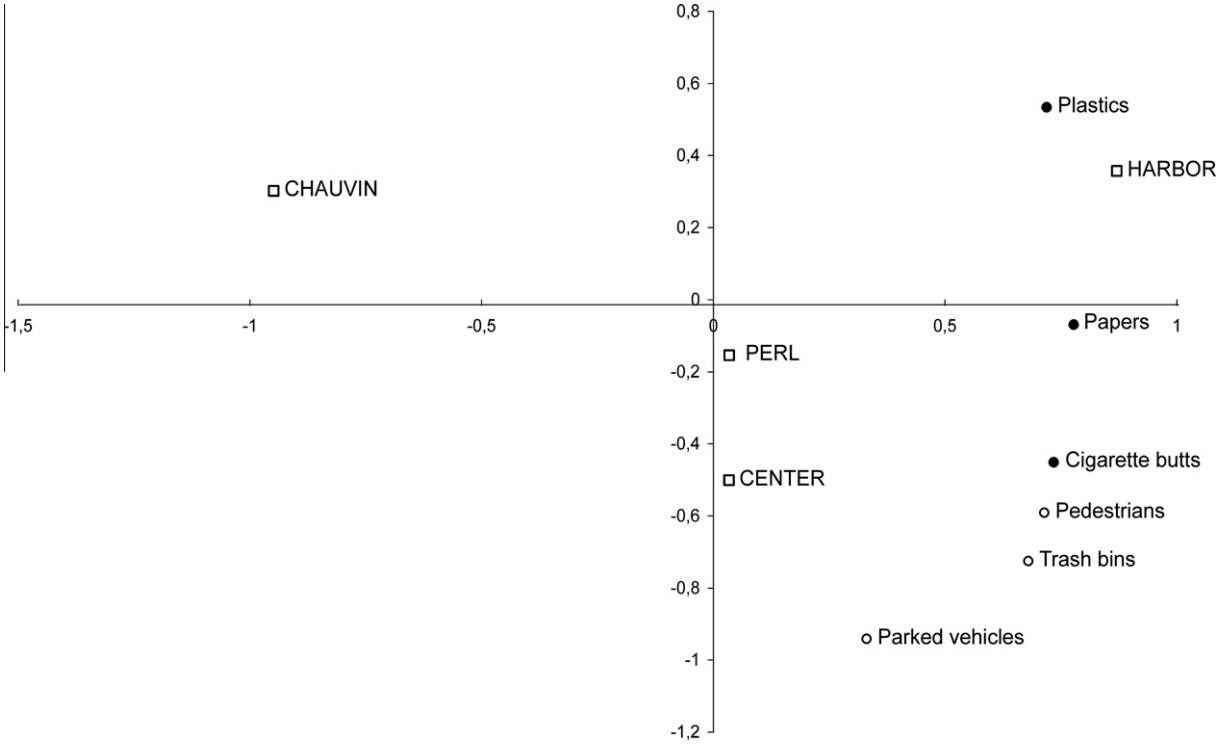

Fig. 3. Redundancy analysis of "anthropogenic variables" (abundance of pedestrians, of parked vehicles, and of trash bins) (open circles) and the most commonly littered data (i.e. cigarette butts, paper and plastics) (full black circles) within sampling sites (areas) in the city of Mar del Plata (open squares).

with Center and Perl sites, where cigarette butts and papers dominated. The Harbor site had high amounts of plastics. Interestingly, there were no dominant littered items nor anthropogenic variables associated with Chauvin site (Fig. 3).

Center and Perl sites (along with Harbor site) are heavily used areas by locals and visitors given the great variety of activities that take place in them and also because of their proximity to the city's coastline. Much of the debris like cigarette butts originates in densely populated areas where they are dropped casually by the smoker (Novotny and Zhao, 1999) or by people who "toss their butt" before entering their parked vehicles (authors, pers. obs.). Beyond asthetics problem, each cigarette butt holds tar, cadmium, lead and arsenic, which may be an acute health hazard to some key organisms in aquatic communities (Register, 2000), and to some extent humans (CDCP, 1997). Moreover, cigarette butts being thrown by pedestrians or from vehicles may be a fire hazard (Arafat et al., 2007). Public trash bins– whose placement, maintenance and design are the responsibility of the city council –did not affect the amount of cigarette butts and papers. Interestingly enough though, studies undertaken in Melbourne, Australia have shown that providing additional trash bins does not necessarily reduce the amount of litter there (*in litt.*, Marias and Armitage, 2004). The most likely explanation for this relationship is that once trash bins become replete with litter, they rapidly turn into "dirty points" as the amount of waste increases around them due to a lack of control or periodical collection (Puldain and Ragonese, 2010). Moreover, public trash bins are, in general, not properly built to contain litter such as cigarette butts (authors, pers. obs.). Still, insufficient availability of trash bins in the streets may be an important cause cited as an excuse to litter (Al-Khatib, 2009). Nonetheless, attempts to reduce litter should be also aimed at considering the design and placement of trash receptacles (Williams et al., 1997). Furthermore, the design of the littered object has a significant influence on the chances of it being littered (Wever et al., 2010). Accordingly, through persuasive or non-activating design of products and trash bins (see De Kort et al., 2008; Wever et al., 2010) we may also remind people of socially desirable behavior.

4. Conclusions and recommendations

The results of this study indicate that cigarette butts, papers, and plastics were among the most common litter in the city of MDP. The preponderance of these items was similar to that reported in several cities from the Northern Hemisphere. Thus, our results may be indicating that the level of street dirtiness in MDP should be considered important at least for some litter items. However, the survey methods employed might bias the amounts of any specific type of litter recorded, particularly given that our transects included street intersections which can allow litter to be transported away due to traffic, street sweeping services, and prevailing winds and run offs among other factors. Moreover, given that our study was based on regular counts from random transects, it is not clear whether the samples represent litter deposited over known or unknown time intervals. Still, this study showed that site factor significantly affected the abundance and distribution of litter in the streets of MDP. Likewise, the three most littered sites within MDP where those areas close to the city' coastline. Interestingly though, the dirtiness of the streets in MDP was even throughout the year at the study area, in spite of the high peak visitor season during summer. Addressing the problems associated with urban litter in MDP should include intensive educational and advertising campaigns directed primarily to pedestrians and owners of parked vehicles to create greater awareness of the litter problem in the area, particularly in regards to cigarette butts and papers. However, waste reduction to diminish the generation of urban waste, clean-up operations to avert urban waste from getting into the environment, and law enforcement to guarantee compliance should be discussed (Menna et al., 2002; Marias and Armitage,

2004). Given that diverse socio-economical factors can affect public attitude towards littering and frequency of littering (see Arafat et al., 2007; Al-Khatib et al., 2009), further investigations are needed to study the influence of educational level, gender, sex, type of residence, income, marital status, and type of city user (local vs. tourist), among other factors on people's littering behavior in MDP.

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