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Seasonal evolution of beach waste and litter during the bathing season on the Catalan coast

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Abstract

Beach waste and litter composition and evolution on popular urban (located in the main nucleus of the municipality) and urbanized (located in residential areas outside the main nucleus) beaches of the Costa Brava (Catalan coast) were assessed during the bathing season. Waste and litter production (amount and composition) were affected by urbanization and varied during the summer. Urban beaches had higher densities of waste deposition and lower percentages of organic, domestic and other miscellaneous waste than urbanized beaches. Litter characteristics were also influenced by type of beach, and varied during the season as a consequence of beach use and cleaning practices, but not environmental factors. Urbanized beaches obtained higher scores for aesthetic quality of sand than urban beaches, and small-sized litter tended to accumulate during the season in the beach of Lloret Centre. The most important problems are management of recyclable materials, litter left by users on the sand, and separation of sand from litter. In addition, current efficiency of mechanical cleaning is low, especially in the withdrawal of cigarette butts. These analyses highlight problems that should be addressed in future management of area beaches.

1. Introduction

The amount of waste produced is currently a matter of great concern in developed countries, and waste management has been considered one of the most important environmental problems affecting the members of the European Union (EU) (Stanners and Bordeau, 1995; EEA, 2005). The EU's Sixth Environment Action Programme identifies waste prevention and management as one of its four top priorities. Between 1995 and 2003, the amount of municipal waste generated in Western Europe increased by 22%. If current patterns are not altered, by 2020 45% more waste may be generated than in 1995. Although some countries have fulfilled the requirements established by Directive 94/62/EC on packaging and packaging waste (requirements of) that defines mandatory values (in percentage) for the reduction, transformation and recycling of packaging waste, the amount of packaging waste is still increasing. Furthermore, our "throwaway" ethos frequently transforms waste into litter (Cutter et al., 1991), which is increasingly accumulating in many previously unpolluted natural environments.

The deterioration of the environmental quality of coastal areas as a consequence of human activity is a problem that has been recognized worldwide. Overcrowding of coastal areas has brought about a sharp increase in waste production in coastal towns (Clark, 1983; Mora, 2004). Analysis of monthly waste production data from various municipalities located on the Catalan coast demonstrates that waste production is much larger in summer than the rest of the year. This seasonal variability sometimes makes it difficult to establish proper waste management programs and facilities aimed at prevention and recycling.

Other than the collection of technical data from the administrative agencies responsible for beach management (e.g., Servei de Prevenció i Medi Ambient, 2005) (Prevention and Environment Service), few studies have been made

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on waste cycles in coastal areas and on beaches. Research on waste components and fluxes has recently been carried out in some urban areas (Tinmaz and Demir, 2006; Henry et al., 2006) and in tourist resorts (Kuniyal et al., 2003). Other waste management research has dealt with consumers' habits and attitudes (Junquera et al., 2001). Waste/litter production and composition, as well as its sources and seasonal variability, depend on natural and social characteristics. The influence of environmental values, situational factors and psychological variables has been demonstrated (Barr, 2001, 2004). Factors affecting characteristics of waste and litter management of beaches, though, have not been analyzed.

A number of studies have quantified beach litter and defined its components. Litter composition varies in the different studies. The most abundant components are plastics (Gabrielides et al., 1991; Silva-Iñiguez and Fischer, 2003; Frost and Cullen, 1997; Golik and Gertner, 1992; Willoughby et al., 1997; Williams and Tudor, 2001), wood (Silva-Iñiguez and Fischer, 2003) and cigarette butts (Rodríguez-Santos et al., 2005). Organic debris is also a very important component (Silva-Iñiguez and Fischer, 2003; Claereboudt, 2004). The origin and factors that affect litter production have been identified. In many places, litter is land-based (Silva-Iñiguez and Fischer, 2003; Moore et al., 2001) although in other locations, not close to populated areas, the origin is marine (Edyvane et al., 2004; Rodríguez-Santos et al., 2005; Moore et al., 2001). The quantity of litter is inversely related to its geographical distance to a population centre and directly to the number of users (Gabrielides et al., 1991; Frost and Cullen, 1997). Studies also have been made of the seasonal variation of litter during the summer season. The importance of beach cleaning (Somerville et al., 2003; Moore et al., 2001; Velander and Mocogni, 1998), local activities (Claereboudt, 2004) and the action of waves, that clean beaches during winter, (Golik and Gertner, 1992; Gabrielides et al., 1991) have been remarked. Long-term litter accumulation trends have also been established. Some studies demonstrate that litter levels have increased substantially during last decades (a twofold increase in some cases) (Thompson et al., 2004; Willoughby et al., 1997; Uneputty and Evans, 1997; Velander and Mocogni, 1998). In some cases, though, local factors may have reversed the common trend (Edyvane et al., 2004). It has been demonstrated that beach cleaning operations are in some cases just a temporary solution. An important part of litter returns to the beach within 1 year (46%). Measures to avoid pollution at the source should be applied (Williams and Tudor, 2001). Other research projects have covered methods for surveying litter. Bias towards highlighting particular litter types exists. There are advantages and disadvantages in each method. The aim of the study should determine the choice (Velander and Mocogni, 1999). Ribic and Ganio (1996) studied the probability of detecting a specified effect in beach litter trends by a US monitoring program, by means of power analysis. They concluded that the estimation of the sample size depends on reliable estimates of the mean, variance and covariance of debris items of interest. The economic impact of pollution events has also been studied. The aggregated economic losses of 1998 pollution events in New Jersey were in the range of $379.1 million to $1597.8 million (1987$) (Ofiara and Brown, 1999). Ballance et al. (2000) determined that cleanliness is the most important factor in influencing choice of beach. Litter densities of more than 10 large items per m^2 would deter 40% of foreign tourists and 60% of domestic tourists from returning to the polluted beaches. Nevertheless, there are still important misunderstandings in the assessment and management of litter in the beach environments. The dynamics of the production and management of waste (residues thrown into bins) and litter (residues present on sand and water surfaces) over the summer season have not been accurately quantified. Sampling has not been intensively undertaken during the bathing season and the efficiency of beach management litter removal practices has not been assessed. The amount of waste and litter production in proportion to total municipal waste is unknown. Differences in waste and litter production according to beach types have not been established, and the possibility of separating and recycling waste on beaches has not been widely covered.

Within this context, the main aim of this paper is to analyze the seasonal evolution of waste and litter on beaches during the bathing season on a coast subject to mass tourism. Our objective is to help to improve waste and litter management of beaches. This work may also be helpful when studying local factors responsible for waste/litter production and management characteristics of Mediterranean beaches. Although the paper uses Catalan beaches in northeast Spain to illustrate the processes analyzed, the results and approach can be extrapolated to beaches used for similar purposes and under similar management schemes.

2. Methodology

2.1. Study area

Our study analyzed beaches in three towns of the southern Costa Brava (Girona, Spain) (Fig. 1), which offers a variety of beach types ranging from highly urban ones to urbanized ones and represents the different ways in which beaches are used. Urban beaches are those located in the main nucleus of the municipality. Urbanized beaches are the ones located in residential areas outside the main nucleus of the municipality. From south to north, these towns are Blanes, Lloret de Mar, and Tossa de Mar. To varying degrees, as in other tourist resorts, these towns have suffered during recent decades from the effect of a high concentration of tourists eager to find environments conducive to spending their leisure time. The quantity, composition and characteristics of beach waste were assessed on two urban beaches (Lloret Centre beach and Tossa-Mar Menuda beach) and two urbanized beaches

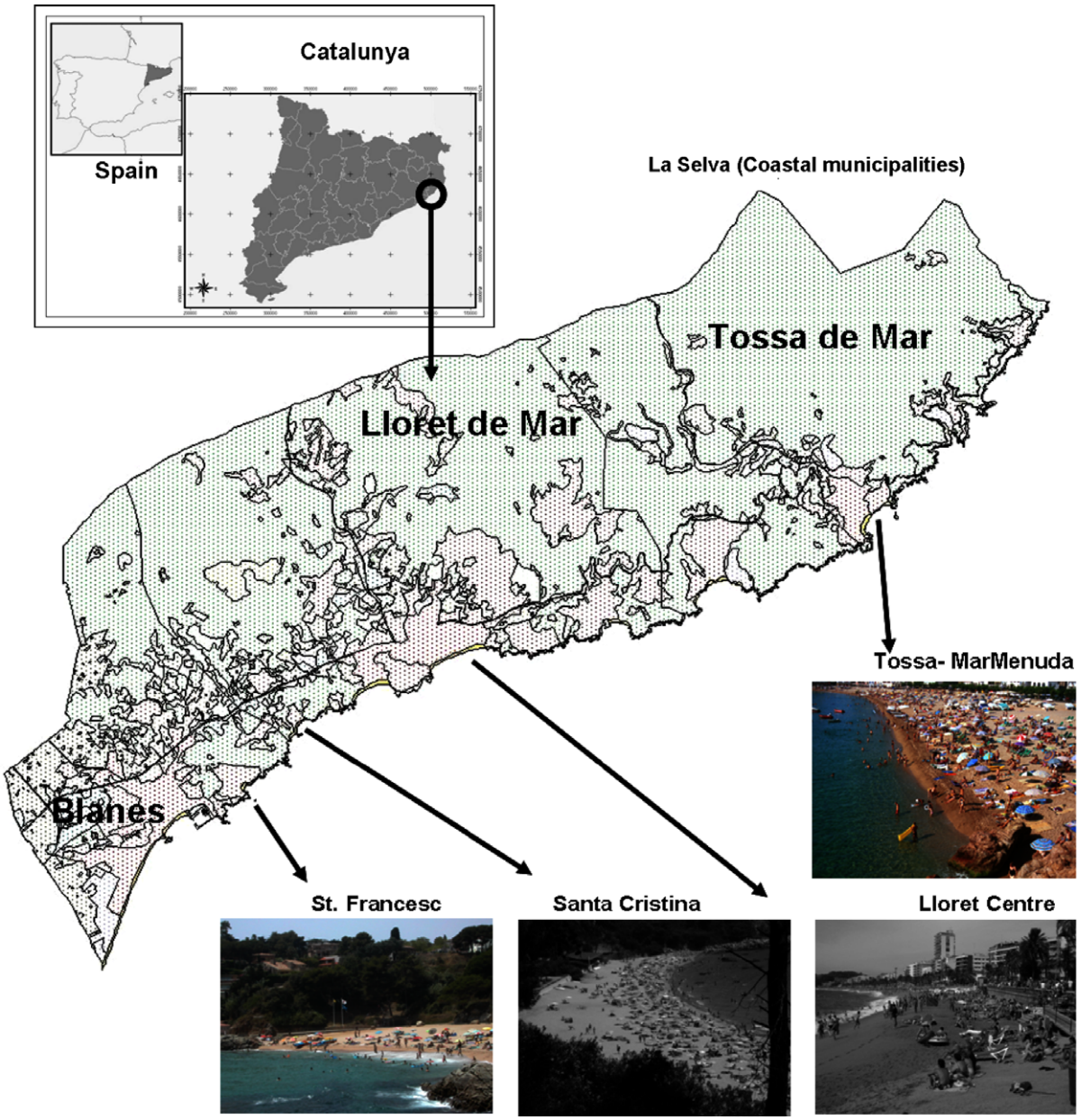

Fig. 1. Map of the area of La Selva (coastal zone). It includes the beaches of the municipalities of Blanes, Lloret de Mar and Tossa de Mar where waste production has been studied.

(St. Francesc beach and Sta. Cristina beach). The aesthetic quality of seven urban beaches (Malgrat de Mar, S'Abanell, Blanes, Fenals, Lloret Centre, Es Codolar and Tossa-Mar Menuda) and six urbanized beaches (St. Francesc, Sta. Cristina, Canyelles, Sta. Maria de Llorell, Giverola and Salions) of the area was also assessed. For this part of the work, the beach of Malgrat de Mar, inside the municipality of Malgrat de Mar, located to the south of Blanes, was also considered. For a detailed description of the beaches of the area, see Ariza (2007).

The study of beach use patterns in the area has shown that these beaches tend to be crowded between 12 noon and 5 pm, although beach use extends from 9 am to 8 pm. Although beaches cannot be said to be permanently overcrowded, at the peak of the bathing season they reach saturation levels (5 m^2/user in the urban beaches of Lloret Centre and Tossa, and 10 m^2/user in the urbanized beaches of Sta. Cristina and St. Francesc; Alemany, 1984). The highest usage of these beaches occurs in July and August (Yepes, 2002), as it does along most of the Mediterranean coast.

2.2. Waste and litter characterization

During the bathing season, the beaches studied were subject to a daily mechanical cleaning and waste withdrawal programs. A preliminary study, in which five garbage bags were removed daily from each beach, showed

that collection of three bags was representative of the composition of waste at each beach. In this study, therefore, three garbage bins on each of the beaches were sampled weekly from July 28 to September 15, 2004 (one garbage bag from each bin was collected and analyzed on each sampling day). The garbage bags were transported to a collection and storage centre, weighed by means of a scale, and separated according to their components. Waste was sorted into the following four categories: (a) plastic, wrapping and non-glass beverage containers; (b) paper; (c) glass; and (d) organic, domestic and other miscellaneous waste. The weight of each category was also recorded to facilitate comparison of waste of different sizes and density (e.g., plastic, wrapping and beverage containers vs. glass) obtained on beaches with that obtained in the municipality. Waste samples were collected between 4 pm and 5 pm, the time when the beach cleaning service replaced the full bags. The total amount of waste generated on each beach was obtained by considering the quantities of waste obtained from the analyzed bags, the number of bins on each beach and the frequency of garbage collection at any given time during the summer season. Two of the studied beaches (Tossa and Lloret beaches) were compared to assess the total solid waste from bins generated per beach user (kg/day). Beach use data were obtained from the study of beach use patterns developed by our team (Ariza, 2007).

We followed the rating protocol used by Agència Catalana de l'Aigua (ACA), the administrative body in charge of the assessment of beach quality, to assess the aesthetic quality of the beaches. Qualitative samples were taken from 13 beaches in the area (7 urban and 6 urbanized beaches). In order to detect sudden, short-term changes (fortnight differences), beaches were visited twice a week from May 26 to September 5. Sampling was based on a visual analysis of water and sand litter, and comprised all sand and water surfaces (bathing area). Visual analysis has been used successfully in other studies on litter (Cutter et al., 1991). The effect of water litter was assessed by establishing a qualitative score (ordinal classification) ranging from 1 (the lowest quality) to 5 (the highest quality), based on the global aspect of the water. In addition, the presence and abundance of litter components such as oil, foam, tar, human-generated litter, terrestrial and marine vegetation, and jellyfish were recorded each day (also in an ordinal classification for each component ranging from 1 to 5). Sand assessment was carried out by a comprehensive inspection of beach surfaces, which included an overall qualitative score and an analysis of litter components (tar, beachgoer's litter, other human-generated litter, terrestrial and marine vegetation, and jellyfish). Data were categorized qualitatively using the previously described ordinal classifications (1–5). Litter assessment data were compared with wave height data for the area of study, which were obtained daily from a surface wave buoy (WANA No. 2070053).

Because of the importance of small items of litter, such as cigarette butts, in beach users' perception of quality, a specific survey was designed to characterize their evolution over the bathing season. The beach of Lloret Centre was sampled three times over the summer of 2005 (early July, mid-August and mid-September) to assess the dynamics of these litter items. Twenty squares measuring 1 m^2 were randomly distributed and sampled on the surface of the beach, which had been previously mechanically cleaned. This is considered a suitable method for surveying litter (Velander and Mocogni, 1999). Samples were taken between 7.30 am and 9 am before the daily arrival of beach users. Cigarette butts and litter present in the top 1 cm of sand were collected in plastic bags (one per quadrant). Litter was later counted and weighed on a Mettler AE200 electronic analytical balance (readability 0.1 mg, 205 g capacity). From these data we calculated the number of cigarette butts remaining after customary mechanical cleaning of this area of the beach, which covers 22,580 m^2 and accounts for approximately 40% of the total beach surface. The efficiency of mechanical cleaning was also quantified by sampling the litter withdrawn by mechanical cleaners at the time the beach samples were taken. Three representative samples, representing 20% by weight of the total amount removed daily by beach tractors, were taken from beach litter after it had been transported to the landfill of Lloret de Mar. In the landfill, the three samples were taken using a shovel and gathered in three separate plastic bags. The contents of the bags were classified into three categories (sand, small sized-litter and cigarette butts) and weighed using a digital portable dynamometer KERN MH10K10 (weighing range 10 kg, readout 10 g). The number of cigarette butts was also recorded. Once the composition of the samples was established, the total amount of each component removed by tractors was determined considering the total amount of litter withdrawn by tractors.

The total amount of waste and litter produced on beaches was compared with total waste production in the municipality by evaluating data for large-sized litter left on the beach of Lloret Centre during August 2005, provided by the municipal cleaning service, and total monthly municipal waste production in Lloret de Mar, provided by the Local Council of Lloret de Mar. Data were analyzed statistically using SPSS 14.0. The Mann–Whitney and Kruskall–Wallis tests were used to detect differences in the amount and composition of waste/litter over time and between urban and urbanized beaches. The Kendall's Tau coefficient was used to test association between visual quality and wave height. One-way ANOVA was used to detect significant differences in the amount of small-sized litter on beaches.

3. Results

3.1. Beach waste evolution and composition

The total production of waste on the urban beaches was greater than on urbanized beaches (Mann–Whitney test $U = 7$; $p < 0.01$) because the beaches are larger and

received more users. The waste density (g/m^2/day) on most beaches was relatively constant from the end of July to the end of August, and then declined sharply at the beginning of September (Fig. 2). The waste deposition density on urban beaches was clearly higher than on urbanized beaches (Fig. 2) (Mann–Whitney test $U = 20$; $p < 0.01$). The highest amount of waste collected per square meter was from the beach of Lloret Centre, whereas that of Sta. Cristina was the lowest. Values for waste per user were 0.066 kg/user/day (SD ± 0.022) (August 1–15) and 0.062 (SD ± 0.006) kg/user/day (August 16–31) at Tossa and 0.068 kg/user/day (SD ± 0.011) (August 1–15) and 0.054 kg/user/day (SD ± 0.021) (August 16–31) at Lloret Centre.

Waste composition varied over time and location (Fig. 3). The highest proportion (in percentage) of plastic, wrapping and beverage containers was found at the peak of the season (28 July–18 August) (Mann–Whitney test $U = 37$; $p < 0.01$), when the proportion of organic, domestic and other miscellaneous waste was at its lowest. The greatest proportional difference between those two kinds of waste was found on urbanized beaches, whereas urban ones had similar quantities in both categories (Fig. 3). As the season advanced, the proportion of organic, domestic and other miscellaneous waste increased and the proportion of plastic, wrapping and beverage containers decreased. The organic, domestic and other miscellaneous waste proportion was significantly different in urban and urbanized beaches (Mann–Whitney test $U = 62$; $p < 0.01$).

The mean percentage value (by weight) for each waste component in August is shown in Fig. 4. Most beaches had a similar composition of waste, which, in ascending order, was as follows: (1) organic, domestic and other miscellaneous waste; (2) plastic, wrapping and beverage containers; (3) glass; and (4) paper. The only exception was Lloret Centre, where the two most frequently found components had similar percentages. Moreover, the quantity of glass observed on this beach was much higher than on the other beaches, and of the same order of magnitude as the more common components.

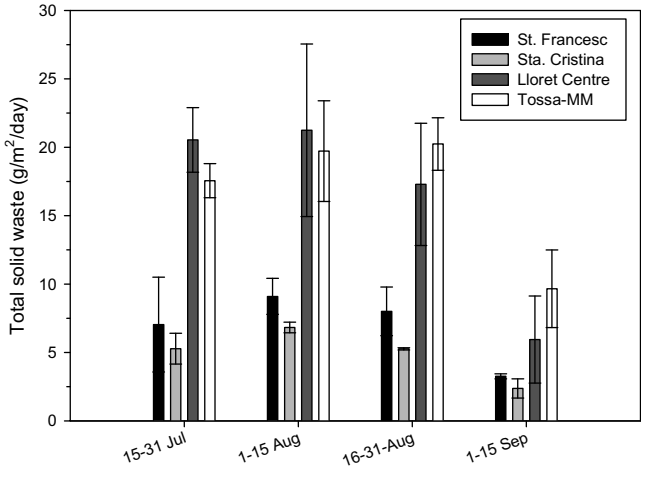

Fig. 2. Seasonal evolution of the amount of solid waste produced per m^2 per day on the beaches of La Selva over the 2004 summer season.

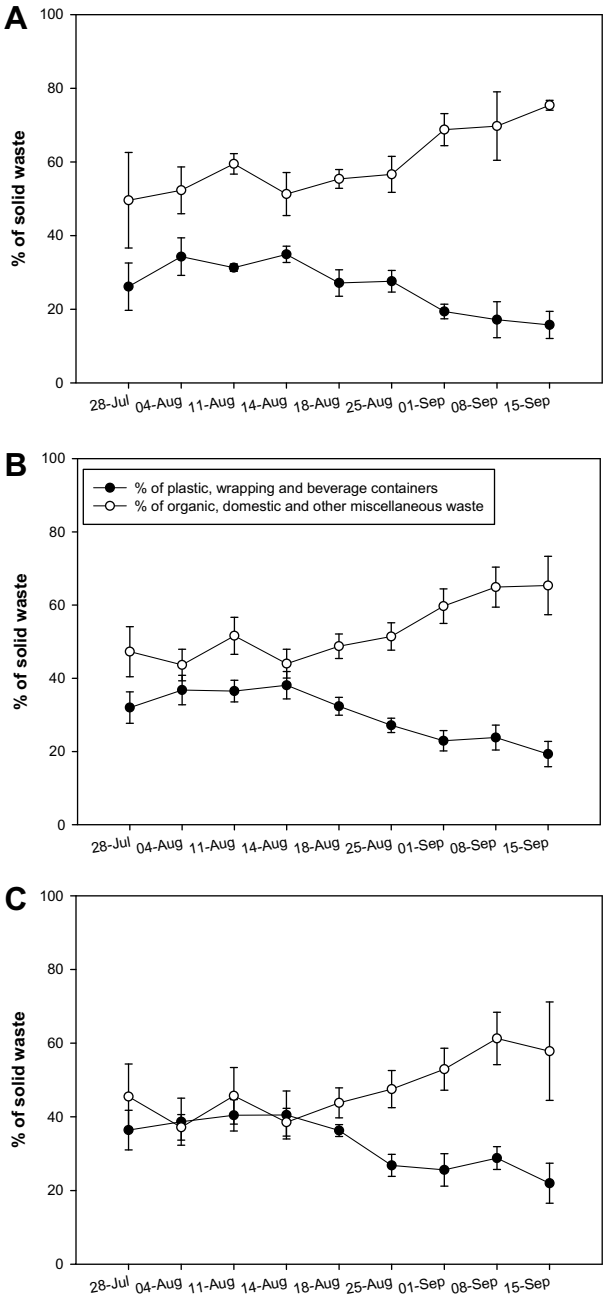

Fig. 3. Evolution in the percentage of main litter constituents (in weight) over the 2004 summer season. (A) Urbanized beaches, (B) all beaches and (C) urban beaches.

3.2. Beach litter and aesthetic quality

The average aesthetic quality of water, as measured by ACA personnel, is shown in Fig. 5. The rated values were always very good, not falling below 4.4 on the scale of 1–5. There was no significant difference in water quality during the season (Kruskall–Wallis test X^2 16.2; $p > 0.01$). Variations in wave height over the summer season were only

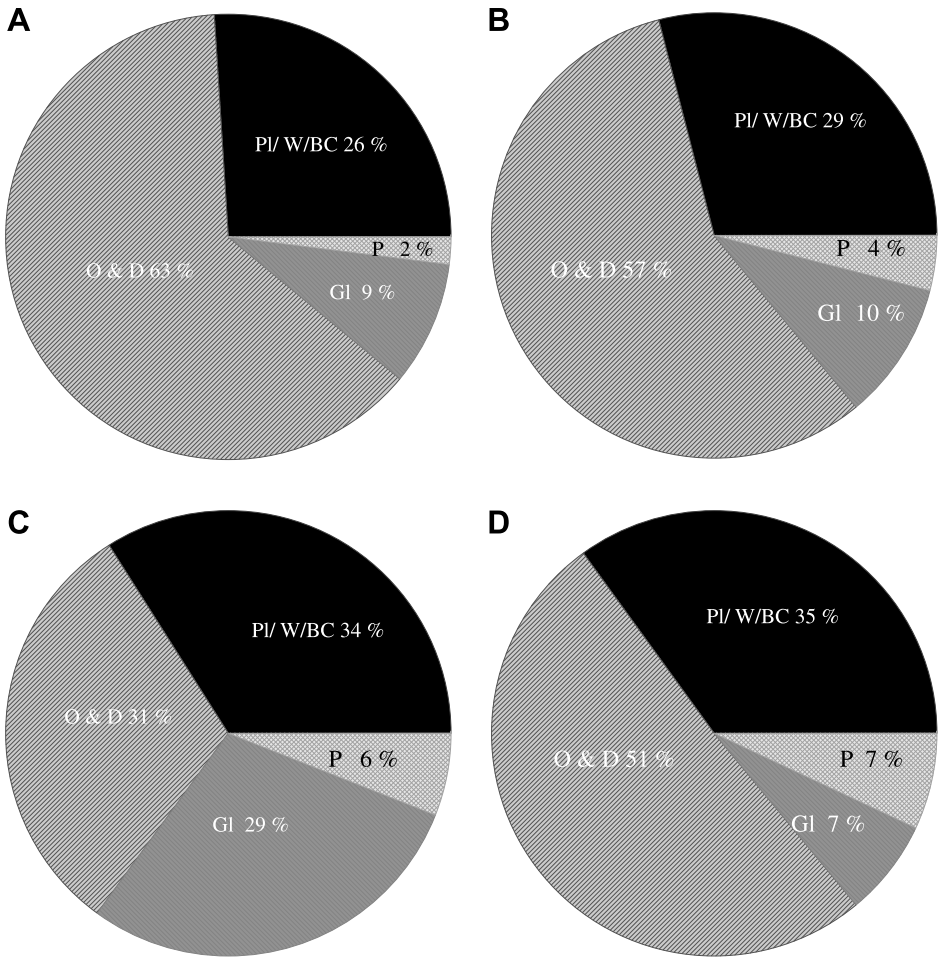

Fig. 4. Waste components (in weight) on the beaches of La Selva in August 2004. Data are mean percentage values. Waste component abbreviations: O & M, organic, domestic and other miscellaneous waste; Pl/W/BC, plastic, wrapping and beverage containers; P, paper; Gl, glass. (A) St. Francesc. (B) Sta. Cristina. (C) Lloret Centre. (D) Gran de Tossa-Mar Menuda.

15 cm, and absolute wave height values were low, which is typical of summer season dynamics. Visual quality did not depend on wave height (Kendall's Tau coefficient −0.07).

The visual quality of sand on urbanized beaches was higher than on urban ones during most of the summer (Fig. 6) (Mann–Whitney test $U = 34{,}605$; $p < 0.01$). Sand quality increased significantly at the beginning of the bathing season (Kruskall–Wallis test X^2 39.8; $p < 0.01$) and was constant throughout the remainder of the season. No differences were detected in the visual quality of water between urban and urbanized beaches (Mann–Whitney test $U = 36{,}763$; $p > 0.01$). Litter from marine vegetation was more common on urbanized beaches (Mann–Whitney test $U = 34{,}628$; $p < 0.01$).

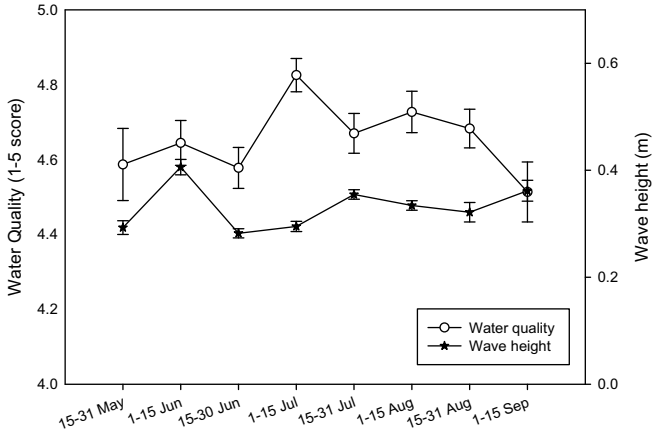

Fig. 5. Evolution of the waters aesthetic quality in relation to wave height.

3.3. Small litter dynamics

Small items of litter on beaches tended to accumulate at the peak of the summer season. Significant differences were found in the results obtained in the first and the second sampling (ANOVA test $F = 13.8$; $p < 0.05$). The deposition density of small-sized litter was 1.3 g/m^2 (SD ± 1.3) at the beginning of July, increased to 4.8 (SD ± 3.3) g/m^2 in mid-August, and maintained in mid-September, 4 g/m^2 (SD ± 3.4). During the season, the number of cigarette butts collected in samples mirrored that general pattern: 2.2 units/m^2 (SD ± 1.7) in the first sampling, 3.5 units/m^2

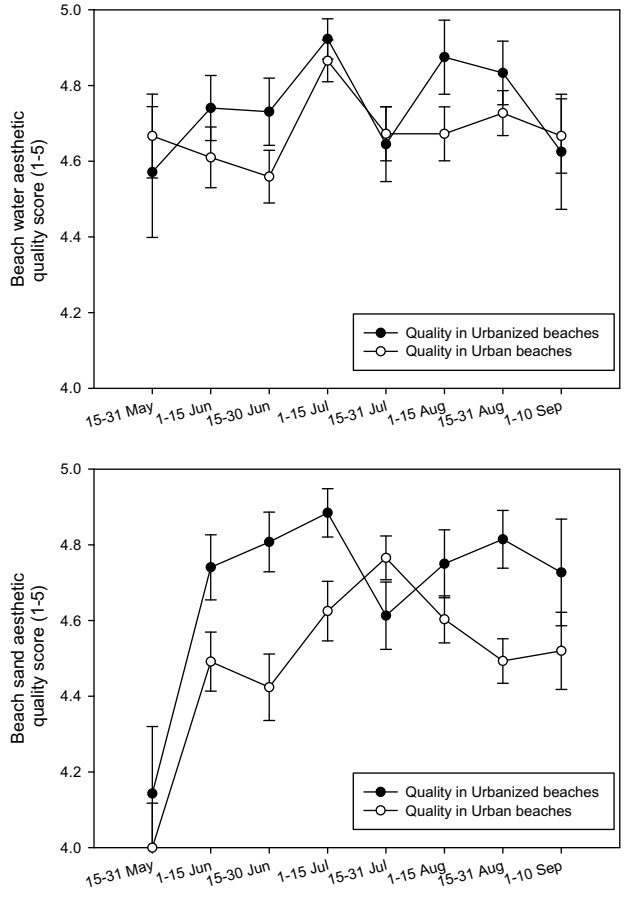

Fig. 6. Evolution of sand and water aesthetic quality scores on urban and urbanized beaches in the Selva area. Scores range between 1 and 5.

(SD ± 3.2) in the second and 2.5 units/m^2 in the last (SD ± 3.6).

The total amount of cigarette butts calculated for the area mechanically cleaned was 49,677 units in early July and 78,128 units in mid-August. The efficiency of mechanical cleaning for cigarette butts was 4.4% at the beginning of July and 14.4% in mid-August. When the overall weight of small items of litter was considered, efficiency increased to 87% at the beginning of July and 29% in mid-August. Mechanical cleaning is less effective for withdrawing cigarette butts than for general small-sized litter. A further fact for consideration is that during the daily mechanical cleaning procedure on Lloret Centre beach, an extremely high proportion of the material collected from the beach is sand, which is retained by the tractor when withdrawing small pieces of litter. On a percentage basis, the weight of real litter that was collected by the machine was just 2.72% at the beginning of July, and 17.13% in mid-August.

3.4. Waste and litter withdrawal

The quantification of the different components of waste and litter collected from bins and sand by the beach cleaning service on the beach of Lloret Centre is shown in Fig. 7. The highest proportion of waste collected from bins was in

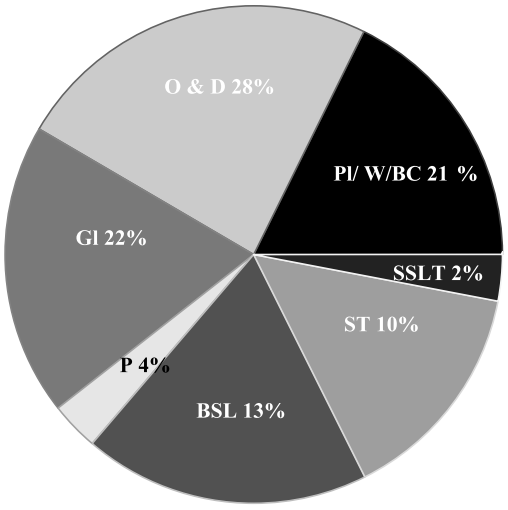

Fig. 7. Average composition of the waste and litter from the beach of Lloret Centre in August 2005. (Flotsam and waste from stand are not included). Waste component abbreviations: Pl/W/BC, plastic, wrapping and beverage containers; O & D, organic, domestic and other miscellaneous waste; Gl, glass; P, paper; BSL, big-sized litter on sand; ST, sand withdrawn by tractor; SSLT, small-sized litter withdrawn by tractor.

Table 1
Percentage of beach waste and litter (of the beach of Lloret Centre and all Lloret beaches) of the total amount of waste collected in the municipality during summer

	Lloret centre (%)	All Lloret beaches (%)
June	1.27	2.48
July	2.14	4.65
August	1.37	3.17
September	1.07	2.64
Average	1.46	3.24

Waste and litter values from Lloret Centre include litter retired from tractors and big-sized litter left by users. Waste and litter from all beaches of the municipality do not.

the category of organic, domestic and other miscellaneous materials (28%), followed by glass waste (22%). Sand collected by mechanical cleaning also formed a significant proportion of the waste and litter collected (10%). Table 1 shows the percentages by weight of waste and litter collected by the cleaning service on all of Lloret de Mar's beaches. These figures are expressed as a proportion of the total amount of waste collected in the town in the period June–September (15,842.6 metric *t*). Although the percentages obtained for all of the beaches are incomplete because it was impossible to determine quantities of large-sized litter left by users and small-sized litter collected by mechanical cleaners, the amount of waste and litter left on beaches was quite high. Taking 3.2% to be the average value at this time of the year, the beaches of Lloret de Mar received 513.3 metric *t* of total solid waste.

4. Discussion

The total production of waste, the components of such waste and the proportion of waste generated per square

meter are related to urbanization. Urban beaches – Lloret Centre and Tossa-Mar Menuda – are generally larger and have more users than other types of beaches, such as urbanized or natural beaches, and consequently, yield larger quantities of wastes. Due to the higher proportion of plastic, wrapping and beverage containers found in urban beach waste (and the fact that this study took weight rather than volume into consideration), when quantities of waste were measured per user (kg per user), values obtained were low on the beaches of Lloret Centre and Tossa. These results are in agreement with other studies carried out on other heavily used beaches, such as Sant Sebastià beach in Barcelona, where 0.046 kg per user day was estimated (Environmental Study of the Beach of St. Sebastià, 2004). This is far removed from current amounts of waste generated per user in residential areas. Due to different beach usage patterns over the summer season, the composition of waste on beaches varied throughout this period (probably as a consequence of the different proximity of urban and urbanized beaches to supermarkets and suppliers, and the time that beachgoers spent on the different types of beaches).

Municipal waste generation in tourist resorts continues to grow, and the towns we studied showed the same tendency. Recycling procedures should be facilitated. On average, 49.4% of the total amount of waste generated on the beaches is composed of plastic, wrapping, beverage containers, glass and paper. Recyclable organic materials have not been specifically quantified in this work (they are mixed with other wastes in the category organic, domestic and other miscellaneous waste (28% in Lloret Centre, Fig. 7)), but they may make up a significant proportion of the waste. If we compare the waste produced on Lloret's beaches and the total waste produced in the town, recycling of beach waste would increase the total amount of waste recycled in the town (11.3%, in 2004) by around 1%. However, these figures are far from satisfactory (e.g., the amount of packaging waste recycled in Lloret de Mar was just 5.4% in 2004, far short of the target of 25% for 2001 and 60% for 2005, as set out in the EU Packaging Waste Directive 62/94). There would possibly be a slight improvement in this situation if beach waste were to be recycled.

With regard to the effect of larger items of litter on the aesthetic quality of the sand and coastal water, conditions remained constant throughout the summer season. This was probably due to the predominant fair weather conditions, which did not seem to significantly worsen water and sand conditions on the Catalan coast, as has been observed in other locations (Lee et al., 2006). There was no significant difference in water aesthetic quality between urban and urbanized beaches, although, in the particular case of marine vegetation, litter was more frequently found in urbanized beach areas, probably due to proximity to habitats with marine vegetation.

The general aesthetic quality of the water and sand remained constant throughout the season, according to public administration criteria, but small-sized litter accumulated on the sand of Lloret beach. The accumulation of litter during the bathing season is due to the low efficiency of the daily mechanical cleaning procedure for collecting small-sized litter, particularly cigarette butts. The fact that public administration did not detect such an accumulation of litter makes us very cautious about current methods used by agencies for the assessment of aesthetic quality. It must be ensured that litter assessment methods take small items of litter into consideration. Other authors have also found this kind of litter to be highly significant (Rodríguez-Santos et al., 2005). The decline of small-sized litter observed in September is a consequence of the weather conditions towards the end of the summer season. Unfavorable weather affected beach use and, subsequently, litter production dropped. Mechanical cleaning was then able to absorb litter production rates. However, cleaning procedures at the time proved to be insufficient to absorb the litter produced during the peak season. These problems are especially evident in the case of cigarette butt withdrawal. Cleaning devices use a sieve that is unable to retain most butts, but which picks up sand from beaches. The beach cleaning service of Lloret de Mar has observed that tractors withdraw more than 50 kg of sand per hour of work. In Barcelona (Servei de Prevenció i Medi Ambient, 2005) (Prevention and Environment Service), the sand withdrawn during mechanical beach cleaning operations also accounted for a very high proportion of beach litter (80% by weight). During the period June-September of 2005, approximately 163,478 kg of sand were collected from all the beaches of Barcelona. It is highly likely that this is a general problem for mechanical beach cleaners on intensively used beaches. Reducing the size of the sieve's holes would improve litter retention, but at the same time would increase sand withdrawal. Sand withdrawal is a problem for beaches, but also for managers, because the cost of litter management increases as a result of collection, transport and disposal operations. All of the above factors, in addition to the impact of mechanical cleaning on sand communities (Llewellyn and Shackley, 1996) and dust dispersal as a result of turning the sand over, are compelling arguments that should be taken into account in decision-making on the most suitable beach cleaning practices in coastal areas.

The quantification of the origin of waste and litter demonstrated that waste and litter management need to be significantly improved. Thirteen percent of waste and litter collected from the Lloret Centre beach was left on the sand by users. If that were avoided, beach quality would be higher. It has been demonstrated that beach user behavior affects the amount of litter left on beaches (Rodríguez-Santos et al., 2005). This litter deposition may significantly diminish the aesthetic quality of the beaches on summer days and increase the cost of beach-cleaning operations. Efforts to improve the attitudes of beach users toward both recycling and discarding of cigarette butts on the beach could also be seen as an educational tool that would go towards improving municipal recycling patterns outside beaches.

In conclusion, this study demonstrated that waste and litter management on Catalan beaches could be substantially improved. A specific management program for waste and litter on beaches (including objectives and targets) could be set up, which could also take responsibility for separating and recycling beach waste. This program could take place inside Environmental Management Systems for Beaches (Ariza et al., 2008). Furthermore, litter assessment methods used by the autonomous government and litter withdrawal practices used by local organizations in special mechanical cleaning operations could be reviewed. Environmental awareness programs targeting beach users may be very useful for achieving this desired improvement. These measures would reduce management costs, enhance beach health and make beaches more attractive to users.

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