Marine Pollution Bulletin 137 (2018) 35–44

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Litter impacts on beach/dune systems along the Atlantico Department, the Caribbean Coastline of Colombia

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ARTICLE INFO

Keywords:
Beach/dune systems
Litter
Scenery
Clean coast index
Colombia

ABSTRACT

Eight beach/dune systems located along the Atlantico Department, Caribbean coast of Colombia were surveyed to determine litter influences over its scenic quality. Application of the Coastal Scenic Evaluation System (CSES) categorized these systems into two of the five available classes. Five of the investigated beach/dune systems belong to Class IV, while three systems correspond to V. Classes I, II and III were not found. Along these beach/dune systems, a total amount of 1908 litter items were collected with average abundances of 4.2 items/m^2. Currently, 82% of surveyed sites are under an unacceptable condition of cleanness. User's habits as well as bad litter management practices are directly responsible for the decline of scenic quality of the Atlantico Department beach/dune systems. Litter management must be centered on strategies to eliminate or minimize litter sources. Specific remedial actions need to be defined and developed.

A beach/dune system is the spatial transition between the continental - terrestrial environments and is characterized by a highly specialized fauna and flora (McLachlan and Brown, 2006; Maun, 2009). Its evolution is the result of the interaction between sand, water, vegetation and external pressures (Short and Hesp, 1982). Inside such systems, sand transported and deposited by waves, currents, and wind are combined with plants to produce an area of significant importance due to its unique ecological functions (French, 1997; Martinez et al., 2004; Babier et al., 2011). The beach/dune system is perhaps one of the most dynamic environments existing over planet Earth. This system occurs at all latitudes, is typical of low-lying coastal margins, and is the result of the conjunction of two critical ecosystems such beaches and dunes which traditionally have been examined as distinct and separated environments (Sherman and Bauer, 1993).

Beach and dunes play a crucial role for humankind. Their optimal position between sea and land produce biodiversity hotspots as well as strategic areas linked to the dunes ability to provide multiple environmental services, such as, raw materials, coastal protection, erosion control, water catchment and purification, maintenance of wildlife, carbon sequestration, education, and tourism - recreation (Carter et al., 1990; Pye and Tsoar, 1990; Neal et al., 2007). Throughout human history, beaches and dunes have supplied essential tourism-recreation benefits. Numerous recreational activities that can be developed inside these systems such as walking, beachcombing and sunbathing, among others, always have been strongly dependent on the exploitation of a very particular resource: its scenery.

Scenery can be defined as the appearance of an area, and its quality is the result of multiple interactions between natural and human factors (Council of Europe, 2000; Rangel-Buitrago, 2019). Also, scenery is a reflection of the current existing interactions between living organisms and the environment, and it is considered to be a fundamental part of the ecosystem (Van der Meulen and Salman, 1996; Williams, 2019). The particular character of scenery as part of ecosystem services of beach and dune environments turns it into one of its most significant assets. The above is due to the increasing volume of coastal tourism, which depends on environmental quality to attract tourists (White et al., 2006). Authors such as White et al., (2006); Papageorgiou (2016); Corraini et al. (2018) and Rangel-Buitrago (2019) have demonstrated that optimal scenery is a prime factor considered by a potential tourist in choosing a coastal vacation destination. Scenery's importance in beach and dune systems is such that in the USA alone, between 65 and 70% of the population visit them during holidays, and 85% of income derived from tourism come from visits to these environments (Houston, 2008; Babier et al., 2011; UNTWO, 2016).

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https://doi.org/10.1016/j.marpolbul.2018.10.009
Received 27 August 2018; Received in revised form 21 September 2018; Accepted 2 October 2018

Currently, litter is an issue that impacts all coastal areas, especially on beach/dune systems. Its presence is a well-recognized problem, and it has been well demonstrated that loss of scenic quality in the coast is a closely related to this issue (Rees and Pond, 1995; Battisti et al., 2009; Tudor and Williams, 2018; Rangel-Buitrago et al., 2019). On beaches and dunes, litter can derive from land- based sources, as well as sea-based sources. Its magnitudes and composition are related to socio-economic activities, and consequent littering behavior (Willis et al., 2017). Similarly, litter transport and accumulation regimes are related to hydrodynamic and climatic conditions (Carson et al., 2013), as well as system characteristics (Araujo and Costa, 2007; Williams et al., 2016; Krelling et al., 2017).

Elimination or at least minimization of damages related to overuse of ecosystem services provided by beaches and dunes, such, as recreation and tourism, requires careful management and planning (Heslenfeld et al., 2004). Combining beach and dune conservation and its recreational use for tourism is a complex task for stakeholders. The management of both environments requires in-depth knowledge about litter magnitudes and sources with an objective of developing optimal waste management practices, adequate infrastructure for collection - treatment, and even, reach better human behaviors.

For example, one of the essential tasks concerning litter management is the cleanup operation. Some employed techniques do not distinguish between litter and biological resources, such as, plants, animals, and organic debris that naturally deposit on the beach and dunes, and therefore cause their complete removal. These techniques may also produce the leveling of the dune system (Poeta et al., 2014). Therefore, litter presence will generate an alteration of biotic communities and could be related to modifications in the entire system that will favour erosion processes (Gracia et al., 2018; Rangel-Buitrago et al., 2018).

All existing studies regarding magnitudes, composition, distribution, and sources of litter along Colombian coastlines have been focused only on the beach environment (Williams et al., 2016; Rangel-Buitrago et al., 2017; Gracia et al., 2018). Also, litter impact on the scenic quality of beach/dune systems is still a topic to be explored, especially if one considers its substantial influence over an essential ecosystem service that beach and dunes provide.

In this work, eight beach/dune systems located on the Atlantico Department (Caribbean coast of Colombia) were assessed and rated according to their Scenic Quality and Litter Magnitude quantification methods. The scope is to analyze these two variables as indicators from a pollution management point of view, opening opportunities for the optimal exploitation of tourism and recreation as ecosystem services. Results provide the baseline data necessary to adopt reasoned management decisions over these issues.

The Atlantico Department is located in the center area of the Caribbean Coast of Colombia (Fig. 1). It is an NE-SW oriented area with 1,378,950 inhabitants that corresponds to 4% of the national total. Specifically, this work was developed on eight beach/dune systems composed of medium sands and separated by headlands (Figs. 1–2 and Table 1). Along these systems, waves arrive predominantly from the NE with an average significant wave height is 1.5 m and peak period average is 7.5 s. Longshore sand drift has a dominant south-westward component, but a minor reversal to the northeast occurs during rainy periods when southerly winds prevail in some areas and set up short, high-frequency waves able to generate significant erosion along beach/dune systems (Anfuso et al., 2015; Gracia et al., 2018). Tides are mixed semi-diurnal, with maximum amplitudes of 65 cm (Rangel-Buitrago et al., 2017).

The study area lies in a semi-arid tropical environment with mean temperatures of < 28 °C and maximum precipitation values of 2500 mm/year (Rangel-Buitrago et al., 2013; Anfuso et al., 2015). Seasonal variations show two rainy periods (April–May and October–November) and two dry periods (December–March and July–-September).

Due to its dynamic landscape, natural environments and the increased popularity for adventure sports, the study area is becoming in an important place for national tourism and is experiencing an infrastructure development to cope with visitors.

A set of five methodological approaches were used to determine litter impacts. As a first step, each of the eight beach/dune systems was categorized in one of the existing typologies into the Bathing Area Registration and Evaluation System (BARE) proposed by Williams and Micallef (2009). This categorization allows the classification of beach and dunes into five different classes (remote, village, rural, urban and resort) taking into account their accessibility degree, environment, facilities, accommodation grade, and safety equipment.

In a second step, the Coastal Scenery Evaluation System - CSES developed by Ergin et al. (Ergin et al., 2004; Rangel-Buitrago, 2019) was applied. The CSES is a checklist which evaluates 26 coastal weighted parameters (18 physical and 8 human, Table 2). The CSES checklist is analyzed using fuzzy logic mathematics to give a final grade "D" that allow classifying any coastal site into one of the following five scenic classes:

- Class I: Extremely attractive natural sites with D values ≥ 0.85.
- Class II: Attractive natural sites, D = 0.85 to 0.65.
- Class III: Mainly natural sites with little outstanding landscape features, D = 0.65 to 0.4.
- Class IV: Mainly unattractive sites, with low landscape values, D = 0.4 to 0.
- Class V: Very unattractive intensively developed urban beaches with D values below 0.

In each of the eight sites a "sample unit" was used to collect, count and categorize all litter available (Fig. 3). On the beach environment of the system, the sampling unit corresponded to an area of 100 long × 2 m width located in the high tide line. Similarly, with the dune environment, the sampling unit covered an area whose length was the dune width × 2 m. Litter results were presented as the number of items and associated densities per square meter.

To evaluate the cleanliness of each of the surveyed systems an adapted version of the Clean Coast Index (CCI) developed by Alkalay et al. (2007) has been calculated using the formula:

$$CCI = \frac{\sum \text{Litter items}}{\text{Lenght (m)} * \text{Width (m)}} * K$$

Where, CCI is the number of litter parts/m^2, taking into account the existing relation between the number of litter items and the total area of transect as a product of the length, width, and a constant value (K = 20). The CCI allows assessing a site in five different classes that range from "very clean" to "extremely dirty" according to the scale provided by Alkalay et al. (2007).

Once the Scenic Quality and Cleanliness were determined, both variables were integrated into a Sector Analysis (SA). SA is a table constructed for each beach/dune system, with scenic class in rows (5) and CCI in columns (5). This table is divided into five sectors:

- The upper left quadrant (green) is comprised of four cells and represents clean sites with good scenic classes where protection measures are necessary.
- The upper right quadrant (orange) is comprised of four cells and represents dirty sites with good scenic classes where cleaning actions are necessary.
- The lower left quadrant (yellow), which also has four cells, describes clean areas having poor scenic classes where measures must be focused over other scenic variables, i.e., noise or skyline.
- The lower right quadrant (red), which also has four cells, describes dirty areas with poor scenic scores where urgent intervention and even restoration measures are necessary.
- Along the middle cells (pink) are located beach dune systems with