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The impact of tourism on marine litter pollution on Santa Marta beaches, Colombian Caribbean

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ABSTRACT

Tourism is an important socioeconomic activity in coastal communities, which deteriorates marine-coastal ecosystem quality when poorly managed, increasing litter pollution on beaches during the main tourist seasons. This study aims to assess the tourism impact on litter pollution on eleven Santa Marta beaches, Colombian Caribbean. During high and low tourist seasons, people on the beaches were counted, macrolitter and microplastics were sampled, and perception surveys about litter on beaches were conducted. During the high tourist season, the number of people and macrolitter pollution increased, compared to the low tourist season. Plastics accounted for 30%–77% of macrolitter and microplastics ranged from 1 to 355 items/m^2. Respondents identified tourism as a main litter source and plastics as the most common litter type. All assessed beaches are impacted by tourism causing litter pollution, therefore, stronger controls, educational, and awareness strategies are needed to reduce litter pollution and prevent ecological and socioeconomic impacts.

1. Introduction

Marine and coastal ecosystems are providers of environmental goods and services, which generate well-being for human populations and promote their socioeconomic development (Hattam et al., 2015). However, due to inadequate management of household waste and socioeconomic activities typical of coastal populations, such as tourism, fishing, and trade, the environmental quality of ecosystems has deteriorated, jeopardizing their ecosystem services (Lu et al., 2018). Among the pollutants generated by socioeconomic activities is marine litter, understood as all manufactured solid materials discarded or abandoned in the marine and coastal environment (CPPS, 2007; UNEP, 2009). One of the most abundant marine litter materials are plastics (between 42% and 96% of the total), due to the high production, use, and characteristics of high persistence in the environment (UNEP, 2009; Iñiguez et al., 2016). These materials are accumulating in coastal marine ecosystems, and one of the most impacted ecosystems are beaches.

Microplastics (plastic particles < 5 mm in diameter) are emerging pollutants that are present in all marine environments in the world (Iñiguez et al., 2016; Yu et al., 2020). They are classified as primary (raw material for cosmetic products, personal hygiene, and household cleaning, among others) or secondary ones (resulting from the breakdown of large plastic debris due to physical, chemical, and biological factors) (Weinstein et al., 2016; Yu et al., 2020). Microplastics are being intentionally or accidentally ingested by marine organisms due to their abundance in the marine environment and because they are colorful and resemble actual pieces of food of fish, birds, crustaceans, mollusks, marine mammals, among others, causing adverse effects (Guzzetti et al., 2018). Microplastics have also been found in food, bottled drinking water, sea salt for cooking, and human feces, suggesting that they are also being consumed by humans (Auta et al., 2017; Antão-Barboza et al., 2018). Macrolitter (items with sizes > 5 mm) and microplastics are a relevant global problem, due to its aesthetic, economic, and ecological impacts (Gall and Thompson, 2015; Auta et al., 2017; Xanthos and Walker, 2017).

Tourism is an important economic activity for coastal populations throughout the world (Ghosh, 2011). Generally, it has a greater intensity (more tourists) during certain months of the year, coinciding with vacation periods, festivities, and weather seasons (Corluka et al., 2016). Massive influxes of tourists on beaches (often beaches with

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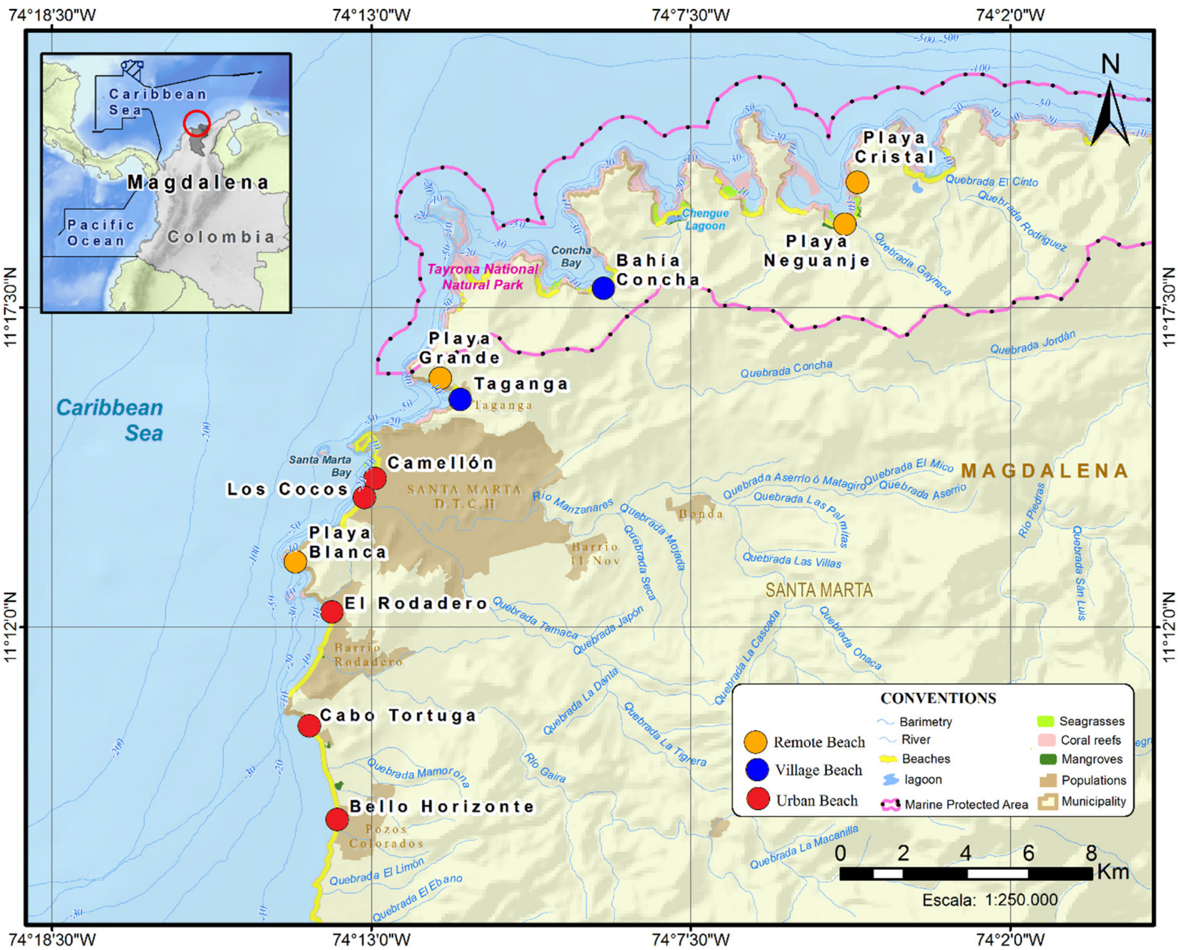

Fig. 1. Study area with the distribution evaluated remote (orange dots), village (blue dots), and urban (red dots) tourist beaches of Santa Marta, Colombian Caribbean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

deficiencies in management) have a huge negative impact on the environmental quality of marine ecosystems (Ghosh, 2011), increasing among others, pollution by marine litter. This situation has been reported for the summer months from various beaches throughout the world, as in Brazil (Lopes da Silva et al., 2016, 2018), China (Pervez et al., 2020), Chile (Hidalgo-Ruz et al., 2018; Gómez et al., 2020), Taiwan (Chen and Chen, 2020), Argentina (Becherucci et al., 2017), and Spain (Asensio-Montesinos et al., 2019). Understanding the distribution and dynamics of marine litter pollution on touristic beaches is essential to find effective solutions in accordance with the local conditions of the countries or municipalities.

Santa Marta municipality, with a current population over 500,000 inhabitants (DANE, 2005), is located in Magdalena Department, on the Caribbean coast of Colombia (Fig. 1). According to the Köppen classification system, the climate in this coastal area is semi-arid (steppe) and very hot (IDEAM, 2014a), with average temperatures ranging from 22 to 34 °C and an annual rainfall from 0 to 120 mm; September and October are the rainiest months, and January and February the driest months of the year (IDEAM, 2014b). In the coastal area of Magdalena Department, there are ~1400 ha of coral areas, ~90 ha of seagrass, ~38,000 ha of mangroves and ~100 km of sandy beaches (Gómez-Cubillos et al., 2015), which are vital ecosystems for local communities, due to direct supply of ecosystem services, especially provision (fishing) and cultural (tourism) on which their economy is traditionally based.

The beaches of Santa Marta municipality are attractive mainly for the beauty of the landscape and crystal clear waters, the most important beaches for tourism activities are El Rodadero, Playa Blanca, Playa Grande, Taganga, Bello Horizonte, Pozos Colorados (Cabo Tortuga), La Piscina, San Juan del Cabo, Boca del Saco, Neguanje, Cinto, Chengue, and Playa Cristal (MinCIT, 2011). Each year approximately 600,000 foreign and national tourists visit these beaches (CITUR, 2018), and according to the District Mayor's Office, 20% of the local population benefits from tourism activities on the beaches (Alcaldía Distrital de Santa Marta, 2016). However, tourism is also one of the main sources of marine pollution (INVEMAR, 2017), since a large part of the solid waste generated by tourists remains on the beach, causing pollution and increasing cleaning costs (INVEMAR, 2017; Rangel-Buitrago et al., 2018).

The aim of this study was to assess the impact of tourism activity on marine litter pollution on eleven touristic beaches of the Santa Marta municipality. The main research questions were: Does the temporal variation of the tourism intensity negatively impact the Santa Marta beaches, increasing litter pollution when there are more users? Does the tourism effect on litter pollution differ between beaches typologies (urban, village, and remote) in Santa Marta? What are the main types and sources of litter on the Santa Marta tourist beaches? Do the users of the Santa Marta beaches perceive the litter pollution and do they take actions to avoid this type of pollution? This study contributes to the general information on qualitative and quantitative characteristics of marine litter on sandy beaches, which is essential to develop strategies to prevent and reduce this pollution, in order to keep Santa Marta beaches (and other regions in the world) in good condition for the enjoyment of present and future generations.

Table 1
Description of the tourist beaches of Santa Marta evaluated in this study. Total length (TL), Estimated area evaluated (EAE).

Beach	Coordinates		TL (km)	EAE (km^2)[c]	Type of beach[d]
Cristal	11° 19.652′ N	74° 4.628′ W	0.33[a]	0.007	Remote, natural park
Neguanje	11° 18.933′ N	74° 4.846′ W	0.88[a]	0.009	Remote, natural park
Grande	11°16′17.01″ N	74°11′48.88″ W	0.19[c]	0.004	Remote
Blanca	11°13′7.52″ N	74°14′18.44″ W	0.40[c]	0.008	Remote
Concha	11°17′49.82″ N	74° 9′0.12″ W	0.93[b]	0.019	Village, natural park
Taganga	11° 15.920′ N	74° 11.468′ W	0.51[b]	0.004	Village
Camellón	11° 14.557′ N	74° 12.938′ W	0.70[b]	0.012	Urban
Los Cocos	11° 14.231′ N	74° 13.121′ W	0.27[b]	0.014	Urban
El Rodadero	11° 12.266′ N	74° 13.679′ W	0.88[b]	0.059	Urban
Cabo Tortuga	11°10′18.34″ N	74°14′4.07″ W	0.56[b]	0.022	Urban
Bello Horizonte	11° 8′41.70″ N	74°13′35.17″ W	2.71[b]	0.015	Urban

Sources:
[a] MinAmbiente (2004).
[b] INVEMAR (2014).
[c] Google Earth Pro 2019.
[d] Anthropogenic beaches typology (William and Micallef, 2009).

2. Material and methods

2.1. Sampling stations

Eleven beaches of Santa Marta municipality were selected, which according to the anthropogenic beaches typologies described by Williams and Micallef (2009), four were remote beaches (Neguanje, Cristal, Grande, and Blanca), two were village beaches (Concha and Taganga), and five were urban beaches (Camellón, Los Cocos, El Rodadero, Cabo Tortuga, and Bello Horizonte) (Fig. 1; Table 1). Neguanje, Cristal, and Bahía Concha beaches are in the Tayrona National Natural Park, a marine protected area (MinAmbiente, 2004), and on these beaches a moderate tourism is developed. On all urban beaches and the Taganga, Grande, and Blanca beaches, intensive tourism is being developed. Los Cocos beach is used both for intensive tourism and for the sale of fishes and shellfish caught by local artisanal fishermen; this beach is also influenced by the Manzanares River, which is highly polluted.

The most intense touristic activities in Santa Marta occur on December–January, Holy Week, June–July and October, and the Sea Festival, one of the most important festivities in the municipality, held in July. Taking into account the dynamics of tourism in the study area, the sampling on the beaches Cristal, Neguanje, Taganga, Camellón, Los Cocos, and El Rodadero, was carried out on April 12–13 (season of low tourism) and on July 27–28 (Sea Festival) of 2018. Likewise, on the beaches Bahía Concha, Grande, Blanca, Cabo Tortuga, and Bello Horizonte the sampling was carried out on September 19–20 (season of low tourism) and on July 25–26 (Sea Festival) of 2019. The samplings were carried out between 10:00 and 13:00 h, during dry climatic conditions, because during 2018 and 2019 there were changes in the normal pattern of precipitation due to the El Niño-Southern Oscillation event (NOAA, 2020).

2.2. Count of people on the beaches

Along a route from one to the other end of each beach, the people (users like tourists and service providers) who were on the beaches were counted using a four-digit manual counter. For this, we considered the distribution of users in the activity zone (wet sand strip with tourist transit), resting zone (strip where the tourist tents are located), and transition zone (strip with vegetation and service infrastructures; Fig. 2). These zones were defined by the District Mayor's Office for orderly use of the Santa Marta beaches (Alcaldía Distrital de Santa Marta, 2015). To compare the number of users on the beaches, data were standardized dividing the total number of users counted on each beach by the estimated area of each beach. The estimated area of the beaches was obtained in the Google Earth Pro 2019 program (Table 1). Results were expressed in number of people km^{-2} of the beach.

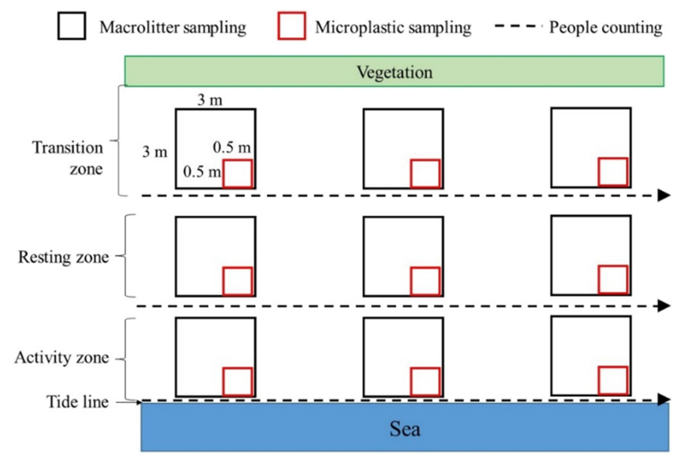

Fig. 2. Scheme of the sampling design of macrolitter and microplastics and user count on the Santa Marta beaches evaluated in this study.

2.3. Macrolitter sampling

To sample macrolitter (items > 5 mm) on the beach, we used an adaptation of the methodology developed by the citizen science program *Científicos de la Basura* “Litter Scientists” from Chile (Hidalgo-Ruz et al., 2018). Three transects perpendicular to the coastline were traced, using as a criterion the beach width, and sections of the beach used for tourism, covering the active, resting, and transition zones. In each transect, three quadrants of 3 m × 3 m (9 m^2) were established (Fig. 2); all macrolitter items present within each quadrant were collected, taking surface sand (0 to 5 cm deep) with a garden rake and sieving through a 5 mm mesh. Macrolitter items were identified according to the product and material, and were classified into eight categories (plastic, metal, glass, textile, processed wood, paperboard, rubble and others) (OSPAR, 2010). The macrolitter items in each category were counted and the concentration was expressed in items m^{-2}.

2.4. Microplastic sampling and polymer analysis

For sampling of microplastics an adaptation of the Hidalgo-Ruz and Thiel (2013) methodology was used. Within the macrolitter quadrants, a sub-quadrant of 0.5 × 0.5 m (0.25 m^2) was delimited (Fig. 2), where all surface sand (0 to 5 cm deep) was collected. Directly on the beach,

Table 2
Class intervals for the qualitative categorization of macrolitter, microplastic and number of users on the Santa Marta beaches, used in the contingency tables and associations tests.

Variables	Qualitative classification		
	Low	Medium	High
Macrolitter pollution (items m^{-2})	(1, 11]	(11, 23]	(23, 36]
Microplastic pollution (items m^{-2})	(1, 100]	(100, 200]	(200, 360]
Number of people km^{-2}	(1, 11,000]	(11,000, 33,000]	(33,000, 57,000]

dry sand was screened over sieves with mesh sizes of 5 mm and 1 mm; wet sand samples were taken to the laboratory, dried in the oven at 60 °C for 72 h, and then sieved. The samples retained on the 1 mm sieve were analyzed directly under the stereoscope (Leica Microsystems) for visual identification, taking into account basic criteria, such as: (1) absence of visible cellular or organic structures, (2) fibers with equal thickness throughout their entire length and not sharpened at the end, and (3) particles with clear and homogeneous colors, not bright (Hidalgo-Ruz et al., 2012; Nor and Obbard, 2014). Precautionary measures were taken to avoid possible fiber contamination during laboratory procedures, such as the use of cotton lab coats, clean and quiet work areas, and the use of air extractors. Microplastics found in the samples were classified into six categories suggested by Kovač et al. (2016): fragment, filament, film, foam, granule, and pellet. The units were expressed in items m^{-2}.

For the chemical characterization of polymers, 102 microplastics were randomly selected, and analyzed by Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy technique, using an ATR detector coupled with a Tensor II Fourier Transform Spectrometer (Bruker Optik GmbH). Absorbance spectra were recorded in the mid-infrared range (4000 to 400 cm^{-1}) by combining 16 individual scans at a resolution of 4 cm^{-1}. Polymers were identified by comparison of sample absorption bands (AB) with those from the published literature (Jung et al., 2018). These analyses were carried out in the Laboratório de Radioecologia e Alterações Ambientais (LARA) of the Universidade Federal Fluminense, Brazil.

2.5. Marine litter pollution perception survey

During the field sampling, a perception survey and awareness about pollution by marine litter was applied to 160 users on the beaches of Santa Marta; 52% of surveyed users were men and 48% women; 21% were aged between 18 and 30 years, 43% between 30 and 50 years, and 36% were > 50 years old. This survey was designed, validated, and applied by Rayon-Viña et al. (2018) on Spanish beaches, and consisted of five open questions: (1) How much litter do you perceive on this beach? (2) Which do you think is the most abundant litter type on this beach? (3) What do you think is the more common origin of litter on this beach? (4) What do you do to avoid litter on this beach? (5) When you go to the beach, do you bring bags or containers with you to take litter away? Additionally, respondents were asked what actions could be proposed to solve this problem on Santa Marta beaches. The answers were recorded in paper formats, and were tabulated in Excel for analysis.

2.6. Statistical analysis

The behavior and variables proportionality was analyzed by descriptive statistics. To determine the effect of beach type (factor 1) and tourist season (factor 2) treatments separately or combined, two-factor ANOVA analysis was applied, after verifying assumptions of data normality and homoscedasticity using the Shapiro-Wilk and Bartlett tests, respectively; and applying a transformation of Log_{10} to normalized some data. The relationship between macrolitter density, microplastics concentration, and number of users on the beaches was determined with Pearson correlation analysis, assuming that macrolitter concentration on the Santa Marta beaches had a positive relationship with the number of users, and microplastics with the macrolitter concentration. Contingency tables and association (Pearson's Chi-square (χ^2) and Pearson's contingency coefficient (C)) tests were used to analyze the dependency between the qualitative variables of user perception and characterization of marine litter. Pearson's contingency coefficient (C) ranges from 0 to 1, where 0 value indicate independence, and values close to 1 indicate a perfect association. For contingency tables and association tests, the quantitative data of marine litter and quantity of people on the beaches were categorized taking into account the class intervals defined for this purpose (Table 2). Statistical analyses were performed using Infostat® software.

3. Results

3.1. Count of people on the beaches

The total standardized numbers of beach users were from 1600 to 24,000 people km^{-2} during the low tourist season and from 4500 to 103,000 people km^{-2} during the high tourist season (Fig. 3a). The remote beaches Grande, Cristal, and Blanca, village beach Taganga, and urban beaches El Rodadero and Camellón had the highest numbers of users km^{-2} in both seasons (Fig. 3a). Although the number of users on the beaches increased during the high tourist season, no significant differences were found between the high and low tourist seasons ($F_{(1-21)} = 2.08$, $P = .1685$), and between the types of beaches (remote, village and urban; $F_{(1-21)} = 0.77$, $P = .4775$). The effect of the interaction of the two factors (type of beach and tourist season) was not significant ($F_{(1-21)} = 0.08$, $P = .9220$).

3.2. Macrolitter pollution on beaches

During the low tourist season, macrolitter concentration on sandy beaches ranged from 2 to 19 items m^{-2} (8 ± 5 items m^{-2}) and during the high tourist season from 2 to 36 items m^{-2} (12 ± 7 items m^{-2}) (Fig. 3b). The average concentration of macrolitter on urban beaches (11 ± 11 items m^{-2}) was higher than on remote beaches (10 ± 6 items m^{-2}) and village beaches (9 ± 3 items m^{-2}). The remote beaches Grande and Blanca and the urban beaches Rodadero and Camellón had the highest macrolitter concentration (Fig. 3b). There were no significant differences in the macrolitter concentrations between tourist seasons ($F_{(1-21)} = 1.42$, $P = .2509$), between the types of beaches ($F_{(1-21)} = 0.17$, $P = .8477$), or between the interaction of these two factors ($F_{(1-21)} = 0.10$, $P = .9060$). Pearson's analysis showed a positive moderate-strong and significant correlation between numbers of users on the beach and macrolitter concentration ($r = 0.62$, $N = 22$, $P = .0012$).

Of the total macrolitter collected on Santa Marta beaches, crown corks, cigarette butts, soda tabs, plastic fragments, and glass fragments were the most abundant item types (Table 3; Fig. 4). Plastic macrolitter was the most abundant category on all studied beaches, representing from 35% to 72% of all items, followed by metal, glass, rubble, textile, processed wood, paper-cardboard, and other litter (Fig. 3c).

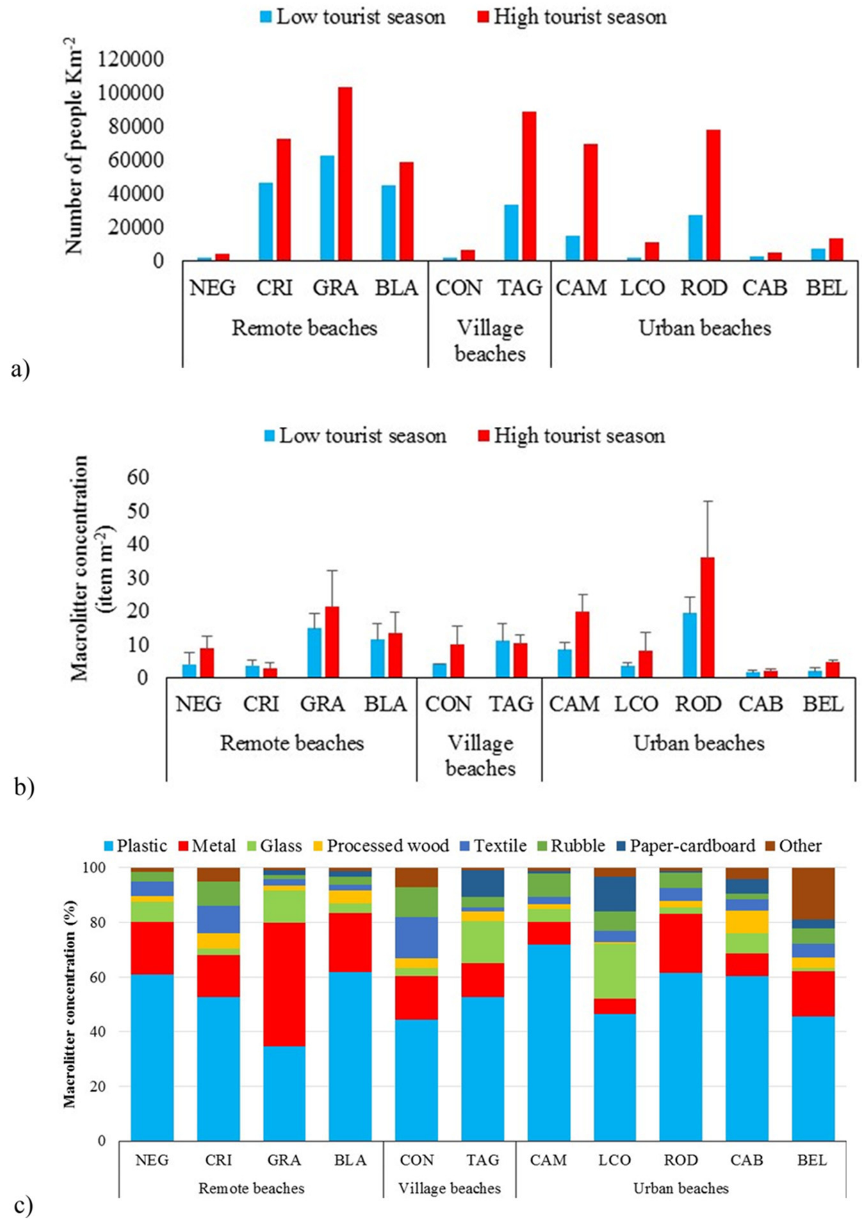

Fig. 3. (a) Standardized total number of people per square kilometer of the beach, (b) average (± standard deviation, n = 9) of macrolitter abundance and (c) percentages of macrolitter categories found on Santa Marta tourist beaches, recorded in the low and high tourist seasons. Beaches: (NEG) Neguanje, (CRI) Cristal, (CON) Bahía Concha, (GRA) Grande, (BLA) Blanca, (TAG) Taganga, (CAM) Camellón, (LCO) Los Cocos, (ROD) Rodadero, (CAB) Cabo Tortuga and (BEL) Bello Horizonte.

3.3. Microplastics pollution on beach sand

During the low tourist season, microplastic concentrations ranged from 1 to 355 items m^{-2} (112 ± 103 items m^{-2}), and during the high tourist season from 2 to 92 items m^{-2} (32 ± 23 items m^{-2}; Fig. 5a). The average concentration of microplastics in the sand of remote beaches (31 ± 48 items m^{-2}) was lower compared to urban beaches (82 ± 125 items m^{-2}) and village beaches (75 ± 51 items m^{-2}). The remote beach Grande, village beaches Bahía Concha and Taganga, and the urban beaches Cabo Tortuga and Rodadero had the highest microplastic contamination (Fig. 5a). The most abundant microplastic categories were fragments, followed by foams, filaments, and films (Fig. 5b). The two factor ANOVA analysis revealed no significant differences between the beach types ($F_{(1,21)} = 1.23$, $P = .3191$) and tourist season ($F_{(1, 21)} = 0.71$, $P = .4121$), nor in the interaction of these two factors ($F_{(1, 21)} = 0.53$, $P = .6008$). The correlations of microplastics concentrations with macrolitter concentrations ($r = 0.10$, $N = 22$, $P = .6647$) and number of users ($r = -0.10$, $N = 22$, $P = .6419$) on the beaches were small or nil.

In the 102 randomly selected microplastics from remote, village, and urban beaches analyzed by ATR-FTIR three types of polymers were detected: polystyrene (PS; 39.2%), polyethylene (PE; 33.3%), and polypropylene (PP; 27.5%) (Table 4). The microplastics with foams shapes found on remote, village, and urban beaches were made of PS, fragments found on three types of beaches were made of PE and PP, and pellets found only on remote and urban beaches were made of PP (Table 4).

3.4. Perception of marine litter pollution on the beaches

The majority of the surveyed users on remote and village beaches perceived low macrolitter pollution, while those on urban beaches

Table 3
Most common macrolitter items found on the beaches of Santa Marta, in this study.

Items type	Number of items	Possible sources
Crown cork	576	Tourist
Cigarette butts	575	Tourist
Soda tap	501	Tourist
Small hard plastic fragments	446	Tourist, sea, river
Glass fragments of bottles	404	Tourist
Plastic bags and packaging	288	Tourist, sea, river
Cords, wool, and thread	192	Tourist, sea, river, fishing
Plastic lids	136	Tourist
Ceramic fragments	144	Construction
Plastic utensils (cups, cutlery, fast food containers)	118	Tourist
Popsicle sticks, toothpicks, and skewer sticks	73	Tourist
Plastic drinking straws	54	Tourist
Fragments of clothing	48	Tourist, river
Pieces of cardboard	41	Tourist, fishing
Napkins	31	Tourist
Remains of food (lemons, fruit seeds, bones, and cob)	27	Tourist
Gum wrappers	21	Tourist

perceived high pollution (Table 5). Pearson's Chi-square test showed significant differences between the perception of macrolitter pollution and the type of beaches, indicating a probable association between these variables ($\chi^2 = 10.68$, P = .0011). Comparing the perception of marine litter pollution with macrolitter concentrations determined in this study, significant differences were found, so there is a probable association ($\chi^2 = 9.22$, P = .0100).

Respondents indicated that plastics are the most common litter items on remote, village, and urban beaches (Table 5), and through Pearson's contingency coefficient (C) it was possible establish a dependency between perception and reality about plastics on beaches (C = 0.29). On the other hand, more than 70% of the respondents identified visitors as the most common source of macrolitter (Table 5). A low association of perception on the main marine litter source and the type of beach was determined (C = 0.18).

More than 40% of respondents indicated that they collect their own litter, another part mentioned that they collect the litter of others (Table 5); on urban beaches, some of the surveyed users indicated that they collect certain types of litter to recycle and another part on remote and urban beaches tries not to generate litter (Table 5). These responses to litter on the beach were not independent of the type beach (C = 0.32). Finally, more than 70% of the respondents manifested that they carry a bag to deposit the litter generated during their activities (Table 5).

4. Discussion

4.1. Macrolitter pollution on beach sand

The beaches of Santa Marta evaluated in this study are contaminated by macrolitter with items between > 5 mm and 40 cm, which are directly associated with tourist activities. Smaller litter, such as cigarette butts and pieces of plastic and metal, are accumulating on the beaches sand despite the daily beach cleaning, because common litter collection mechanisms are ineffective for small litter. This situation has also been observed on other beaches in the Colombian Caribbean (Rangel-Buitrago et al., 2018), Brazil (Portz et al., 2011; Lopes da Silva et al., 2016, 2018), Chile (Hidalgo-Ruz et al., 2018), Australia (Wilson and Verlis, 2017), China (Zhao et al., 2015), among many other places in the world (Araujo and Costa, 2019).

Santa Marta is an attractive tourism destination, and it is estimated that nearly 600,000 national and international tourists visit this municipality every year, to pursue recreational activities on beaches and other tourist sites (CITUR, 2018). On remote (Blanca and Grande) village (Bahía Concha) and urban (Rodadero and Camellón) beaches evaluated in this study, it was observed that the influx of more tourists to the beaches increased macrolitter pollution. Similar results have been observed for beaches in different parts of the world during summer and vacation periods (Lopes da Silva et al., 2016, 2018; Pervez et al., 2020; Gómez et al., 2020; Chen and Chen, 2020; Becherucci et al., 2017; Asensio-Montesinos et al., 2019).

Santa Marta urban beaches are the most visited by tourists and residents due to easy access and availability of commercial services (lodging, restaurants, and stores); these beaches are also frequently cleaned during the day by the municipality. Remote and village beaches are very attractive because of natural landscapes, some within marine protected areas (e.g. Cristal, Neguanje, and Bahía Concha), but these beaches are typically smaller in area (e.g., 0.4–0.8 ha, Cristal, Grande, and Blanca; Table 1), with less commercial services, and are far away from the city; these beaches are cleaned community tourist associations. These differences influence the state of litter pollution on the types of beaches.

Among the remote beaches, Cristal beach located in the Tayrona National Natural Park had the highest density of visitors during the high tourist season (total 502 people registered, standardized value: 72,000 people km^{-2}), this amount exceeds the carrying capacity established by the Environment Ministry of Colombia (350 users per day, standardized value: 50,000 people km^{-2}; MinAmbiente, 2004). Nevertheless, the concentration of macrolitter on Cristal beach was low compared to other remote beaches (Neguanje, Grande, and Blanca), village beaches and urban beaches (Rodadero, Camellón, and Taganga), which is attributed to awareness talks on the use and conservation of the beaches for visitors before entering Tayrona Park, which would be influencing user behavior regarding litter disposal in the park. In addition to the daily cleanings that the community tourist associations.

Los Cocos urban beach, unlike the other evaluated Santa Marta beaches, is influenced by the Manzanares River discharges and artisanal fishing. This beach was the third urban beach with highest macrolitter concentration. The high proportion of plastics (polystyrene or styrofoam, hard fragments), glass (bottle fragment), paper-cardboard (pieces of cardboard, cigarette boxes, napkins), textiles (clothing, ropes, cloths), and rubble (ceramics fragments), are generally being associated with tourism, fishing, and poorly managed waste from inland municipalities that can transported by rivers to the sea (Topçu et al., 2013; Lopes da Silva et al., 2018; Honorato-Zimmer et al., 2019; Daniel et al., 2020). At Los Cocos beach, these three sources of macrolitter (tourism, fishing, and river) converge and may be influencing the patterns of macrolitter distribution on the beach, as reported in other studies conducted in Chile and China (Rech et al., 2014; Zhao et al., 2015).

In general, the composition of macrolitter on Santa Marta beaches is fairly comparable to the composition of litter reported for other beaches in the world (Lopes da Silva et al., 2016; Becherucci et al., 2017; Vlachgianni et al., 2018; Honorato-Zimmer et al., 2019; Gaibor et al., 2020), being plastics the most abundant material (between 30% and 77% of the total beach macro-litter collected). Metal and glass were also relatively common on all studied Santa Marta beaches, their presence on the beaches are health hazards for humans and wildlife, and causes a deterioration of landscape quality (Botero et al., 2017; Rangel-Buitrago et al., 2018, 2019). Additionally, a lot of cigarette butts were found between the surface and 5 cm deep in the sand, considered as an indication of the main litter source are beach visitors; similar results have also been found at tourist beaches in Brazil (Lopes da Silva et al., 2016, 2018), Argentina (Becherucci et al., 2017), and Chile (Honorato-Zimmer et al., 2019). The cigarette butts have become a serious threat to marine life because they contain harmful chemicals (Araujo and Costa, 2019).

Fig. 4. Photographs of some samples of macrolitter found on the tourist beaches of Santa Marta: (a) Plastic utensils, (b) Plastic bags and packaging, (c) Cigarette butts, (d) Soda tap, (e) Crown cork, (f) Plastic drinking straws and plastic Sticks, (g) Plastic lids, (h) Glass fragments of bottles, (i) Ceramic fragments, (j) Small hard plastic fragments, (k) Cords, wool, and thread.

4.2. Microplastic pollution on the beach sand

All studied beaches were found to contain microplastics (with sizes from 1 to 5 mm), however, their abundance in the sand was poorly correlated to macrolitter concentrations, unlike the reports by Lee et al. (2013) on beaches in South Korea, in areas where microplastics and mesoplastics were abundant. Microplastic concentration was higher on urban beaches during the low tourist season, unlike macrolitter concentrations that were higher during the main tourist season. These microplastics are mostly of secondary origin (fragments, filaments, and foam) derived from the breakdown of larger plastic macrolitter exposed to UV radiation under direct sunlight or physical abrasion in the sands and rocks, which may reach the beaches by coastal currents (Weinstein et al., 2016; Yu et al., 2020). Solar radiation on the Santa Marta beaches ranges between 4.5 and 5.5 KWh m^{-2} (IDEAM, 2015).

Microplastic concentrations on the Santa Marta beaches are lower than those reported in other beaches of tourist importance in the Colombian Caribbean, such as those of Coveñas and Cartagena (maximum 1000 and 4000 items m^{-2}; Acosta-Coley et al., 2019) and Mexican beaches (32–546 items m^{-2}; Alvarez-Zeferino et al., 2020), Peruvian beaches (16–490 items m^{-2}; De la Torre et al., 2020), and Panamanian beaches (16–420 items m^{-2}; Delvalle et al., 2020); but they are higher than reported for continental Chilean beaches (< 1–169 items m^{-2}; Hidalgo-Ruz and Thiel, 2013).

Three types of polymers (PE, PS, and PP) were identified in the microplastics analyzed in this study, which are commonly used for a wide variety of consumer products (e.g. PE: supermarket bags, plastic bottles; PS: packaging foam, disposable cups, food containers; PP: packaging, bottle caps, ropes, drinking straws; Costa et al., 2017) commonly used in tourism, which have been found in tourist beaches at different parts of the world (Zhao et al., 2015; Acosta-Coley et al., 2019; De la Torre et al., 2020; Delvalle et al., 2020). Microplastics on the beaches represent a risk for ecosystems and human health, and it becomes a challenge for countries to find solutions to this problem (Antão-Barboza et al., 2018; Alimba and Faggio, 2019).

4.3. Perception of marine litter contamination and behavior of users

The users of Santa Marta beaches surveyed are aware of the problem caused by marine litter. Most of the respondents perceived high pollution on urban beaches, while others, low pollution on remote and village beaches, mainly those of Tayrona Natural Park. This perception of respondents agrees with the litter quantities registered, as well as the perception of plastics as the most common type of litter. A clear

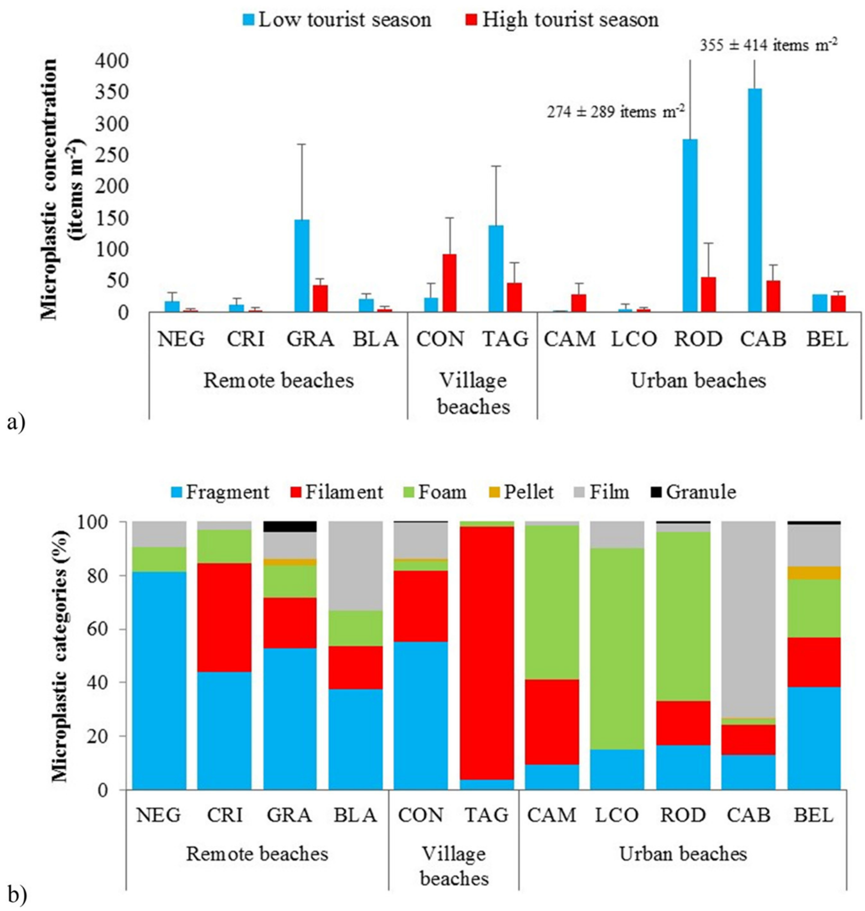

Fig. 5. (a) Microplastic concentration (average ± standard deviation) and (b) percentage of microplastics categories found in the sand of the Santa Marta beaches, during the low and high tourist seasons. Beaches: (NEG) Neguanje, (CRI) Cristal, (CON) Bahía Concha, (GRA) Grande, (BLA) Blanca, (TAG) Taganga, (CAM) Camellón, (LCO) Los Cocos, (ROD) Rodadero, (CAB) Cabo Tortuga and (BEL) Bello Horizonte.

Table 4
Types of polymers per shape of microplastic found in the sand of remote, village, and urban beaches evaluated in Santa Marta, according to the samples randomly selected for the ATR-FTIR analysis. (PE) Polyethylene, (PP) Polypropylene, (PS) Polystyrene.

Type of beach	Shape	Number of polymers		
		PE	PP	PS
Remote	Foam	0	0	4
	Fragment	20	19	0
	Pellet	6	1	0
Village	Foam	0	0	6
	Fragment	2	2	0
Urban	Foam	0	0	30
	Fragment	6	5	0
	Pellet	0	1	0
Total		34	28	40

relationship between litter pollution level and perception of beaches users also was reported by Rayon-Viña et al. (2018, 2019) on Spanish beaches, and by Kiessling et al. (2017) on Chilean beaches.

The high percentage of respondents who perceive the problem of marine litter on Santa Marta beaches may be related to the awareness campaigns on the marine litter impacts that are carried out at the national and local levels. Santa Marta is the first Colombian city where the urban environmental authority -DADSA leads the fight against single use plastic through the campaign "*Desplastifica tu ciudad*", which seeks to reduce and prevent pollution by single use or disposal plastics in rivers and the Caribbean Sea coast of Santa Marta. A regulation was created with the Resolution No 1017 of 2018 in order to discourage the use of disposable plastics and to promote the use of biodegradable materials to contribute to the conservation of ecosystems (DADSA, 2018). In addition, together with the regional environmental authority -CORPAMAG, the Marine and Coastal Research Institute -INVEMAR and other environmental Colombian entities have developed educational and awareness activities with good community involvement, such as cleaning of beaches and urban rivers, awareness videos, sports and cultural days, postconsumer waste collection days and workshops of socialization of environmental research results carried out in the municipality.

Respondents recognized visitors as the main marine litter source on touristic beaches of Santa Marta, which is closely associated with use of different types of macrolitter by tourist that were identified in the characterization; similar results were obtained in a marine litter perception study on Chilean beaches, where respondents also identified visitors as the main litter source (Kiessling et al., 2017). Users surveyed in Santa Marta consider vendors as another litter source on the studied beaches, since it is common to observe in restaurants and fast-food sales close to the beach, with waste bins overflowing with polystyrene food containers, disposable plastic forks and glasses, napkins and soft drink plastic bottles (e.g. Rodadero and Camellón urban beaches). Furthermore, bags and other light materials given out by beach vendors are blown by the wind to other areas of the beach. Users of Los Cocos urban beach, perceived the Manzanares River as the main litter source, because in the rainy season it is common to observe a lot of litter discharging from the river into the sea, and part of this is deposited on the nearby beaches. This situation has also been observed on Chilean beaches in the vicinity of major rivers (Rech et al., 2014).

Many respondents collect their own litter (59–79%), and some touristic service providers collect litter of other beach users. On urban beaches, it is common to observe certain users collecting beer cans and plastic bottles for recycling. Nevertheless, not all the litter generated by users is collected; they generally leave the smallest litter (e.g. cigarette

Table 5
Perception of the 160 users surveyed on the marine litter problem on the remote, village, and urban beaches evaluated in this study in Santa Marta municipality, Colombian Caribbean.
Questions were taken from Rayon-Viña et al. (2018).

Question and grouping categories	% of responses		
	Remote beach	Village beach	Urban beach
1. How much litter do you perceive in this beach?			
Low	58.3	76.5	35.9
High	41.7	23.5	64.1
2. Which do you think is the most abundant litter type in this beach?			
Plastic	50.0	58.8	82.4
Metal	33.3	23.6	13.7
Others	16.7	17.6	3.9
3. What do you think is the more common origin of litter in this beach?			
Visitor	75.0	94.1	72.5
Vendor	16.7	0.0	6.1
Resident	8.3	0.0	1.5
Sea	0.0	5.9	4.6
River	0.0	0.0	15.3
4. What do you do to avoid litter in this beach?			
Collects their own litter	41.7	70.6	79.3
Collect litter of others	33.3	11.8	6.9
Indicate container	16.7	17.6	2.3
Recycle	0.0	0.0	4.6
Not generate	8.3	0.0	6.9
5. When you go to the beach, do you bring bags or containers with you to take litter away?			
Carry a bag	75.0	88.2	74.8
Not carry anything	25.0	11.8	25.2

butts and soda tab) behind on the beach, where they become buried in the sand. Beach clean-up can remove the macrolitter, but smaller ones remain on the beach, as reported by Zhao et al. (2015) for beaches in southern China.

A high percentage of respondents who carries bags to collect their own litter could be explained by three possible ways: (1) users are aware of the marine litter problem, and carry their own bag to avoid contamination of the beach (Hartley et al., 2015; Rayon-Viña et al., 2019), (2) users are aware of the litter problem, but they do not carry a bag specifically to collect litter, instead, they use one brought for another purpose, and (3) the users possibly were not honest with their answers (Eastman et al., 2013). The behavior of remote and village beaches users to carry bags for deposit litter could be influenced by previous planning, little expectation of finding litter cans, and the figure of the natural protected areas. On urban beaches, the percentage of respondents who did not bring anything to pick up their own litter stated that they would expect to find waste bins on the beach. Further study is required on the attitude and behavior of users towards litter contamination on the Santa Marta beaches, considering socioeconomic and environmental factors and social experiments.

5. Conclusions and recommendations

This study investigates the impact of tourism on marine litter pollution on eleven beaches of great tourist importance in Santa Marta, Colombian Caribbean, providing information on the characteristics of macrolitter and microplastics and the perception of users of this type of pollution, which helps to understand the problem and guides local government efforts to reduce litter on the beach. Variations in the influx of beach users are generating marine litter pollution, with the greatest abundance of litter in the high tourist season, with plastics, metals, paper, cardboard, and glass being the most abundant, of which the smallest they are accumulating in the sand due to the current cleaning mechanism (rake), which is not efficient for their removal.

Users of Santa Marta beaches are aware of the problem of marine litter, and they identify tourism as an important source of litter, in particular plastics. Nevertheless, strategies of education and awareness about the environmental impacts of macrolitter and microplastics are required on an ongoing basis, in order to improve the awareness of beach users and achieve better environmental management. In addition, an effort should be made to articulate environmental authorities and stakeholders, such as the tourism sector and local communities, to promote the protection and conservation of beach ecosystem and perform their roles as beach caretakers, in order to reduce pollution, prevent ecological and socio-economic impacts and develop sustainable tourism, by keeping the beaches without litter.

CRediT authorship contribution statement

Ostin Garcés-Ordóñez: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing.**Luisa F. Espinosa Díaz:**Resources, Project administration, Funding acquisition, Writing - review & editing.**Renan Pereira Cardoso:**Investigation, Methodology, Writing - review & editing.**Marcelo Costa Muniz:**Investigation, Methodology, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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