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Review

To clean or not to clean? A critical review of beach cleaning methods and impacts☆,☆☆

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ABSTRACT

Cleaning is a fundamental concern of beach managers in many destinations as well as an important requirement in beach quality awards. However, it has been largely neglected in the literature. This paper provides an overview of empirical studies on beach cleaning and analyzes cleaning-related requirements of 11 beach awards that generate controversy in the literature. This study comments on key aspects of beach cleaning, resolves various misconceptions, and provides new perspectives by integrating related topics drawn from a wide range of literature. The arguments based on both the ecological and tourism managerial perspectives are presented, indicating the gaps and proposing research solutions. The paper calls for empirical studies with regard to the efficiency of different cleaning approaches on beaches with varying levels of use intensity and for methodological designs that separate the impacts of mechanical grooming from those of trampling, dune destruction, shore armoring, artificial lighting, among others.

1. Introduction

Traditionally, coastal areas attract millions of visitors, which bring sizeable direct and indirect profits to national and local economies (Clark, 1996). Despite the significant human induced threats to coastal environments, beaches remain the primary assets that attract visitors through sun, sea, and sand (3S) tourism (Yanes et al., in press). Among beach tourism destinations there is a strong competition for the visitors who can choose from a wide range of beaches based on their preferences. A reduction of income from tourism might be severe if, for some reason, a beach user group opts out from visiting a particular destination (Krelling et al., 2017). The presence of litter is a strong reason for visitors to leave a beach or not to visit (Ryan, 2014; Williams and Micallef, 2009) because it creates a feeling of unhealthy conditions and poor beach aesthetic value among the users (Corraini et al., 2018). The lack of beach cleanliness can lead to a loss of recreational potential of a beach which impacts the economy and social well-being, especially because coastal populations have become more dependent on beach areas (Portman and Brennan, 2017). Hence, cleaning is one of the fundamental concerns of beach managers in many destinations (Ariza et al., 2008). In order to satisfy users' preference for litter-free beaches, a considerable amount of funds is spent each year for beach cleaning. Krelling et al. (2017) reported that the municipality of Pontal do Paraná (Brazil) employed 40 people, spending US$200,000 for cleaning a 25 km long stretch of a beach during a 53-day period. Similarly, the UK spends €18 M each year for cleaning the beach litter, while the municipalities in the Netherlands and Belgium spend approximately €10.4 M each year (Mouat et al., 2010).

It is unsurprising that beach quality awards, or beach certification schemes (BCS), pay considerable attention to this particular aspect. The academic literature is still divided on the value and significance of beach awards despite the increasing body of research (McKenna et al., 2011). Cleaning is one category of BCS which has often received much criticism based on assumptions lacking substantial evidence. A large number of papers have been published on the type, distribution and origin of litter and the impact it has on the aesthetic value of beaches in the past two years (Table 1). Yet, despite a respectable body of research on this subject in the field of ecology, botany, and biology, beach

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Table 1
Most recent studies of beach litter.

Reference	Country	# sites	Focus
Battisti et al., 2017	Italy	2	Litter diversity metrics
Becherucci et al., 2017	Argnetina	24	C, W
Botero et al., 2017	Cuba	99	C
Corraini et al., 2018	Brazil	8	C, W, SI
da Silva et al., 2018	Brazil	3	C, W, TV
Giovacchini et al., 2018	Italy	11	C, W
Gracia et al., 2018	Colombia	26	C, identification of associated fauna
Hidalgo-Ruz et al., 2018	Chile	69	C, TV
Krelling et al., 2017	Brazil	2	Perceptions and reactions of tourists
Pasternak et al., 2017	Israel	8	C
Portman and Brennan, 2017	Israel	3	C, TV
Rangel-Buitrago et al., 2018	Colombia	137	C, SI
Vlachogianni et al., 2018	Various	31	C, TV
Watts et al., 2017	UK	9	C, TV
Williams et al., 2017	UK	14	C, TV

C – composition; W – weight; TV – temporal variations; SI – scenic impact.

cleaning practices and their impacts are considered as one of the most understudied topics within the beach management and BCS debate (Botero et al., 2018b). There are very few studies that provide a comprehensive view on beach cleaning research, including the ecological and managerial strengths and weaknesses of different solutions and other aspects often neglected in beach management discussion that sheds light on many arguments for, or against, certain cleaning approaches.

The primary objective of this study was to provide an overview of studies on beach cleaning and to analyze cleaning-related requirements in all current BCS that generate controversy in the literature on beach management and beach certification schemes. The empirical research was the main focus, providing clear overview of the impacts of mechanical cleaning, wrack removal, trampling and to a lesser extend effectiveness and cost effectiveness of different cleaning solutions. Other types of sources such as non-empirical studies and documents published by certification bodies provided information on beach certifications' requirements and additional arguments to support the discussion on various aspects of cleaning. This review presents arguments for some of the opinions about beach cleaning, clears up several misconceptions, and provides new perspectives on aspects that are related but rarely investigated together, considering a wide range of literature. The purpose of the information gathered here is to contribute to future studies on tourist beaches and BCS, which might be focused on sociocultural, environmental, and economic aspects of the beaches. Furthermore, the authors present various solutions to achieve an agreement between conservation and recreation, and indicate the gaps in the field of beach cleaning and suggest research ideas to address them.

1.1. Demand for clean beaches

Tourist beaches are defined in this paper as 'socioecological resources located mainly in coastal destinations, which is developed and managed for the primary purpose of attracting tourists interested in sun, sea, and sand activities' (Botero et al., 2018a, p. 1). Beach users around the world are primarily concerned with five factors (the 'Big Five'): Scenery, Absence of litter, Safety, Facilities and Water Quality (Williams and Micallef, 2009). The absence of litter is considered to be the primary factor for beach choice in many countries (Table 2). The probability of return visitation, especially for first-time visitors, is strongly associated with the perceptions of beach quality (Schuhmann, 2011). The research supports the notion of loss of visitation and income

Table 2
Studies that identified 'clean sand and water' as the primary factor for beach choice.

Country	Reference
Australia	Maguire et al., 2011
Colombia	Botero et al., 2013
Italy	Marin et al., 2009
Malta	Williams and Barugh, 2014
Mexico	Williams and Barugh, 2014
Poland	Jędrzejczak, 2004
Portugal	Quintela et al., 2009; Vaz et al., 2009
South Africa	Lucrezi and Saayman, 2015; De Ruyck et al., 1995
Spain	Alves et al., 2014; Lozoya et al., 2014; Roca and Villares, 2008
Turkey	Williams and Barugh, 2014
UK	Morgan, 1999; Morgan et al., 1993; Nelson et al., 2000; Tudor and Williams, 2006
USA	Cutter et al., 1979; Lew and Larson, 2005

as a result of excessive litter (Table 3).

Independently of the origin of litter left by visitors or washed ashore, its presence is a factor of outmost importance not only for the economy but also for health and safety of beach users (Williams et al., 2013). In this context, Campbell et al. (2016) evaluated relatively clean Tasmanian beaches and concluded that 21.6% of the respondents had received injuries due to litter when they visited a beach. The primary injuries that were reported are wounds (65%), followed by discomfort (24%) and then diseases (11%). Grenfell and Ross (1992) analyzed profile of injuries sustained on a resort beach during the summer holiday in Australia and arrived at similar proportion of wounds attributed to beach litter (19%). Finally, do Sul and Costa (2007) carried out a review of 70 studies of beach litter in Latin America and reported that injuries (cuts) and ingestion problems were the main types of health issues related to litter.

A general concern of all beaches (Sheavly and Register, 2007; Williams et al., 2013) is the presence of sharp items, which was observed in an Australian study by Whiting (1998) and in the Chilean coasts by Kiessling et al. (2017). Human health can also be affected by beach litter by coming in contact with pathogenic agents proliferated in food scraps left on the beach (Zuza-Alves et al., 2016) as well as fecal coliforms found in animal feces (Kinzelman et al., 2003), and through contact with hazardous wastes (Portz et al., 2018). Solo-Gabriele et al. (2016) and Whitman et al. (2014) have published a complete review of the potential of beach sand for transmitting infectious diseases. Although this topic has been relatively well studied, the physical damage to human health caused by beach litter has been largely neglected in the literature (Campbell et al., 2016; do Sul and Costa, 2007).

2. Methods

The collection of the studies of the impacts of mechanical cleaning, wrack removal, trampling and other impacts of human activities on beaches was carried out using Web of Science platform through EndNoteX9 software. The search was carried out using the base keyword 'beach' together with additional keywords found in title, keywords and abstract in the particular order shown in Table 4. The objective was to carry out a broader analysis to make sure that relevant papers were not missed. The search generated 3173 hits (Stage I). After removing duplicates (stage II) 2533 articles remained that were further scanned for their eligibility. Four hundred and sixty-three articles were chosen as potentially useful for the study based on the abstract. Only articles that studied impacts of cleaning, trampling and urbanization (that includes cleaning, trampling, shore armoring, intensive tourism, etc.) were selected. Consequently, a search was conducted in Google to identify additional references and papers published in journals that are not included in Web of Science. Additional 9 papers were found (Stage III). Finally, the snowball technique was used to search for more sources

Table 3
Impact of litter on income and visitation.

Location	Loss of beachgoers	Loss of income	Reference	Method
Brazil (Parana)	20–85% (depending on level of litter)	Up to 39,1% - US$3.2M	Krelling et al. (2017)	Contingent valuation
USA (California)	No Data	US$29.5M (25% reduction in litter)	Leggett et al. (2018)	Random utility travel cost
USA (New Jersey)	8% - 33%	15%–40%	Ofiara and Brown (1999)	Benefits transfer
Greece	45%	No Data	Brouwer et al. (2017)	Perception of hypothetical litter pollution
Bulgaria	95%			
South Africa (Cape Peninsula)	85%	US$0.8M (Annual expenditure on travel)	Ballance et al. (2000)	Travel cost method

Table 4
Stages in the identification of references.

Topic of interest	Keywords	# of papers Stage I	# of papers Stage II	# of papers Stage III & IV	Final selection
Beach cleaning	Cleaning	383	–	48	13
	Grooming	30	+26		
	Litter	536	+460		
	Wrack	218	+174		
	Debris	921	+553		
Trampling	Trampling	76	+63		20
	Urbanization	214	+189		
	Disturbance	795	+685		

to a point that no new references were identified in all collected publications (Stage IV). Thirty-three cases were selected that met all the selection criteria.

3. Results

3.1. Mechanical cleaning, wrack removal, and trampling

Beach cleaning, or 'grooming', involves the removal of anthropogenic litter as well as natural debris known as 'wrack' or 'beach cast' (Davenport and Davenport, 2006; Fairweather and Henry, 2003). Beach cleaning can be carried out manually by hand or by using mechanical machinery to rake and sieve the upper layer of beach sand (Gheskiere et al., 2006). The critics of mechanical beach cleaning point out that besides the human litter, the machine also removes beach wrack, including algae and plants such as *Posidonia oceanica* and Eelgrass leafs, which is a source of food and habitat for many organisms (Dugan et al., 2003). The beach wrack is also removed for aesthetic and public-health reasons in many manually cleaned tourist beaches (Schlacher et al., 2016). The wrack supports a variety of organisms, including invertebrate macro-fauna using the wrack as a food source, meiofauna associated with sediments and predators such as shorebirds (Dugan et al., 2003). The removal of wrack eliminates valuable nutrients that may affect sandy beach and dune ecosystem's food chains, which lead to the loss of abundance of species (Del Vecchio et al., 2017; Defeo et al., 2009; McLachlan and Brown, 2006).

Although a large number of empirical studies support the notion that mechanical beach cleaning decreases biomass, organic content, abundance of bacteria, meiofauna and macro-fauna (see Table 5), there are several factors that should be considered to draw a complete picture of beach cleaning. All the above-mentioned studies on mechanical cleaning are centered on the impact of wrack removal. Yet, no difference in terms of abundances of bacteria, meiofauna, macrofauna and ocypodid crabs (Morton et al., 2015), and macroinvertebrate assemblages (Lavery et al., 1999) were found between cleaned and uncleaned sites characterized by low macroalgal inputs when wrack component was removed from the equation.

Furthermore, all species do not react to a disturbance in the same way and many species seem to adapt to the changes (Fanini et al., 2005), some recover faster or are not impacted at all (Gheskiere et al., 2006; Vieira et al., 2016). Because the wrack plays an indispensable role in local food chains, the intensity of grooming is a key factor for the severity of the impact. The results reported by Morton et al. (2015) were obtained for the beaches that were cleaned weekly or twice a week. Malm et al. (2004) reported that a moderately cleaned beach shows similar organic content level and animal biomass of a non-cleaned beach. Similarly, Stelling-Wood et al. (2016) reported the highest Ghost Crab burrow densities on beaches that were mechanically cleaned up to three times a week and the lowest densities on daily groomed beaches.

The alteration in native plants (Dugan and Hubbard, 2010), destruction of hummocks, embryo dunes and modification of beach profile are other important impacts of mechanical cleaning which are supported by empirical studies (Roig-Munar, 2004). Furthermore, it is assumed that the dynamics of sediment accumulation, retention, and loss of sandy beaches might be affected by wrack removal and the reduction of cover of native plants (Cheessa et al., 2000; Dugan and Hubbard, 2010; Fairweather and Henry, 2003; Nordstrom et al., 2006; Ochieng and Erftemeijer, 1999; Roig-Munar et al., 2006) and that wave energy can be buffered by accumulations of wrack supporting sand deposition (Fairweather and Henry, 2003; Mclachlan et al., 1985; Ochieng and Erftemeijer, 1999). With general exception of the Mediterranean beaches (Simeone and De Falco, 2012), the accumulation and permanence of wrack is higher on lower wave energy beaches and during fair weather conditions, and lower on beaches along exposed coasts with high wave energy (De Falco et al., 2008; Jimenez et al., 2017). In case of former beach-cast wrack might resist waves and be effective in suppressing wave run-up (Nordstrom and Jackson, 2012), while in the latter the impact might be negligible as banquettes are continuously built up and destroyed (Gomez-Pujol et al., 2013; Ochieng and Erftemeijer, 1999). Thus far very few studies have been published on this issue and more research is required (Simeone and De Falco, 2012; Vacchi et al., 2017). With regard to the physical damage to fauna by mechanical beach cleaning, Willmot and Smith (2003) observed that machine removes the top layer of sand that frequently includes amphipod burrows that often contain animals ready to molt or breed. Conversely, no empirical evidence for any damage to beach meiofauna, macro-fauna, and ocypodid crabs was found by Morton et al. (2015) in their study.

It is surprising that very few studies evaluated other effects of mechanical grooming besides the impact of wrack removal. The major disadvantage of almost all of the above-mentioned studies, which compared mechanically cleaned and uncleaned beaches, is that they considerably neglected the intensity of beach use as a factor for loss of species abundance, and attributed the impact to grooming alone. Groomed beaches are generally those that are used most intensively; this results in the higher amount of litter and consequently require more frequent and cost-effective cleaning regime, as observed by Noriega et al. (2012), Morton et al. (2015) and Stelling-Wood et al.

Table 5
Studies on the impacts of mechanical beach cleaning.

Reference	Location	Sample size and frequency of cleaning	Sampling period	Findings
Llewellyn and Shackley (1996)	Wales, UK	3 beaches	Study inaccessible	Evidence of a negative ecological impact of beach grooming on the biodiversity and abundance of macroinvertebrates. Note: A single beach cleaning event.
Lavery et al. (1999)	Western Australia	3 beaches – 2 ungroomed and 1 groomed beach	Once at each site and once before and after a single wrack removal event	The decrease in the biomass of macrophyte detritus and densities of epifauna and fish was observed. The recovery occurred within two months. Regularly cleaned beaches had a fauna similar to non-cleaned beaches without algae.
Dugan et al. (2003)	California, USA	15 beaches – 12 ungroomed and 3 groomed (frequency unknown)	15 days in September and October	Cleaned beaches in southern California had lower species richness, abundance, and biomass of wrack-associated macrofauna.
Willmot and Smith (2003)	Sand Bay, England	1 beach – previously groomed and ungroomed sections,	February, March and April 1999 (baseline) and June, July, August 2003	Two years after the cessation of strandline mechanical cleaning, there was a dramatic increase in the population of amphipod species
Malm et al. (2004)	South-Eastern Sweden	3 beaches – groomed and ungroomed sections (wrack removed once a week: a) June to September; b) throughout the year	Period from summer to autumn	The organic content was lower on cleaned beaches. The total animal biomass was significantly lower on the intensively cleaned beach compared with the un-cleaned beach, but the moderately cleaned beach showed no such effect. No evidence to suggest that macrofaunal assemblages were affected by beach cleaning.
Fanini et al. (2005)	Southern Italy	2 beaches – 1 ungroomed and 1 mechanically groomed (once or twice weekly)	Once monthly for 13 months	Sandhoppers were found to be sensitive to a seasonal depletion of their macroalgal food source caused by beach cleaning. The trampling factor was not significant.
Gheskiere et al. (2006)	Belgium	One beach – groomed and ungroomed sections	Before and after a single beach cleaning event	Total density, species-specific densities and assemblage structure of meiofauna were all significantly (statistically but not ecologically) influenced by mechanical beach cleaning, while biodiversity suffers no direct impacts. Recovery rate immediately after the high water following the cleaning.
Dugan and Hubbard (2010)	California, USA	24 beaches - 12 groomed and 17 ungroomed (frequency unknown)	Once per site in summer	Plant abundance and plant species richness within coastal strand ecosystems were 16 and three times lower on groomed beaches.
Gilburn (2012)	Scotland, UK	60 beaches - 36 ungroomed and 24 groomed (varied frequency)	Once or twice (groomed and ungroomed section) at each site	Wrack removal through beach cleaning had major effects on the diversity of associated macrofauna. Note: Only areas underneath found wrack were sampled.
Morton et al. (2015)	New South Wales, Australia	5 beaches - 2 ungroomed and 3 partially groomed (once or twice weekly)	3 days in summer and 3 in winter	Low macroalgal inputs. There was no difference in the total nitrogen, nitrates, bacteria, meiofauna, macrofauna, and ocypodid crabs between the cleaned and uncleaned sites at partially cleaned locations. Note: Low macroalgal inputs.
Vieira et al. (2016)	Brazil and Spain	4 beaches before and after removing the wrack	4 sampling days before and 4 after wrack removal	Wrack removal (mangrove propagules in Brazil and seagrasses and macroalgae in Spain) caused decreases in the densities of supralittoral arthropods. Note: Only the impact of wrack removal was measured.
Stelling-Wood et al. (2016)	Sydney Harbor, Australia	38 ungroomed and groomed beaches (≤ 3 and 5–7 times per week)	3 times (July, October and January)	Highest Ghost Crab burrow densities on beaches that were mechanically cleaned up to three times per week. Lowest density on intense cleaned beaches (5–7 times a week) and non-cleaned beaches
Griffin et al. (2018)	Scotland (UK) and Sweden	104 ungroomed and groomed beaches (unknown frequency)	2 times (grooming and non-grooming season)	Mechanical beach grooming had a marked effect on the strandline macroinvertebrates. Diversity is predominantly determined by the depth of wrack. Recovery depends on the tidal range. Note: Only areas underneath found wrack were sampled.

(2016). Researchers surveyed groomed and the nearest ungroomed beach (Gilburn, 2012; Griffin et al., 2018) or ungroomed section of the same beach in order to obtain more representative results (Dugan and Hubbard, 2010; Griffin et al., 2018). This, however, does not eliminate the issue because the ungroomed section is usually less intensively used and it is not cleaned as regularly as the groomed one. The cleaning practice with heavy machinery is also less common on intensively used beaches. This poses a question about the severity of the impacts that can be specifically attributed to mechanical cleaning and impacts that are caused by the intense use of beaches, trampling and generally urbanization of the coast. Urbanization refers to changes to the beach natural conditions caused by high level of recreational activities, destruction of dunes, shore armoring, construction of permanent infrastructure on the beach or immediately above the beach, vehicle traffic on the sand and artificial night lighting.

A considerable body of research well documents the negative impact of anthropogenic activities on the beach ecosystem. By using ghost crabs as an indicator species to evaluate anthropogenic threats and environmental change, Schlacher et al. (2016) presented a meta-analysis of 37 studies reporting that there is a consistent loss of abundance. The studies on different species of macro-fauna (Cardoso et al., 2016; Moffett et al., 1998; Veloso et al., 2006) and more specifically amphipods (Sandhopper) (Barca-Bravo et al., 2008; Fanini et al., 2005; Veloso et al., 2009; Ugolini et al., 2008; Weslawski et al., 2000) and arthropods (darkling beetles) (Gonzalez et al., 2014) produced similar results. Furthermore, most studies applied approaches that compare abundance of species on different beaches characterized by different levels of urbanization, though some studies distinguish these threats by designing methods to measure the impact of vehicles, artificial illumination and shore armoring (Table 6). The results of empirical studies consistently indicate a lower abundance and diversity of species on intensively used urban beaches as compared to the natural beaches. Conversely, considering semi-intensively used beaches, available studies report no effects or increased abundance of certain species such as ghost crabs (Aheto et al., 2011) likely due to the food wastes left by visitors (Schlacher et al., 2011; Steiner and Leatherman, 1981; Stelling-Wood et al., 2016) or due to the presence of dunes under a relatively good condition (Magalhaes et al., 2009). These studies are relatively rare and more research is needed that compare abundance and diversity of different species, not just ghost crabs, of on semi-urban/less visited and natural beaches to identify the threshold to the intensity of beach use when major damage occurs.

Despite a clear and well-studied effect of urbanization on beach ecosystems, a large majority of studies do not isolate different types of pressures such as noise pollution, artificial night light, shore defenses, trampling, grooming and nourishment (Lucrezi et al., 2009; Reyes-Martinez et al., 2015; Schlacher and Thompson, 2012; Schlacher et al., 2016). Although this is less relevant for researchers who investigate anthropogenic impacts on relatively natural and undisturbed beaches, this fact is highly relevant for tourist beach managers responsible for selecting most ecologically appropriate and cost-effective cleaning methods on already highly degraded beaches. While the isolated impact of wrack removal has been studied, the effect of cleaning machinery on mechanical disturbance has not. Perhaps the studies on trampling are the most relevant to this issue. Despite the commonality of trampling on many shores worldwide, only few study designs isolated it from other effects of urbanization. In this context, Lucrezi et al. (2009) examined the short-term changes to ghost-crab burrow density and size distribution following intense trampling on an urban beach and concluded that the crabs are not strongly affected by intense trampling over a period of three days. The study of Moffett et al. (1998) on the impact of trampling on beach macro-fauna supports the notion, and asserts that the most affected areas are those exposed to highest physical impact and containing shallow burrowing species. On the contrary, the isolated effects of trampling by comparing trampled and control areas on a relatively unmodified beach were evaluated by Schlacher and Thompson (2012). They reported significant changes in macrobenthos abundance, diversity, and community structure in the areas of lower beaches which are most intensively used by beachgoers. A similar methodology was employed in a recent study by Reyes-Martinez et al. (2015), but in this study, the areas before and after trampling event for an extended period of time were sampled. The authors established that the number of beach users was negatively associated with the species density. All studies concluded that the impact may be more severe, particularly in the case of intense trampling at small scales, or sustained for a much longer period of time. Under such circumstances, the beach habitats could become unsuitable for sandy beach macro-fauna in the medium or long term (Defeo et al., 2009).

Table 6
Studies of different human impacts on beach fauna.

Reference	Location	Impact measured	Methodology	Indicator
Barros, 2001	Australia	Urbanization (various human impacts)	Comparing urban (disturbed) with natural or semi-urban beaches	A* (Ghost crabs)
Cardoso et al., 2016	Brazil			A (crustaceans)
Gonzalez et al., 2014	Chile			A (marine beetle)
Hubbard et al., 2014	USA			A (2 isopod species)
Magalhaes et al., 2009	Brazil			A* (Ghost crabs)
Neves and Bemvenuti, 2006	Brazil			
Ocana et al., 2012	Cuba			
Souza et al., 2008	Brazil			
Yong and Lim, 2009	Singapore			
Veloso et al., 2006	Brazil			A, richness (9 species)
Veloso et al., 2009	Brazil			A (amphipods)
Ugolini et al., 2008	Italy			
Jonah et al., 2015	Ghana	Sand Mining		A* (Ghost crabs)
Lucrezi and Schlacher, 2010; Moss and McPhee, 2006; Schlacher et al., 2007	Australia	Off-road vehicle traffic	Comparing areas with different intensity of traffic	
Steiner and Leatherman, 1981	USA			
Schlacher et al., 2008	Australia			M (surf clams)
Walker and Schlacher, 2011	Australia		Before–after control-impact design	A, richness, diversity (macrobenthos)
Wolcott and Wolcott, 1984	USA			M and damage (macroinvertebrates)
Davies et al., 2015	UK	Artificial illumination		A (epifaunal invertebrates)
Dugan et al., 2008	USA	Shore armoring	Comparing armored and unarmored segments of a beaches	A, biomass, size (upper intertidal macroinvertebrates); A, spicies richness (shorebirds)
Lucrezi et al., 2010	Australia			A* (Ghost crabs)

A – abundance; A* - abundance measured using burrows' count as a proxy; M - mortality

If trampling can adversely affect the beach ecosystem, it is expected that repeated, regular mechanical cleaning would affect the beach ecosystem as well, but this remains to be examined empirically (Defeo et al., 2009; Ugolini et al., 2008). Ideally, the evaluation of species density over a period of high tourist season on three specific beaches with three distinct levels of urbanization would be considered the best design solution. Each beach would have two sampling areas that are characterized by similar beach use intensity, which is measured according to the visitor density and the type of activities performed on the beach. One area would be cleaned manually, while the other would be cleaned mechanically. In order to mirror the effect of mechanical grooming, the former would have wrack removed manually. The design allows for examination of the physical impact of mechanical grooming alone, separating it from the impact of wrack removal on a heavily visited beach. Similarly, it allows the isolation of the impact of trampling from mechanical cleaning on a less visited beach. On one hand, it would answer the question of the severity of mechanical cleaning on already degraded beach that practice wrack removal. On the other hand, it would allow comparison of the impact of mechanical cleaning with that of trampling on relatively undisturbed beach. In addition, type of equipment, depth of raking and intensity of cleaning are other variables that might be included in the investigation (daily vs. once or twice a week). The indicator species and the sample design should be chosen carefully. The work of Underwood (1996, 2009) and Hairston (1989) deal with the experimental study designs and their components in the field of ecology.

3.2. Cleaning of certified beaches

Beach certification schemes (BCS) include awards, ecolabels, or management systems, which are based on the constant improvement in the performance, that evaluate the characteristics of a particular beach by using measurable compliance criteria (Botero et al., 2015). In general terms, beach certifications indicate the degree to which tourism beaches operate according to the given standards and in return they are allowed to use a name and logo for commercial purpose. In the tourism industry, the development of ecolabels started in 1985 with the introduction of the Blue Flag (BF) Campaign that was first implemented in 1987 (Botero et al., 2012). Based on the number of certified beaches and geographic coverage of the label, the BF has been considered to be a global leader. By the end of 2018, there were > 4400 BF beaches in 45 countries around the world (www.blueflag.org, 2018). Besides BF, the Seaside Awards were introduced in the UK in 1992 and Bandera Azul Ecologica in Costa Rica in 1996. Many other national beach certifications were created shortly thereafter (Table 7). Though some of them have been implemented successfully, others have not been able to move beyond conceptual stage.

Relatively few studies have been carried out on BCS. The BF has received the most attention in the literature due to its high popularity. The cleaning requirements of the BF have been widely criticized, alongside its other aspects. However, arguments used by the critics often have partial or no reflection in the actual requirements provided by the organization in charge. Hence, Boevers (2008) reported that the BF has paid less attention toward the ecosystem impacts of beach grooming, adding that the environmental management measure that uses beach grooming for removing beach wrack if deemed “a nuisance” is the most questionable criterion of the Blue Flag Program (Boevers, 2008). In the same vein, Mir-Gual et al. (2015) stated that the systematic withdrawal of wrack is a parameter that is valued as positive by the BF award protocol. Other authors asserted that the BF entails mechanical cleaning measures (Fraguell et al., 2015) or that mechanical cleaning is an obligatory activity for achieving the certification (Roig-Munar, 2004; Roig-Munar et al., 2018).

The revision of 11 BCS guidelines and requirements (Cabrera et al., 2006; Colombian Institute of Technical Standards and Certification [ICONTEC], 2011; Foundation for Environmental Education [FEE], 2008, 2018; International Organization for Standardization [ISO], 2015; Keep Wales Tidy, 2017a, 2017b; Ministry of Environment and Energy [MINAE], 2014; Ministry of Tourism and Sport [MTD], 2008; Secretariat of Environment and Natural Resources [SEMARNAT], 2016) indicates that only the BF, the Ecuadorian INEN 2631, and Mexican MMX consider the wrack. BF award criteria from 2008 and 2018 (FEE, 2008, 2018) state that the wrack removal is not only unnecessary for award status but, in fact, it is actively discouraged by the awarding bodies. The guidelines state (FEE, 2008, p. 15):

> *Seaweed is a natural component of the littoral ecosystem. The coastal zone must also be considered as a living and natural environment and not only as a recreational asset to be kept tidy. (…). Natural disposal by tides and waves at the beach should be accepted, as long as it does not present a nuisance, which means that it should not be allowed to accumulate to the point where it becomes a hazard or distasteful to the public. Only if it becomes absolutely necessary the algal or other vegetation should be removed, and consideration must then be given to disposing of it in an environmentally friendly way, e.g., through composting or using it as fertilizer.*

More recently, “seaweed and other vegetation/natural debris” have been included in the FEE guidelines, which provide more information on “hazard” and state that it refers to the “accumulation of seaweed in warm weather causing decay, which in turn produces odors that attract flies and their larvae. Rotting seaweed could also be slippery and become a hazard for people walking on the shoreline. It could also reduce

Table 7
Beach certification schemes in the world.

Beach Certification Scheme	Coverage	Creation/Latest Version	No. beaches/last available information	Type of beaches most suitable for	Categories of certification
Bandera Azul Ecológica	Costa Rica	1996/2014	141/2016	Re, U, Ru, V	5 levels of compliance
Blue Flag	International	1987/2018	Over 4500/2018	Re, U	None
Blue Wave	USA	2001	61/2018	–	–
Green Coast Award	UK, Ireland	1998/2017	101/2018	Ru, V	None
INEN 2631:2012	Ecuador	2012	0/2016	Re, U, Ru, V	(a) Urban; (b) Rural; (c) Uninhabited
IRAM 42100	Argentina	2005/2012	3/2018	Re, U	
ISO 13009:2015	International	2015	Unknown	Re, U	None
Marca Q (UNE-ISO 13009:2016)	Spain	2002/2016	248/2018		
NMX-AA–120-SCFI–2016	Mexico	2006/2016	38/2017	Re, U, Ru, V	(a) For recreational use; (b) for conservation
NTS-TS–001–2	Colombia	2007/2011	0/2018	Re, U	None
Playa Ambiental	Cuba	2008	4/2018	Re	None
Playa Natural	Uruguay	2003/2006	5/2013	Re, U	None
Seaside Awards	UK	1992/2017	125/2018	Re, U	None

The classification of beaches (Re-resort, U-urban, Ru-rural, V-village) follows Williams and Micallef (2009).

access to the beach for recreational activities or for disabled users" (FEE, 2008, p. 15). Finally, the guidelines recommend that not all of the seaweed should be removed, indicating the need for consulting environmental specialists regarding management of algal vegetation and leafs of *Posidonia oceanica*, Eelgrass or those of other plants washed on the beach. Similarly to BF, INEN 2631 state that wrack can be left on the beach unless it causes "hazard" to beach users, and it should be disposed of in an environmentally friendly way if removed (INEN, 2012). The definition of "hazard" is not provided in the guidelines. Finally, only the appropriate ways of disposal of removed wrack are mentioned in MNX.

In terms of mechanical cleaning, only three BCS make reference to this aspect (BF, Green Coast Award and NMX-AA–120-SCFI–2016) out of a total of 11 BCS, while the remaining BCS focus only on the result, not the process and state that the awarded beach should remain clean or should have a regular cleaning service. It is interesting to note that some BCS provide the expected frequency of cleaning (NMX and NTS) or state the limit of the quantity of litter (the number of litter items or weight) permitted for certification (BAE, NMX, and INEN). Because the Mexican NMX differentiate recreational and conservation beaches, the mechanical cleaning is not allowed for the latter. On the contrary, the Green Coast Award has been designed specifically for more natural beaches (Nelson and Botterill, 2002). It is important to note that wrack removal is not mentioned in the criteria, but the cleaning criteria require the authority in charge to choose "the most environmentally advantageous [cleaning] option (…), even if it costs more to provide" (Keep Wales Tidy, 2017a, p. 5). Although the manual cleaning is clearly encouraged, it is unclear that whether this statement prohibits mechanical grooming. Finally, beach managers are given an alternate plan in the BF guidelines that state "beach cleaning may be mechanical or manual, depending on the size, appearance, and sensitivity of the beach and its surroundings" (FEE, 2008, 2018, p. 14). There is no indication to obligatory mechanical cleaning and the guidelines emphasize the importance of local flora and fauna and other sensitive areas such as dunes that should be considered when selecting the most appropriate cleaning solution.

3.3. Tourist beach management considerations

If none of the BCS encourage mechanical cleaning and BF actively encourage manual cleaning of sensitive areas, then why is it so often criticized for promoting mechanical grooming? The studies of Scottish and Spanish beaches show that, indeed, there is a statistical relationship between certified beaches (BF and Seaside Awards) and mechanical cleaning (Gilburn, 2012; Mir-Gual et al., 2015). However, based on such an association, a causal inference cannot and should not be made without considering the beach use intensity and urbanization of the beaches in question. Except for the Green Coast Awards and specific categories of INEN 2631 and NMX-AA–120-SCFI, which were designed for natural beaches, beach certifications are not recognition awards given solely for their environmental status. Hence, the decision to employ mechanical cleaning is a common management strategy chosen as most appropriate for largely urbanized beaches and it is likely to happen irrespective of the award status.

The managerial decision to carry out mechanical grooming depends on beach users' preference for cleanliness of beach and water (Roca and Villares, 2008) and BCS requirements to ensure clean beaches. Mainly the urban certified and non-certified beaches require mechanical grooming as there is a strong correlation between beach visitor density and litter generation (Ariza et al., 2008; Becherucci et al., 2017; Martinez-Ribes et al., 2007; Santos et al., 2005) as well as between the proximity to an urban center and the contamination of beaches (Araujo et al., 2018; Hardesty et al., 2017; Leite et al., 2014; Poeta et al., 2016). The aesthetic and safety of beach users play an important role in the management of urban beaches. High intensity of beach cleaning has been found to improve water clarity (Malm et al., 2004). Similarly, an algal wrack removal is highly desired by beach visitors (Williams et al., 2016a, 2016b) as it decomposes quickly producing an unpleasant smell (Alves et al., 2014) and attracts beach flies and buzzards (Davenport and Davenport, 2006; Kinzelman et al., 2003; McLachlan and Brown, 2006). In addition to the odor, the algal mats pose a health hazard by sheltering *Escherichia coli* and *enterococci* (Byappanahalli et al., 2003; Whitman et al., 2003, 2014). It is reported by many studies that fecal indicator organisms are able to persist, and possibly proliferate, in supra-littoral wrack piles on a beach that holds the sand moist (e.g., Ward, 2009; Dunhill et al., 2013). The swash zone attracts shorebirds that feed in this area and contribute to the microbial load through their droppings (e.g., Bonilla et al., 2007; Levesque et al., 1993; Wright et al., 2009; Edge and Hill, 2007; Lu et al., 2011). Finally, natural debris and litter are more likely to pose a greater risk or injury on intensively used beaches as compared to relatively natural and regularly cleaned beaches (Campbell et al., 2016). These aspects must be considered together with the local context of each particular beach.

Several characteristics of a beach environment can decide for (or against) mechanical cleaning. The urbanizations and intensity of use are the major factors for the increased presence of litter and for the ecological state of the beach. Most effective and cost-effective methods of cleaning are required for a high quantity of litter. Based on this, Dominguez and Belpaeme (2005) demonstrated that a 1 km of beach requires only 2 h to be cleaned manually. However, the studied Belgium beaches were not used intensively and therefore required only sporadic cleaning (twice a month). In the Netherlands, the cost of nation-wide manual and mechanical cleaning is relatively comparable, with manual cleaning being less expensive, according to a more comprehensive study (Doomen et al., 2009). This study considered the machine costs and depreciation and averaged out the cost of intensively and less intensively used Dutch beaches. The cost-effectiveness of mechanical cleaning seems to be highest on urban and most littered beaches because it incurs the same cost irrespective of the quantity of litter. A study in the UK supports this hypothesis, which reports that 47% of 36 municipalities surveyed combine mechanical and manual cleaning, while 51% carry out only manual cleaning (Mouat et al., 2010). This study also reports that 54.9% of municipalities deal with medium usage beaches and 43.1% remove litter from low usage beaches.

From the standpoint of effectiveness of cleaning, both mechanical and manual methods have their strengths and weaknesses. The mechanical cleaning is effective for withdrawing all kinds of litter including relatively small-sized pieces burrowed in the sand up to 200 mm, but its effectiveness has been reported to be low in withdrawing cigarette butts and very small items (Ariza et al., 2008; Williams et al., 2016a, 2016b). The removal of the high quantity of sand ranging up to 80% of the weight withdrawn or 50 kg of sand per hour of work was reported by beach cleaning services in a study of Ariza et al. (2008), while other study claimed that beach harvesters were efficient with very little sediment collected in the process (Lavery et al., 1999). Both studies were based on anecdotic evidence, demonstrating the research gap in this area.

On the other hand, manual cleaning is effective in addressing macro-litter on the surface, but it is less effective against small-sized litter that is often burrowed in the sand (Haseler et al., 2018). It is clear, that the withdrawal of cigarette butts remains to be a major problem for both manual and mechanical solutions. The amount of sand captured in the process of mechanical cleaning would only be increased by reducing the size of the sieve's holes. Currently there is no effective solution to this issue and more research is desperately needed. While the prospect of replacing mechanical cleaning with manual cleaning seems to be very attractive from the environmental and economic perspectives previously discussed, it is also important to ask whether it is feasible on urban beaches. The effectiveness and cost-effectiveness of manual and mechanical cleaning remain largely unknown besides a few published studies. More studies that compare both methods on intensively used urban and semi-urban beaches are required.

The ecological state of the beach is another aspect to consider the impact of mechanical cleaning. The high intensity of use in medium or long terms degrades the habitats, rendering them unsuitable for sandy beach macro-fauna, in the case of highly urbanized beaches often backed by seawalls, boardwalks, and roads replacing natural dunes (Defeo et al., 2009). This is supported by many studies that reported a complete lack of certain species on intensively used beaches as compared to less used beaches (e.g., Barros, 2001; Fanini et al., 2005; Gilburn, 2012; Gonzalez et al., 2014; Veloso et al., 2006; Weslawski et al., 2000). This poses a question on the magnitude of the impact caused by the mechanical grooming and intensive trampling on already degraded beaches that are not able to reduce the use intensity and the level of urbanization.

The above considerations intensify the debate among researchers and beach managers on different aspects of beach cleaning. Wrack removal and mechanical cleaning that are applied on so many beaches worldwide are the results of decisions made by managers and municipalities, but they are not the requirements of any of the 11 beach certifications presented in this paper. In Scotland, the study of Gilburn (2012) indicates that many municipalities liberally interpret the guidelines of BF and declaring any wrack deposited over a 24 h period to be a nuisance. The balance between user safety and satisfaction and conservation is difficult to strike by commercially oriented certifications. Consequently, the great majority of BCS ignores the aspects of mechanical cleaning and wrack removal. Nonetheless, a certification is merely a tool for beach management; one of many at the managers' disposal (see Botero et al., 2018b). After all, they are the ones who decide to employ mechanical cleaning, remove wrack and implement carrying capacity or other measures of user control or ecosystem restoration. Unfortunately, few beach managers have the academic knowledge or technical capacity to understand and use the variety of tools to make educated decisions (Esteves, 2018). On the contrary, these beach managers might opt for BCS as the only tool for beach management. Although certifications provide a good template for management (McKenna et al., 2011; Zielinski and Botero, 2015), they are not a panacea for all problems faced by tourist beaches, and they should be used in conjunction with other tools to achieve the best results.

4. Final remarks

This paper has presented the aspect of beach cleaning from both the conservation and intensive tourism use perspectives. It is very difficult to achieve a compromise between these two perspectives as long as the economic value of the coasts for the tourism industry and urbanization is prioritized. However, a few management strategies achieved some level of success on tourist beaches. Ideally, the manual cleaning should replace mechanical grooming on low and moderately used beaches. The wrack should be removed only in specific cases of very large accumulation (Llewellyn and Shackley, 1996). This method has been proved to be economically and ecologically sound (Dominguez and Belpaeme, 2005; Doomen et al., 2009) and has been applied on many British beaches (Frampton, 2010; Mouat et al., 2010).

Despite its potential, the manual cleaning of urban and intensively used beaches remains problematic. This is not due to the feasibility of the manual cleaning, but due to the recommendation to manage wrack and clean the sand in order to minimize the persistence of indicator microbes and some pathogens (Kinzelman and McLellan, 2009; Solo-Gabriele et al., 2016). In this context, relatively easy to implement solutions are recommended by a number of studies. Firstly, a scheme of grooming is proposed in which a beach is divided into a mechanically groomed stretch of tourist beach and a less intensively used stretch of beach that is left ungroomed throughout the year (Defeo et al., 2009; Dugan and Hubbard, 2010; Vieira et al., 2016). This allows the beach macro-fauna leave the highly disturbed area and build new habitat nearby. Secondly, it is recommended to relocate the wrack collected on tourist beaches to a nearby stretch of less intensively used beach for degradation, thus allowing nutrients to be redistributed along the beach by the action of waves, tides, and currents (Griffin et al., 2018; Morton et al., 2015). This approach has been applied in Sweden, but it is limited to larger beaches that are not used for tourism in their entirety (Griffin et al., 2018). There is a need to develop recommendations on the length and spacing between groomed and ungroomed stretches of a beach and the impact of wrack relocation. Moreover, the acceptance of the two abovementioned approaches by users, local community and public administration have not been studied and require further investigation.

Thirdly, for tourist beaches that experience extensive and frequent cleaning operations that cause major ecological impact, it is recommended to reduce the frequency of mechanical cleaning by supplying it with manual methods (Gilburn, 2012; Morton et al., 2015; Noriega et al., 2012; Stelling-Wood et al., 2016). It is reported by many studies that the abundance and diversity of species is much higher on less frequently cleaned beaches that are cleaned up to three times a week (Malm et al., 2004; Morton et al., 2015; Stelling-Wood et al., 2016), and in many cases it is comparable with natural and non-mechanically cleaned beaches (Reyes-Martinez et al., 2015). The variation of manual and mechanical cleaning is also beneficial from the perspective of the effectiveness of each method on collecting cigarette butts, as well as small litter or larger pieces burrowed in the sand. Grooming only the lower part of the beach is considered to be the fourth managerial solution to compromise support of natural resources on non-urban beaches and recreational activities. Based on this method, the study of Kelly (2016) on New Jersey beaches found that 83–97% of recreational uses can be still supported along with 85% of potential vegetation and 52% of wrack. This approach is compatible with the first three approaches. Besides, it is supported by experiences of researchers from Brazil, South Africa, Spain and Australia who identified similar spatial patterns of recreational uses concentrated in the lower part of the beach (Araujo and Costa, 2008; Guillen et al., 2008; De Ruyck et al., 1997; Schlacher et al., 2008; Valdemoro and Jimenez, 2006). Table 8 shows the recommendations in relation to level of littering, natural conditions of the beach and restrictions posed by types of beaches. The intensity of littering is used as a proxy for intensity of beach use by visitors. It should be noted that it is not a guideline, but a conceptual approximation based on the findings of this paper and should be treated as such.

The fifth recommendation proposes the reduction of beach littering and litter generation by beach users. This approach includes staff training and user environmental education, adequate provision of waste receptacles (bins) and fines for littering (Ballance et al., 2000; Campbell et al., 2016; Dugan and Hubbard, 2010; Eastman et al., 2013). Education and bins received the highest support of beach users in the study of Campbell et al. (2016). In Chile education and fines were preferred (Eastman et al., 2013), and in South Africa fines were preferred (De Ruyck et al., 1995). Researchers found that the effectiveness of education in reducing littering is highly dependent on the characteristics of the programs, their delivery, and content (Marion and Reid, 2007). Programs that combine different methods are likely to produce better results (Eastman et al., 2013). The involvement of volunteers or schools in beach cleaning programs is widely accepted and brings desirable results with regard to increased environmental awareness (Bravo et al., 2009; Hartley et al., 2015; Loizidou et al., 2018; Wyles et al., 2017). Moreover, social marketing (Campbell et al., 2016), personalized verbal and non-verbal requests or demonstration (Brown et al., 2010; Cingolani et al., 2016), interpretative and sanction messages by using signs or brochures (Duncan and Martin, 2002) and legislation (Loizidou et al., 2018; Velander and Mocogni, 1998) are also recommended by many scholars.

As a consequence of the trend among the managers and users toward natural aspects of beach ecosystems, the common cleaning approaches include manual or mixed methods. On the other hand, the

Table 8
Conceptual approximation of cleaning solutions in relation to beach type and use intensity based on findings from literature review.

Beach type	Littering	Natural condition	Cleaning solutions			Wrack removal		Management by beach type		
			MC	MM	M	W0	W1	S1	S2	S3
Urban/Resort	Very high	Bad	X					X		
		Medium	X					X		
	High	Bad	X					X		
		Medium	X	X			X	X	X	X
	Medium	Bad		X				X	X	X
		Medium		X	X		X	X	X	X
		Good			X		X		X	
Village	Medium	Bad		X			X	X	X	X
		Medium		X			X	X	X	X
		Good			X	X	X		X	
	Low	Bad		X	X		X	X	X	X
		Medium			X	X	X		X	
		Good			X	X	X		X	
Rural	Medium	Medium		X	X		X	X	X	
		Good			X	X	X			
	Low	Medium			X	X	X			
		Good			X	X				
Restrictions (R)	Pocket beach								R	R
	Pocket beach used intensively							R	R	R
	Open on both sides, only a part of beach is used intensively									
	Open on both sides, the entire beach is used intensively							R	R	

Cleaning solutions: MC-mechanical cleaning mixed with periodic manual cleaning for cigarette butts withdrawal; MM-mechanical and manual cleaning (balanced approach); M-manual cleaning only.
Wrack removal: W0-wrack completely left of the beach; W1-parcial removal of wrack for health and safety concerns.
Management solutions: S1-Division into a mechanically groomed stretch of beach and a less intensively used stretch of beach; S2-Relocation of wrack to a nearby stretch of less intensively used beach; S3-Grooming only the lower part of the beach.
Beach types: P-Pocket; O-Open on both sides, but a part of beach is used intensively; O2-Open on both sides, but the entire beach is used intensively.

wrack removal on recreational beaches is used invariably because of aesthetic and safety considerations, but its intensity is likely to decrease as a consequence of increasing environmental awareness of users and informed acceptance of certain amount of wrack as a natural beach component. The management tools to achieve advocated by Kelly (2016) "compromise management" exist, but they largely lack scientific evidence to support their use over the currently practiced solutions. The most evident research gaps are outlined in this paper. In order to develop practical cleaning recommendations for managers and local authorities in charge of managing the beaches, further research should focus on filling the gaps among different approaches and testing the effectiveness of the proposed management solutions.

Authors' statements

All authors have materially participated in the research and/or article preparation. All authors have approved the final article.

CRediT authorship contribution statement

Seweryn Zielinski: Conceptualization, Investigation, Methodology, Writing - original draft. **Camilo M. Botero:** Conceptualization, Supervision, Writing - review & editing. **Andrea Yanes:** Investigation, Writing - review & editing.

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