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Development of a management-based ranking of beaches

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Abstract

Beach rankings are very frequent on the internet; however, the information provided on how these rankings are made is often unclear and their content is mostly subjective. In addition, the vast majority of these rankings do not take into account the fact that beaches are coastal eco-systems. The aim of the research was to develop an objective framework to rank the quality of beaches worldwide. The framework integrates indicators to assess the socio-ecological system quality and can be used as a basis for effective beach management. The methodology involved the collection, evaluation and grouping of indicators into domains and categories. Moreover, a measurement technique and a 5-point rating score for each indicator was used. Weights were calculated for different beach types using an analytical hierarchical process and the methodology was validated by a focus group of beach management experts. The quality value of each beach was calculated through equations and the results were presented in graphs inspired by the Circles of Sustainability and the Ocean Health Index. The theoretical application was tested on Portuguese beaches. The framework presents a holistic assessment of four domains: Recreation, Protection, Conservation and Sanitary. The resulting Beach Ranking Framework (BRF) is an objective, holistic framework designed to communicate with society, unlike the existing beach quality assessments.

Keywords Best beach, Ranking, Indicators, Beach quality, Beach management

1 Concept and background

The coastal zone provides goods (e.g. food and medicine) and services (e.g. shoreline protection and areas for recreation) highly valuable to human society (Martinez et al. 2007). One of these services is related to the cultural use of beaches, mainly for leisure and recreation. Beaches are chosen as an area for individuals to relax and meditate, making them a key destination for coastal tourism (Li et al. 2023). According to Drius et al. (2019), while it is undeniable that tourism is important for economic development, it is also obvious that its continued rise will place growing stress on coastal zone environmental resources. In order to control the pressures and plan the development of tourism in an area, a beach quality assessment is essential. Beach quality is defined in terms of environmental quality as *"the state of the beach as a socio-natural system in a certain time, concerning its ecosystem functionality and satisfaction of human needs"* (Botero et al. 2019).

The coastal tourism sector uses a number of aesthetic measures to rank recreational areas in order to draw the attention of visitors and let them know where the 'best beaches' are (Williams and Micallef 2009). Travelers increasingly use travel intermediaries and social media in their destination selection process (Echtner and Ritchie 1991; Oluwakemi and Özdemir 2020; Gretzel 2021; Weissmann 2021), so promotion strategies like the 'best beaches' lists play an important role in image construction (Mendes et al. 2011) and contribute to the popularity of a destination. However, the majority of the current web-based rankings are subjective (Oliveira

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et al. 2024). They mainly rely on subjective opinions from the editorial team, "traveler specialists", personal experience, or user's perception to classify the beaches, without specifying objective criteria. One of the most famous examples is the list provided by TripAdvisor (www.tripadvisor.com), which is based on the opinion of the users: each person rates the beaches on a scale of 1 to 5 based solely on their own personal experience. Furthermore, these rankings are evaluating beauty rather than quality, as they are based solely on aesthetic factors, such as color of water, color of sand, scenic value, and well-kept vegetation (Oliveira et al. 2024). The indiscriminate propagation of these lists can have a variety of impacts on the beaches included on these lists.

There are numerous beach quality assessments in the scientific literature. Quality of beaches is mainly assessed by indices that describe and evaluate the beach. Indices developed to assess beach quality often emphasize water quality (El-Sorogy et al. 2023; Uddin et al. 2023) or address specific management issues, such beach litter (Schattschneider et al. 2020; Scarrica et al. 2022), sea level rise (Revell et al. 2021) or beach erosion (Andreadis et al. 2021). Nevertheless, some indices propose an integrative approach to assess beach quality holistically, considering the physical characteristics, the environmental quality and human aspects, such as socioeconomic and recreation (Ariza et al. 2010; Gine et al. 2018; Bombana and Ariza 2019; Diniz et al. 2022; Li et al. 2023).

Ariza et al. (2010) proposed the Beach Quality Index (BQI) to evaluate urban and urbanized beaches in Spain, based on 13 partial indices distributed into three components (recreational, natural, and protective). The BQI is one of the best-known beach assessment methodologies, having been applied in Chile (Gonzáles and Holtmann-Ahumada 2017), Vietnam (Huong et al. 2017), and Indonesia (Rafif et al. 2023). The assessment was later improved by Bombana & Ariza (2019) to incorporate the perceptions and narratives of the stakeholders engaged, and to include other levels of beach development on the Catalan coast. Giné et al. (2018) designed a tool to assess the beach quality in protected areas in Spain. The Dynamic Index for Beaches in Protected Areas (DIBA) evaluates nine indicators divided into three sub-indexes (environment, landscape, and recreation). Diniz et al. (2022) proposes a coastal scenery quality index to measure the quality of Brazilian beaches, which includes 67 indicators distributed among eight categories (accessibility, environmental quality, water quality, comfort, scenic quality, services and infrastructure, safety, and environmental education and information). Li et al. (2023) assess the quality of beaches in Yangkou Beach, China using 18 indicators divided into three aspects (natural, environmental and social factors).

Despite having an integrative and holistic approach, beach-user satisfaction is at the forefront of these indices (Bombana and Ariza 2018). Even when other aspects are included, such as environmental and physical characteristics, these are also aimed to promote recreation. In addition, most of the indices neglect the complexity of socio-ecological systems, due to the lack of transdisciplinary approaches (Bombana and Ariza 2018). Moreover, the indices display their results in a similar way, using a numerical scale or a qualitative rating scale, without a graphical output (Bombana and Solé, 2017). The lack of a graphical representation of the results makes comprehension by the public harder; hence, these indices do not break out beyond the barriers of academy. Another gap is that indexes are created to help the management of beaches but not to rank the best ones or help the tourist to decide their destination (Espínola and Marques 2021). In other words, they are not designed to correct the subjectivity of the 'best beaches' lists or to communicate with the society. Thus, there is a need for a methodology that standardizes rankings to reduce the subjectivity of existing best beach lists, communicates the results clearly to beach-users in society, while applying the concepts of scientific beach quality assessment.

The goal of the research was to develop a robust and objective framework to assess the beach quality and to rank beaches worldwide. The framework was designed to consider socio-ecological indicators and to display the results in a graphical output, making them more understandable and attractive for the beach-users in society.

Coastal tourism, and especially beach tourism, is a significant sector of the Blue Economy (EC 2021) and one of the goals of the Ocean Health Index (Halpern et al. 2012). Tools that contribute to improve the use and conservation of beach resources are therefore economically, socially and environmentally useful and necessary. Hence, a fit-for-purpose beach-assessment framework could support the sustainable development and conservation of coasts. Furthermore, the framework could provide a reliable source of information for beach-users when choosing a destination to visit, by eliminating the subjectivity embedded in the existing rankings.

2 Materials and methods

The methodology followed some steps that are described into the flowchart exhibited as Fig. 1. As a first step, listings of 'best beaches' and beach quality assessments were surveyed to extract relevant indicators. Searches using Google for the term 'best beaches' were conducted five languages (English, French, Portuguese, Spanish, and Italian). Over 200 websites were checked of which 71 were selected, based on their original content. Websites that merely replicate or translate other rankings were

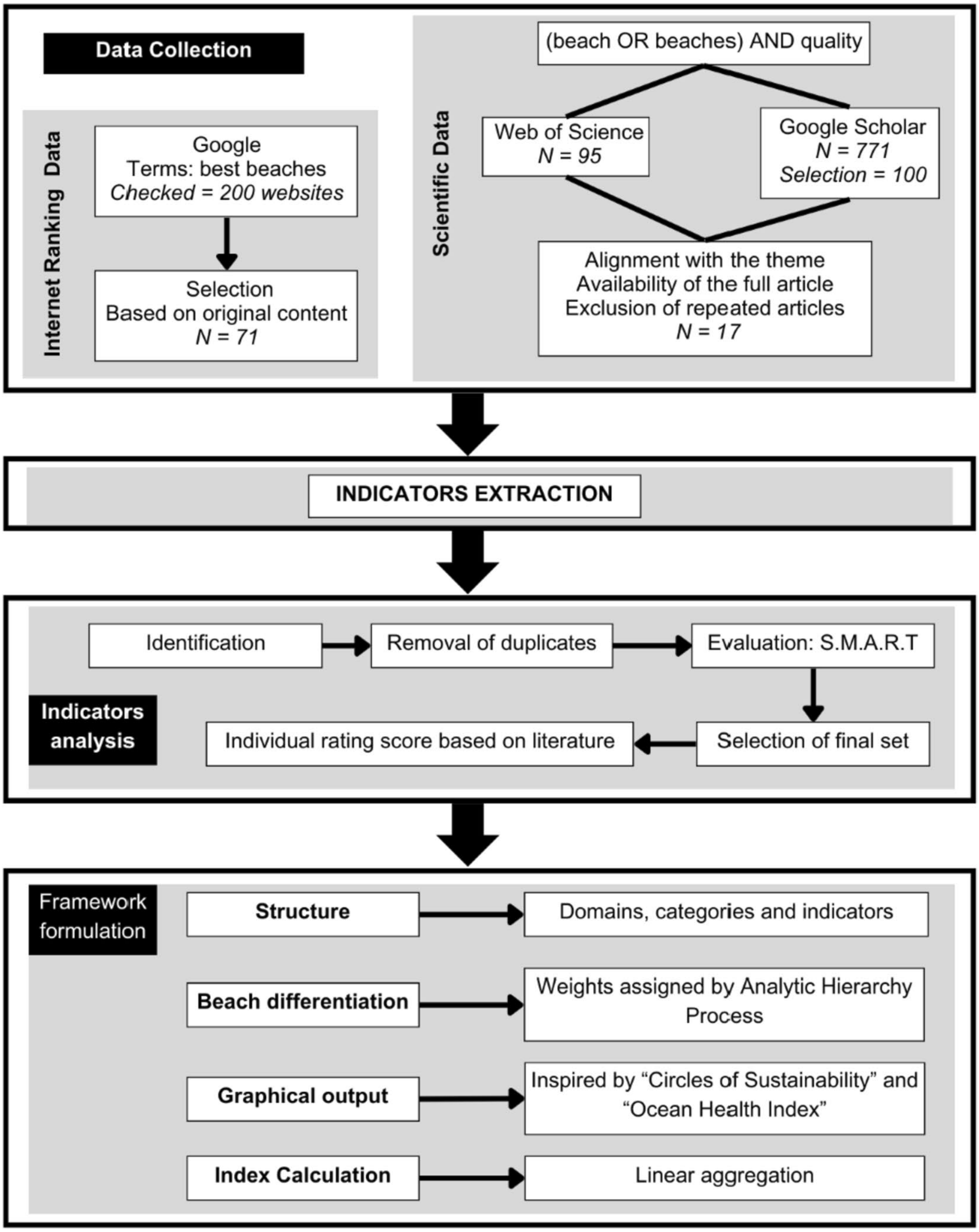

Fig. 1 Flowchart of the methodological process. Prepared by the authors

disregarded. The indicators were summarized according to their presence and frequency of appearance. Scientific literature was also surveyed in Google Scholar (GS) and Science Direct (SD) journal databases for the combination of the terms 'beach' AND 'quality'. The survey returned 95 articles in SD and 771 in GS. The titles of all articles in SD and of the first 100 articles in GS were filtered to identify the alignment with the theme and check the availability of the full article. Repeated articles were excluded. Articles that incorporated the opinion of beach experts (managers, planners, investigators) and beach users were prioritized. This resulted in the identification of 17 peer-reviewed journal articles (highlighted in Oliveira et al. 2024) that proposed an index to evaluate overall beach quality through a holistic approach. The content of these articles was analyzed based on the number of indicators, the type of indicator and on the methodology performed. These results were recorded in a spreadsheet.

The potential indicators identified from both assessments were analyzed to remove the ones with similar meaning. The remaining were evaluated according to the relevance for management based on the S.M.A.R.T. criteria (specific, measurable, achievable, realistic and time-bounded) (Elliott 2011). Indicators that did not fulfill the SMART criteria were discarded. In addition, indicators derived from a technical report of the European Commission (Maes et al. 2018) and from ecosystem indicator literature (Atkins et al. 2015; Hattam et al. 2015) were considered during the framework composition. The final set of indicators was selected based on: (i) the frequency of occurrence in the rankings and indices analyzed; (ii) the availability of data to support them; (iii) the appropriateness for describing beach function; (iv) the main issues requiring management; and (v) the communicability of the information.

The indicators considered relevant and appropriate were divided into domains and categories according to their classification by the scientific literature or by the government agencies and on their suitability for each domain. The decision to divide the framework into four domains was based on three primary reasons. Firstly, drawing inspiration from established beach quality indexes that categorize their methodology into components, namely Recreation, Natural, Physical, and Socioeconomic. By segmenting the framework into distinct components, all aspects relevant to beach management can be comprehensively addressed. Secondly, equal importance is placed on the primary functions of a beach – protection, recreation, and conservation. This approach reflects a commitment to acknowledging and balancing the multifaceted roles that beaches play in their ecosystems and communities. Lastly, the objective included creating a visually impactful output. In pursuit of this goal, cues were taken from existing frameworks, particularly the Circles of Sustainability' (James 2015), which features four domains. This visual representation enhances the framework's accessibility and facilitates a clearer understanding of the interconnected elements governing beach management.

Circles of Sustainability (CS) is an assessment framework, based on the social-ecological systems (SES) theory, to measure urban sustainability through a holistic approach by assigning scores to categories divided into four domains: ecology, politics, culture and economics. In the current framework, the domains were adapted to reflect the main quality areas that need to be evaluated in a beach. Therefore, here the domains are divided into recreation, protection, conservation, and sanitary. Each domain is divided into five categories and each category is measured by a variable set of indicators that embrace the characteristics necessary to describe them. The variable number of indicators in the categories aims to include all aspects considered relevant. It does not represent a higher importance and does not affect the weighting. The hierarchical division of the framework is represented in Fig. 2. This holistic approach grants equal relevance to each domain, regardless of whether more established indicators exist in one domain than in another. The use of this framework also ensures that the results are represented graphically, facilitating transmission to the public and comprehensibility of the information.

For each indicator, a measurement technique and a 5-point Likert-type scale was used, following the literature and the established regulations (Cendrero and Fischer 1997; Leatherman 1997; Morgan 1999; Ergin et al. 2004; Araújo and Costa 2008; Roca et al. 2009; Williams and Micallef 2009; Ariza et al. 2010; Keller et al. 2011; Mclachlan et al. 2013; Amyot and Grant 2014; Atkins et al. 2015; Lucrezi et al. 2016; Peña-Alonso et al. 2018; Bombana and Ariza 2019; Directives 75/440/EEC, 91/676/EEC, 2000/60/EC 2006/7/EC). Once each indicator was

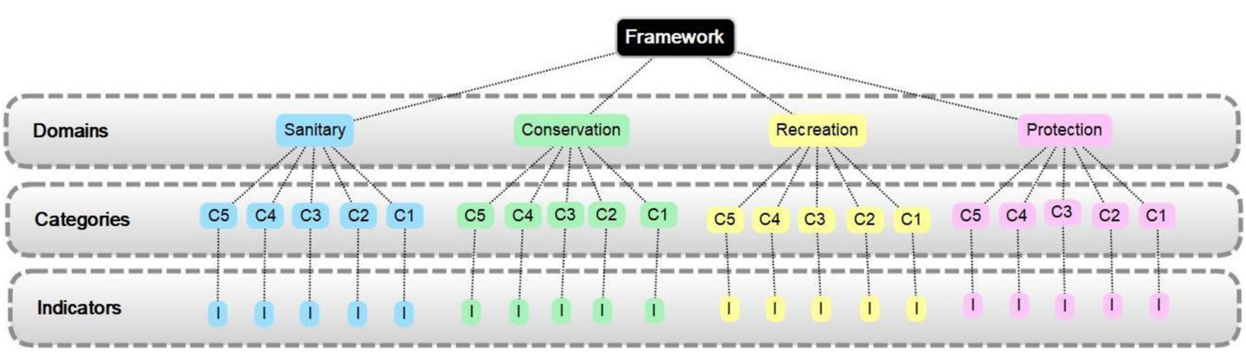

Fig. 2 Hierarchical division. The framework is divided into four domains. Each domain is composed of five categories and each category is measured by a variable set of indicators

scored on the 5-point scale, the results were normalized. The normalization was done by dividing the sum of the score allocated to each indicator in a category by the total maximum score for each category. For example, the category 'Habitat' is composed of two indicators: ecosystem connectivity and ecosystem condition. The sum attributed for each indicator was summed (e.g. 4 + 5 = 9) and divided by the maximum score for the category (5 + 5 = 10) resulting in a normalized score (9 / 10 = 0.9).

Weights were assigned for each category and for each domain using the Analytic Hierarchy Process, following the procedure explained by Saaty (2008). The method was applied for different beach types to respect different management strategies. The beach types included were Urban, Village and Rural, following the anthropogenic classification of Williams and Micallef (2009). Urban beaches are generally open to the public, have well-established public services (e.g. banks, cafes, internet, markets) and commercial activities in the proximity (fishing, harbors and marinas), whereas village beaches are located outside the main urban environment, reached by public or private transport and associated with a small and permanent population, with access to organized and small-scale community services (Williams and Micallef 2009). A rural beach, on the other hand, is described as the one located outside the urban/village environment and not readily accessible by public transport. These beaches have little or no beachfront development or facilities and are valued by their quietness and natural qualities (Williams and Micallef 2009).

A Focus Group of beach management experts and practitioners from different countries was used to check for and to reduce cultural differences, subjectivity and bias. The group was formed by five coastal management experts (1 oceanographer, 1 geographer, 1 environmental engineering and 2 geomorphologists) from Proplayas Network with experience ranging from 5 to 25 + years, with different approaches regarding the four dimensions of the framework. An online workshop was organized on June 02/2021 to explain the methodology and the procedure of weighting. Later, the experts were asked to fill in a set of spreadsheets made available on a cloud service, according to the method of AHP (Saaty 2008). The comparison was made according to the importance of the domains and categories within each beach typology, using the pairwise comparison scale. The responses obtained were average and the final weight values and standard deviation were calculated for each beach type.

The final Beach Quality Value (BQV) was calculated using linear aggregation. The BQV has been established as the sum of the quality per domain, each with different weighting, as shown in the equations below (Eq. 5). The r, p, c and s coefficients adjust the importance of the categories for each domain, while the w coefficient adjusts the importance of domains for each beach typology. The quality of the domain is calculated by the sum of the normalized value in each category by its weight (Eqs. 1 to 4). The ranking is the decreasing order of beaches based on the BQV.

$$RD = [(r_1 \times AP)] + (r_2 \times CC) + (r_3 \times FS) + (r_4 \times SV) + (5_5 \times Saf) \tag{1}$$

$$PD = \left[\left(p_1 \times SB\right)\right] + \left(p_2 \times SS\right) + \left(p_3 \times IC\right) + \left(p_4 \times SbD\right) + \left(p_5 \times RV\right) \tag{2}$$

$$CD = [(c_1 \times EQ)] + (c_2 \times GA) + (c_3 \times Hb) + (c_4 \times SP) + (c_5 \times Her) \tag{3}$$

$$SD = [(s_1 \times WQ)] + (s_2 \times SQ) + (s_3 \times EP) + (s_4 \times SF) + (s_5 \times LW) \tag{4}$$

$$BQW = (w_1 \times RD) + (w_2 \times PD) + (w_3 \times CD) + (w_4 \times SD) \tag{5}$$

where; AP = Access & Parking; CC = Carrying Capacity; FS = Facilities & Services; SV = Scenic Value; Saf = Safety; SB = Storm Buffer; SS = Shoreline Stability; IC = Induced Changes; SbD = Subaerial Dissipation; RV = Risk & Vulnerability; EQ = Environmental Quality; GA = Governmental Acts; Hb = Habitat; SP = Species; Her = Heritage WQ = Water Quality; SQ = Sand Quality; EP = Episodic Pollution; SF = Sanitary Facilities & Services; LW = Litter & Waste; RD = Recreation domain; PD = Protection domain; CD = Conservation Domain; SD = Sanitary domain.

3 Resulting beach ranking framework (BRF)

A holistic and systemic approach to ranking is necessary to identify tourism characteristics and recurring problems that may endanger the ecosystem, if the results are to be useful for coastal management. It must also be adaptable to be appropriate for various types of beaches while respecting their unique characteristics. The comparison metrics must be clear and standardized to reduce

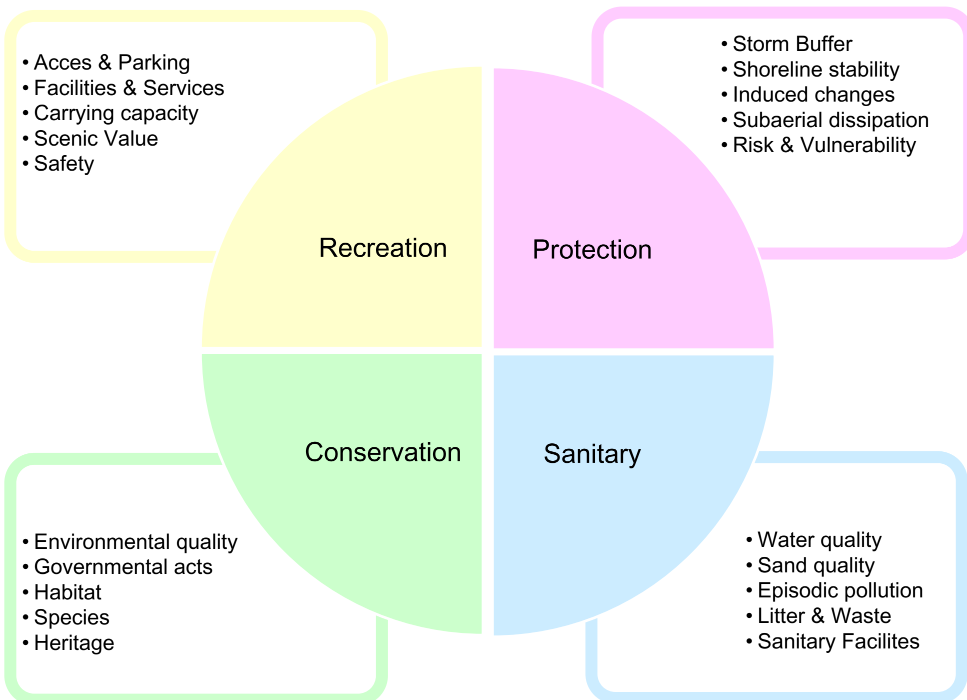

Fig. 3 Division of the BRF inspired by the 'Circles of Sustainability' showing the domains (in the quadrants) and categories (in the rectangles)

classification subjectivity. To achieve these goals, a structure separated into domains and categories based on the Circles of Sustainability (CS) framework (James 2015), and updated for the coastal areas by Alencar et al. (2020), was utilized in the design. The domains in the BRF were adapted to reflect the main functions of a beach, coastal defense, recreation and conservation (Williams and Micallef 2009), and to reflect the sanitary conditions. Each domain is divided into five categories that includes its main elements, as shown in Fig. 3. The categories, according to Alencar et al. (2020), are generic sustainable qualities that can be represented in a way that improves transparency across sectors and scales.

The 'Recreational' domain (RD) refers to the provision of services and infrastructure that enable beach users to relax, have fun and be entertained. The five categories included aims to identify the key attributes for tourism. The 'access & parking' category aims to identify the type of entrance and the availability of parking on the surroundings. 'Facilities & services' evaluates the offer of amenities and adaptations for disabled users. The 'Carrying capacity' category considerate public crowding perception, while the 'Scenic value' category measures the coastal scenery of a specific site. Finally, 'Safety' includes the aspects related with security in the beach including currents, rescue services and dangerous situations.

The 'Protection' domain (PD) is going to evaluate the beach potential to dissipate energy and defend the city against possible harmful events. The categories are going to identify vulnerabilities and anthropic modifications that can damage the natural defense of the coast. The 'Storm buffer' category evaluates the capacity of beach to defend and resist against storms and includes aerial beach elements. The 'Subaerial dissipation' category identifies the presence of subacute features (e.g. saltmarshes, mangroves) that absorb wave energy. 'Shoreline stability' refers to the position of the shoreline along the time while the 'Induced changes' category evaluates the human modifications on the beach and surroundings. 'Risk & Vulnerability' evaluates the occurrence and frequency of events (e.g. hurricanes, sea level rise) that can generate impacts at a site.

The 'Conservation' domain (CD) refers to the preservation of the environment, including measurements of biodiversity, environmental quality and management conservation actions. The 'Environmental quality' category evaluates the overall quality of the environment of a beach, identifying problems such as noise, air pollution and eutrophication. The 'Governmental acts' category refers to legal instruments to regulate the use and conservation of a beach. 'Habitat' evaluates the presence and condition of beach habitats present at the beach, whereas 'Species' examines the richness and abundance of species in an area and identify the presence of endangered and invasive species. The 'Heritage' category evaluates the presence of sites with specific conservation interest.

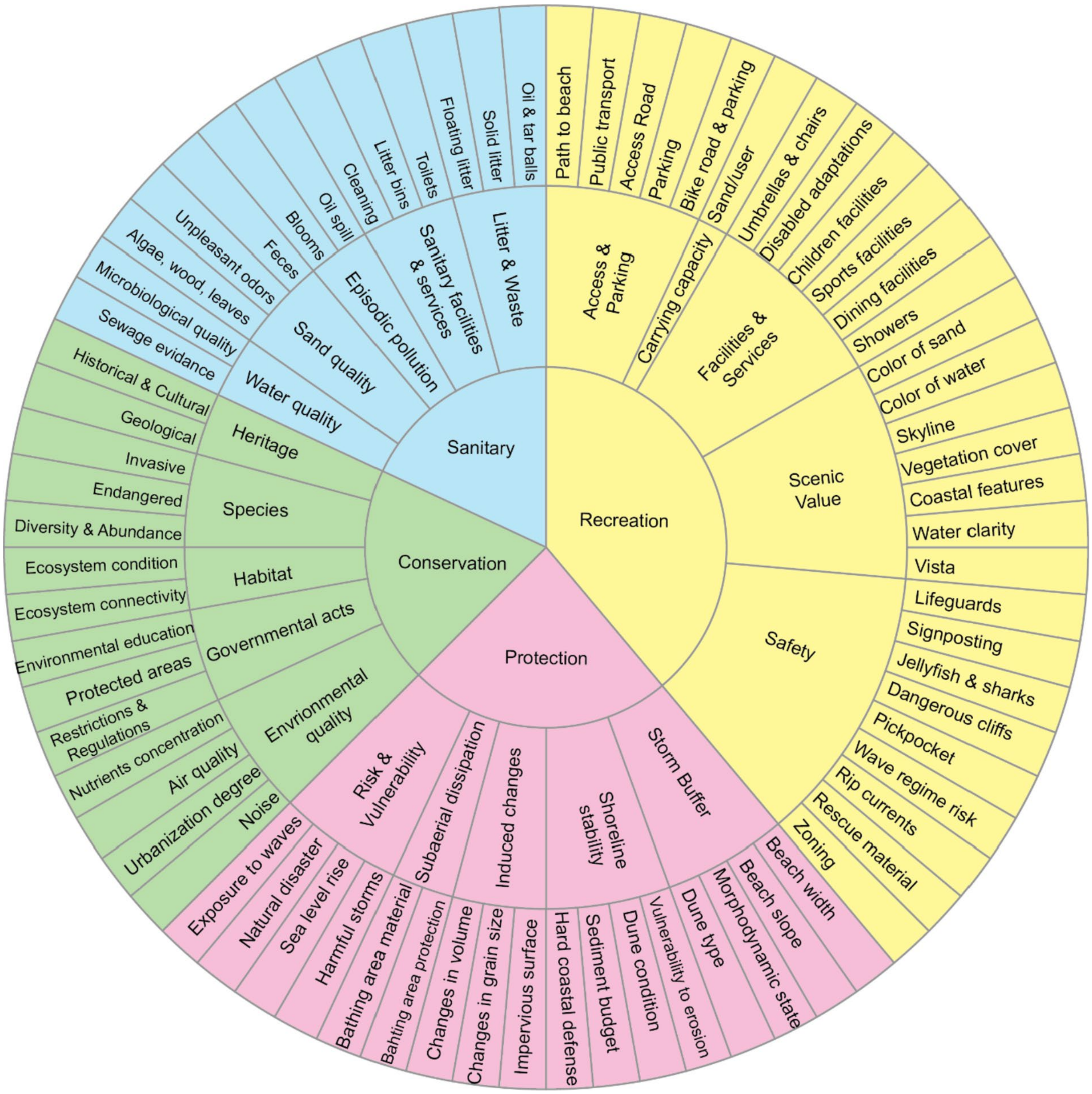

Fig. 4 Graphical representation of the BRF showing the domains (in the inner circle), the categories (circle in the middle) and the indicators (outer circle). Colours are representative of each domain. The variable number of indicators in the categories aims to include all aspects considered relevant. It does not represent a higher importance and does not affect the weighting

Finally, the fourth domain is dedicated to 'Sanitary' (SD) issues that aims to identify the presence and impacts of litter and pollution. The 'Water quality' category evaluates the overall quality of the bathing waters while the 'Sand quality' category aims to identify the comfort and cleanliness of sediments. The 'Episodic pollution' category evaluates the occurrence and frequency of potential pollution sources whereas the 'Litter & waste' category examines the presence and volume of different types of litter. Finally, the 'Sanitary facilities & services' category investigates the provision of sanitary amenities such as toilets and refuse collection points.

Each category is measured by a set of indicators that embrace the characteristics necessary to describe them (Fig. 4). There are a total of 79 indicators in the framework, as shown in Fig. 3. The indicators chosen to compose the framework evaluates the beach by a holistic approach, considering it as a socio-ecological system to

Table 1 Proposed rating Score for each indicator composing the Beach Ranking Framework. The colors in the first column are indicative of the domain. D represents the Domain and C the Category

D	C	Indicator	Metric	Score					Source
				1	2	3	4	5	
Recreation	Access & Parking	Path to the beach	Presence of Stairs or Steps	Presence of stairs	Path with steps > 20 cm	Path with steps between 10 and 20 cm	Main access clear; presence of stairs or steps in the middle	Clear path to beach	Araújo & Costa (2008); Morgan (1999); Ariza *et al.* (2010)
		Public transport	Frequency (hours) and variety	Access only by private transport	Bus stop far from the beach(>2km); Scarce (≤3 bus/day)	Bus stop far from the beach; Bike roads not existent	Bus every 1 to 2 h; Bike roads available	Diverse (bus, train, bike) with high frequency (<1 h/day)	Peña-Alonso *et al.* (2018); Roca *et al.* (2009)
		Access Road	Width, Sign & Conditions of Roads	Non existent	Narrow and not asphalted	Narrow and asphalted, but with irregularities	Wide and asphalted, but not well signposted	Well signposted, wide, well asphalted	Morgan (1999); Ariza *et al.* (2010)
		Parking	Abundance; Distance from the beach; fee	Non existent	Limited (1); Only Private; ≥ 300 m	Moderate; private/public; 200 to 300 m	Abundant; Public available; 200 to 300 m	Very abundant ; public options available; <200m	Amyot & Grant (2014); Ariza *et al.* (2010)
		Bicycle parking	Distance from the beach; Capacity	Absent	>300m	200 to 300 m; <5 bikes	Between 100 to 200 m; 5 - 10 bikes	≤ 100 m; >10 bikes	Peña-Alonso *et al.* (2018)
	Carrying capacity	Availability of sand by user	Nº of visitors; beach length; social perception	Overcrowded; [< 4m²/user]; Small beach with very high number of visitors	Crowded [4-8 m²/user]; Small to median beach	Crowded [4-8 m²/user]; Large beach	Satisfactory [4-8m²/user]; small to median beach	Optimal conditions [>8m²/user]; Large beach	Ariza *et al.* (2010)
	Facilities & Services	Umbrellas and chairs	% of occupancy of beach surface	Concentrated (>50%)	-	Between 30% and 50%	-	Scarce (<30%) or inexistent;	Ariza *et al.* (2010)
		Dining facilities	Concentration and distribution of restaurants, bars, etc.	Absent	Scarce (<5 options) along the year	Seasonal facilities	Good variation of options well maintained	Wide selection well maintained, well-distributed and with minimum impacts	Morgan (1999); Ariza *et al.* (2010)
		Adaptations for disabled users	Presence of braille panels, adapted access to bathing area, dog allowed, adapted facilities	Absent	-	Partially adapted (≤ 2 adaptations)	-	Adapted (>2 adaptations)	Peña-Alonso *et al.* (2018); INR (Praia acessível)
		Facilities for children	Presence, size, maintenance, distance	Nonexistent if Urban	-	Existing and well maintained; >150 m from the beach	Existing, well maintained; small, at the beach	Existing and well maintained; medium/large, at the beach	Ariza *et al.* (2010)
Recreation	Facilities & Services	Showers/feet showers	Distance; Number	Absent	≥ 250 m; only 1	Between 150 and 250 m; 2	-	<150 m; >2	Morgan (1999); Ariza *et al.* (2010)
		Sports facilities	Presence of facilities; options available (fixed, renting)	Nonexistent if Urban	-	Rent equipment during summer	-	Rent equipment; presence of facilities on the surroundings	Ariza *et al.* (2010)
	Scenic Value	Color of Sand (Beach Face)	Scenic Evaluation	Absent	Dark	Dark tan	Light tan	White/gold	Ergin *et al.* (2004)
		Color of Water	Scenic Evaluation	Brown or gray	Milk blue or green	Green, gray or blue	Light or dark Blue	Turquoise	Ergin *et al.* (2004)
		Skyline	Scenic Evaluation	Very unattractive	-	Sensitively designed	Very sensitively designed	Natural/historic features	Ergin *et al.* (2004)
		Vegetation cover	Scenic Evaluation	Absent	Bare (<10%)	Scattered	High natural cover	Very high natural cover	Ergin *et al.* (2004); Araújo & Costa (2008);
		Coastal Features	Presence of lagoons, peninsulas, caves, headlands, reefs, arches, deltas, waterfalls, estuaries.	Absent	1	2	3	>3	Ergin *et al.* (2004)
		Water clarity	Scenic Evaluation	Muddy	Opaque	-	Clear	Very clear	Ergin *et al.* (2004)
		Vista	Scenic Evaluation	Open on one side	Open on two sides	-	Open on three sides	Open on four sides	Ergin *et al.* (2004)
	Safety	Lifeguards	Distribution along the year	Absent	Occasional	Peak season weekends	Seasonal	Permanent	Morgan (1999); Peña-Alonso *et al.* (2018)
		Signposting	Presence and visibility	Absent	-	Present, but not well-locatedr	-	Visible and clear	Araújo & Costa (2008);
		Dangerous animals (jellyfish, sharks)	Frequency of shark attacks; jellyfish report	Frequent (>5/y) jellyfish and shark attacks	Frequent (>5/y) jellyfish; occasional shark attacks (<5/y)	Occasional (1-5/y) jellyfish and shark attacks	Rare (<1/y) jellyfish and no history of shark attacks	Absent	Araújo & Costa (2008); Morgan (1999)
		Dangerous cliffs	Unstable cliffs, stone fall danger	Dangerous, loose cliffs directly above beach	-	Unfenced cliffs, negligible, stone fall danger	-	None directly above beach	Morgan (1999)
		Pickpockets & crime	Frequency of crimes and surveillance	Common; no police surveillance	Common; Occasional surveillance	Rare; Occasional surveillance	Rare; Surveillance during high season	Rare; Permanent surveillance	Leatherman (1997); Peña-Alonso *et al.* (2018)
Recreation	Safety	Wave regime risk	Size and type of breaking; Sea state warning flags	Dangerous (Wave >1,5m; surging and plunging waves)	Presence of Sea state warning flags; Wave >1,5m	Presence of Sea state warning flags; Moderate energy (0.5 to 1.5 m)	Safe; Moderate energy (0.5 to 1.5 m)	Safe; Low energy: (<0.5m); Spilling breaking wave	Leatherman (1997); Peña-Alonso *et al.* (2018)
		Rip Currents	Presence and frequency	Frequent; Not well marked; without information	-	Occasional; well-marked; information provided	-	Absent	Araújo & Costa (2008);
		Rescue material	Distribution along the year	Absent	Occasional	Peak season weekends	Seasonal	Permanent	Morgan (1999); Peña-Alonso *et al.* (2018)
		Zoning of activities (bathing, surfing, etc.)	Allocation of space for each activity	Competition for use of space	-	Allocation of space for boats or sports (only sea)	-	Allocation of space for each activity, with buoys or flags, including on land	Araújo & Costa (2008); Leatherman (1997)
Protection	Storm Buffer	Beach Width	Beach width (m)	Narrow (<10 m)	10-30 m	30-60 m	60-100 m	wide >100 m	Leatherman (1997)
		Beach slope	Beach slope (°)	Very Steep (>20°)	15°-20°	10-15°	5-10°	Gentle (<5°)	Araújo & Costa (2008); Morgan (1999);
		Morpho-dynamic state	Morphodynamic state	Very reflective	Mostly reflective	Intermediate	Mostly dissipative	Dissipative	Amyot & Grant (2014)
		Dune type	Stage of dunes	Absent	Incipient	Foredune ridge only	Secondary ridge	Several, fixed dunes	Ergin *et al.* (2004); Bombana & Ariza (2019)
	Shoreline stability	Vulnerability to erosion	Rate of erosion (m/y)	Very High (>1m/year)	High	Moderate	Low	Very Low (0 m/year)	Cendrero & Fischer (1997); Araújo & Costa (2008);
		Dune condition	Dunes condition	Absent, replaced by hard engineering	Severely disturbed and limited in extent	Disturbed but largely intact	Well developed, little disturbance	Pristine and extensive	McLachlan *et al.* (2013)
	Shoreline stability	Vulnerability to erosion	[Sources - Sinks]	Erosional	-	Stable	-	Depositional	Leatherman (1997)
		Hard coastal defense	Presence and quantity of seawalls, groins, etc.	>3	3	2	1	None	Ergin *et al.* (2004)
Protection	Induced changes	Impervious surface	Cover area around 500 m of the beach (%)	>60%	40-60%	20-40%	5-20%	<5%	Ariza *et al.* (2010)
		Changes in grain size	(%) of beach area affected	Severe (>30%)	-	Moderate (<30%)	-	No alterations	Ariza *et al.* (2010)
		Changes in volume (nourishment)	(%) of beach area affected; Number of interventions	Severe (>30%); >3 interventions	Severe (>30%); <3 interventions	Moderate (<30%); 2 interventions	Moderate (<30%); 1 intervention	No alterations	Ariza *et al.* (2010)
	Subaerial dissipatio	Bathing area protection	Distribution of reefs, saltmarshes	Absent	-	Low protection/ coverage	-	High protection; high coverage	Araújo & Costa (2008);
		Bathing area material	Predominant material	Rocky	Mixed rock and coarse sand	Coarse sand	Mixed coarse sand and fine sand	Fine or medium sand	Araújo & Costa (2008);
	Risk & Vulnerability	Harmful storms	Nº events/century; Vulnerability	Frequent (>50); High vulnerability	Recurrent (26-49); High vulnerability	Occasional (11 - 25); Medium vulnerability	Scarce (1-10); Low vulnerability	Rare (<1); Low vulnerability	Cendrero & Fischer (1997); Araújo & Costa (2008);
		Sea level rise	Rate of sea level rise (mm/y)	>20 mm/year	-	0.5 to 20 mm/y	-	<0.5 mm/year	Cendrero & Fischer (1997);
		Natural disaster	Probability of occurrence; Vulnerability	Very High (Return Period <100 years); High vulnerability	Moderate (Return Period: 100 and 1000 y); High vulnerability	Moderate (Return Period: 100 and 1000 y); Low vulnerability	Little (Return Period > 1000 years); Very low vulnerability	Absent	Lucrezi *et al.* (2016)
		Exposure to waves	Beach shape (pocket, linear)	Exposed	-	Half-sheltered	-	Sheltered	Araújo & Costa (2008);
Conservation	Environmental quality	Noise	Scenic Evaluation	Intolerable	Tolerable	-	Little	None	Ergin *et al.* (2004)
		Degree of urbanization	Area of construction (%) - around 500 m of the beach	>75%	75-50	25-50	1 to 25	0	Peña-Alonso *et al.* (2018)
		Air quality (air pollutants)	Emission of pollutants (PM2.5, PM10, O3, NO2, SO2); Directives	Bad PM_{10}>101; $PM_{2.5}$>51; NO_2>401; O_3>241; SO_2>501	Weak (PM_{10} 51-100; $PM_{2.5}$ 26-50; NO_2 201-400; O_3 181-240; SO_2 351-500)	Regular (PM_{10} 36-50; $PM_{2.5}$ 21-25; NO_2 101-200; O_3 101-180; SO_2 201-350)	Good (PM_{10} 21-35; $PM_{2.5}$ 11-20; NO_2 41-100; O_3 81-100; SO_2 101-200)	Very Good (PM_{10}<20; $PM_{2.5}$<10; NO_2<40; O_3<80; SO_2<100)	APA PT
	Environmental quality	Concentration of Nutrients	Concentration of Nitrogen according Directives; Changes on the environment	>50 mgNO_3/l; Severe alteration with high impacts	>50 mgNO_3/l; Little alteration or impacts	<50 mgNO_3/l; Alteration on the state of habitat without significant impact	<25 mgNO_3/l; Alteration on the state of habitat without significant impact	<25 mgNO_3/l; No alterations on the state of habitat	Directives 91/676/EEC; 75/440/EEC
	Governmental acts	Restrictions & Regulations	Legal instruments; Communications at the beach	Absent	One restriction (e.g. dogs)	Moderate (two restrictions visible)	-	Many (e.g. dogs, drinks, dunes, parking)	Lucrezi *et al.* (2016)
		Protected areas (%)	(%) area under conservation	0%	<10%	10 - 30%	30 - 50%	>50%	Cendrero & Fischer (1997)
		Environmental Educational	Number of initiatives and engagement with society	Absent	Few activities	Moderate	Many activities	Many activities, high engagement	Lucrezi *et al.* (2016)
Conservation	Habitat	Ecosystem connectivity	Number (nº habitats/ha), size and connectivity of ecosystems	Absent	Few (1-5), medium, disconnected	Many (5), small, connected	Many (5-10) medium-large, connected	Numerous (>10), medium-large, connected	Amyot & Grant (2014); Lucrezi *et al.* (2016); Cendrero & Fischer (1997)
		Ecosystem condition	Conservation status of habitats; % of area changed	Very badly preserved (>75%)	Badly preserved (50-75%)	Moderately preserved (20-50%)	Well preserved (5-20%)	Very well preserved; <5%	Araújo & Costa (2008); Atkins *et al.* (2015)
	Species	Diversity & Abundance	Number and size of populations; level of conservation	Low abundance; high modification; missing the majority of communities	Intermediate; high modification; missing some expected communities	Intermediate; moderate modification; missing some communities	Species rich and abundant; little modification; missing some communities	Species rich and abundant; pristine; all expected communities present	McLachlan *et al.* (2013); Directive 2000/60/EC
		Endangered and iconic	Number of species; nesting	Absent	-	Present in low numbers, not nesting	-	Nesting/spawning present in large numbers	McLachlan *et al.* (2013)
		Invasive species	Establishment; Invasive potential; Commercial Value	Well-established; impacts reported; No commercial value	Well-established; medium/high potential; low commercial value	Species established; medium/low invasive potential; high commercial value	Species introduced; low invasive potential; Very high commercial value	No reported/Absent	Keller *et al.* (2011)
Conservation	Heritage	Geological interest	Geological diversity	Absent	-	-	-	Present	Bombana & Ariza (2019)
		Historic, archaeological cultural & scientific interest	Nº of units; conservation	Absent	Few; bad conservation	Moderate nº and conservation	High (>5); Bad/fair conservation	High (>5); Good conservation	Cendrero & Fischer (1997); Lucrezi *et al.* (2016)
Sanitary	Water quality	Sewage discharge evidence	Items per linear meter on strand line	Clear evidence (>3 items)	-	Some evidence (1-3 items)	-	No evidence	Ergin *et al.* (2004); Araújo & Costa (2008)
		Microbiological water quality	Accordance of directives/standards; (cfu/100ml)	Not suitable (frequent)/Without analysis	E.intestinalis >185; Escherichia coli >500	Enterococcus intestinalis 185; Escherichia coli 500	Enterococcus intestinalis 200; Escherichia coli 500	Enterococcus intestinalis 100; Escherichia coli 250	Directive 2006/7/EC
	Sand quality	Accumulation of wood, leaves, algae	Items per linear meter on strand line	Heavily contaminated (>10); Unpleasant walking	-	Some accumulations (5-10)	Traces (0-5)	Absent	Araújo & Costa (2008);
		Unpleasant Odors	Complaining reports; Field observations	Strong	-	Detectable	-	Absent	Araújo & Costa (2008);
		Feces on the sand	Items per linear meter on strand line	Frequent	-	Some	-	Absent	Lucrezi *et al.* (2016)
	Episodic pollution	Blooms	Nº of events/year; impacts	>5/year; toxicity detected; economic and environmental impacts	>5/year; toxicity not detected; only economic impacts	2-5/year; toxicity detected; only economic impacts	2-5/year; toxicity not detected; without impacts	<2/year; without any effects	Peña-Alonso *et al.* (2018)
		Oil spills	Nº of events/year	>2/y	-	>1/y	-	Absent	Lucrezi *et al.* (2016)
	Sanitary facilities & services	Cleaning of the beach	Method applied	Absent	Mechanic (heavy) -high frequency (>3/week)	Mechanic (heavy) - low frequency	Mixed (mostly manual)	Manual / Not necessary	Peña-Alonso *et al.* (2018); Lucrezi *et al.* (2016)
		Litter bins	Distribution and maintenance	Absent	Scarce, rarely emptied	Existing, but poorly managed	Regularly emptied, without separation	Regularly emptied and with litter segregation	Williams & Micallef (2009)
		Toilet provision	Distribution and maintenance	Absent	Poorly managed at the beach and surroundings	Poorly managed on the beach; no gender specification	Clean, limited to private places	Clean; public toilet at the beach; gender specific	Williams & Micallef (2009)
Sanitary	Litter & waste	Floating debris/litter	Accumulation by strand line	Continuous accumulations	Full strand line	Single accumulation	Few scattered	Visually absent	Ergin *et al.* (2004)
		Solid human waste	Accumulation by area	High along all the beach	High next to the access point	Some in specific points	Few scattered	Visually absent	Ergin *et al.* (2004)
		Oil & tar balls	Items per linear meter on strand line	Many patches evident	-	Traces	-	Absent	Morgan (1999)

Table 1 (continued)

Source: Araújo & Costa (2008); Morgan (1999); Ariza et al. (2010); Peña-Alonso et al. (2018); Roca et al. (2009); Morgan (1999); Ariza et al. (2010); Amyot & Grant (2014); Ariza et al. (2010); Peña-Alonso et al. (2018); Ariza et al. (2010); Ariza et al. (2010); Morgan (1999); Ariza et al. (2010); Peña-Alonso et al. (2018); INR (Praia acessível); Ariza et al. (2010); Morgan (1999); Ariza et al. (2010); Ariza et al. (2010); Ergin et al. (2004); Ergin et al. (2004); Ergin et al. (2004); Ergin et al. (2004); Araújo & Costa (2008); Ergin et al. (2004); Ergin et al. (2004); Ergin et al. (2004); Morgan (1999); Peña-Alonso et al. (2018); Araújo & Costa (2008); Araújo & Costa (2008); Morgan (1999); Morgan (1999); Leatherman (1997); Peña-Alonso et al. (2018); Leatherman (1997); Peña-Alonso et al. (2018); Araújo & Costa (2008); Morgan (1999); Peña-Alonso et al. (2018); Araújo & Costa (2008); Leatherman (1997); Leatherman (1997); Araújo & Costa (2008); Morgan (1999); Amyot & Grant (2014); Ergin et al. (2004); Bombana & Ariza (2019); Cendrero & Fischer (1997); Araújo & Costa (2008); McLachlan et al. (2013); Leatherman (1997); Ergin et al. (2004); Ariza et al. (2010); Ariza et al. (2010); Ariza et al. (2010); Araújo & Costa (2008); Araújo & Costa (2008); Cendrero & Fischer (1997); Araújo & Costa (2008); Cendrero & Fischer (1997); Lucrezi et al. (2016); Araújo & Costa (2008); Ergin et al. (2004); Peña-Alonso et al. (2018); APA PT; Directives 91/676/EEC (EC 1991); 75/440/EEC (EC 1975); Lucrezi et al. (2016); Cendrero & Fischer (1997); Lucrezi et al. (2016); Amyot & Grant (2014); Lucrezi et al. (2016); Cendrero & Fischer (1997); Araújo & Costa (2008); Atkins et al. (2015); McLachlan et al. (2013); Directive 2000/60/EC (EC 2000); McLachlan et al. (2013); Keller et al. (2011); Bombana & Ariza (2019); Cendrero and Fischer (1997); Lucrezi et al. (2016); Ergin et al. (2004); Araújo & Costa (2008); Directive 2006/7/EC (EC 2006); Araújo & Costa (2008); Araújo & Costa (2008); Lucrezi et al. (2016); Peña-Alonso et al. (2018); Lucrezi et al. (2016); Peña-Alonso et al. (2018); Lucrezi et al. (2016); Williams & Micallef (2009); Williams & Micallef (2009); Ergin et al. (2004); Ergin et al. (2004); Morgan (1999)

respect the ecosystem services and functions provided by the beach. The recreation domain includes indicators like parking, availability of sand by user, adaptations for disabled users, facilities (children/ dinning / sports), lifeguards, dangerous animals (jellyfish, sharks), and rip currents. The protection domain comprises beach width and slope, dune type and condition, rate of erosion, impervious surface, morphodynamic state, rate of sea level rise, and exposure to waves. Among the conservation indicators are concentration of nutrients, protected areas, ecosystem condition and connectivity, endangered, iconic and invasive species. Sanitary indicator embraces microbiological water quality, feces on the sand, cleaning of the beach, litter bins, toilet provision and solid human waste. The indicators can be used to identify some of the most common environmental issues in beaches, such as erosion, flooding, eutrophication, pollution, alteration of landscape and decrease of biodiversity. At the same time, they also reflect the quality of the services provided.

The use of a rating score with measurements for each indicator (Table 1), instead of a simple rating by order of excellence, decreases the subjectivity of the index, since the scale of comparison is the same for every investigator applying the framework. The use of 'Bad' to 'Good' scale gives space for personal interpretation, since what can be seen as good for a person can be faced as regular by another one with more restrictive criteria. The standardization of scores, with a clear definition of what is good or bad for each indicator is essential since it guarantees that all beaches will be analyzed based on the same criteria and the ranking is a reliable comparison of elements.

3.1 Aggregation & weighting

The final weights, derived from the average of the values obtained through the focus group, can be seen in Table 2. The mean values for the domains and categories varied according to beach typology. These weightings are in accordance with the expectations for each beach type: urban beaches are known for their development and offer of services and amenities, while rural ones are known for their natural aspects. Since village beaches are semi-urban, the transition between the two, they have a mixture of elements. For urban beaches, 'Recreation' and 'Sanitary' have higher weight, while for rural, the 'Conservation' domain has a greater weight. Meanwhile, for 'Village' beaches, all the domains have similar weights. The weights for the categories also changed between beach types: 'Scenic value' and 'Carrying capacity' have higher weighting for rural and village beaches, while 'Safety' was considered the most important for urban. Concerning conservation, 'Environmental quality' is the most important category for urban beaches whereas 'Habitat' is priority for rural beaches. The 'Sanitary facilities and services' have the lowest weight for all beach types in the sanitary domain. Finally, the 'Protection' domain did not show any relevant variation of priorities between the categories.

The standard deviation (Table 2) shows the variability of weights between the scholars in the survey. Regarding the domains, urban beaches show the lowest values of variability. Rural beaches have higher inconsistency for conservation and protection, and village beaches have higher values for the sanitary domain. All beach types presented high variability for scenic value and induced changes. In the sanitary domain, urban beaches showed stronger disagreement on episodic pollution. Finally, rural beaches had a higher variability for the categories 'habitat' and 'environmental quality' on the conservation domain, whereas village beaches had higher disagreement on environmental quality and heritage.

3.2 Communication of the BRF

Ranking does not explain why a particular beach is placed in a specific position; it is therefore useful to represent the overall performance of the beach using a graphical output, in addition to a numerical output. The graphic

Table 2 Weights assigned for domains and categories for the three types of beaches. (μ) is the mean value and the (σ) is the standard deviation

		Urban		Rural		Village	
		μ	σ	μ	σ	μ	σ
Domains	Recreation	0.372	0.08	0.104	0.03	0.256	0.12
	Conservation	0.139	0.06	0.457	0.14	0.278	0.11
	Protection	0.196	0.05	0.257	0.1	0.228	0.1
	Sanitary	0.294	0.11	0.182	0.09	0.238	0.14
Recreation	Access & Parking	0.177	0.04	0.0842	0.08	0.127	0.06
	Carrying Capacity	0.187	0.07	0.2828	0.11	0.241	0.08
	Facilities & Services	0.183	0.03	0.0904	0.06	0.128	0.04
	Safety	0.263	0.06	0.1958	0.08	0.18	0.05
	Scenic Value	0.19	0.11	0.3468	0.12	0.324	0.1
Protection	Subaerial dissipation	0.181	0.05	0.177	0.09	0.237	0.03
	Risk & vulnerability	0.231	0.11	0.2	0.1	0.14	0.07
	Induced changes	0.221	0.11	0.223	0.1	0.219	0.11
	Shoreline stability	0.185	0.06	0.204	0.1	0.176	0.06
	Storm buffer	0.182	0.06	0.196	0.06	0.228	0.07
Conservation	Environmental quality	0.268	0.07	0.173	0.1	0.185	0.1
	Governmental acts	0.186	0.06	0.138	0.03	0.206	0.07
	Habitat	0.218	0.08	0.272	0.1	0.219	0.04
	Species	0.181	0.07	0.212	0.03	0.196	0.05
	Heritage	0.147	0.05	0.205	0.05	0.194	0.09
Sanitary	Water quality	0.209	0.07	0.2034	0.07	0.264	0.05
	Sand quality	0.185	0.06	0.2546	0.08	0.176	0.06
	Episodic pollution	0.258	0.1	0.2276	0.07	0.214	0.08
	S. facilities & services	0.145	0.02	0.078	0.04	0.102	0.03
	Litter & Waste	0.203	0.03	0.2364	0.05	0.244	0.08

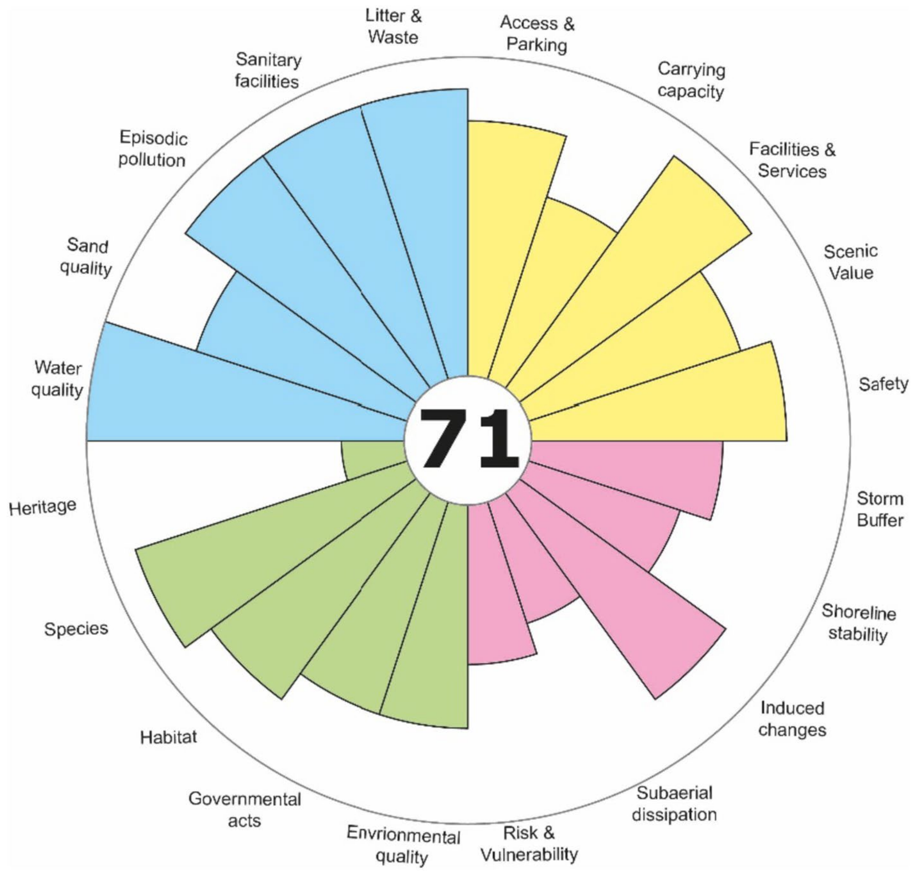

Fig. 5 Example of a graphical representation of the BRF framework. The beach quality value is at the center of the circle. Colours represent the domains (yellow for recreation, pink for protection, green for conservation, blue for sanitary). The more filled the slice, the better the beach's performance

can provide a user-friendly and simple perspective of the beach quality for each domain, delivering a better communication tool for coastal managers and tourists. Moreover, it can help to avoid the self-destructive cycle that tourism can provoke.

The graph created (Fig. 5) is inspired by the combination of the visual output of two Social-Ecological System frameworks: the 'Circles of Sustainability' (James 2015) and the 'Ocean Health Index' (Halpern et al. 2012). Color represents the domains, yellow for 'Recreation', pink for 'Protection', green for 'Conservation', blue for 'Sanitary'. The axis of the graphs shows the normalized score for each category and varies from 0 to 1, being one the greatest value at the outside border (the more filled the slice, the better the performance of the beach in this particular category). The overall BQV is shown in the center of the graph.

The graphic representation of the framework allows the visualization of the performance of the beach at each domain, facilitating the communication and interpretation of the data. The graphic output allows the user to understand why the beach is at a specific position in the ranking and helps the managers to identify which categories could be improved to raise the position in the ranking. Moreover, users can use the graphic to easily identify beaches that are better in a specific domain. Families, for example, can choose beaches that are better in the recreation quadrant, whereas groups that are looking for nature or adventure can look at conservation and find the beaches that fit their visitation purpose. The same applies for the categories. Beach-users can look for slices of the graph that fit their interest to identify the beaches with better access or greater diversity of species and habitats, for example.

4 Study case

The BRF was tested on eight beaches (Rocha, Benagil, Marinha, Falésia, Luz, Camilo, Faro and Dona Ana) in the Algarve region, in southern Portugal (Fig. 6). The Algarve extends from the Odeceixe estuary on the West coast, to the Guadiana river-mouth on the South coast, totalizing 210 km (Moura et al. 2019). The coast is marked by a high geodiversity, having vertical cliffs segments as well

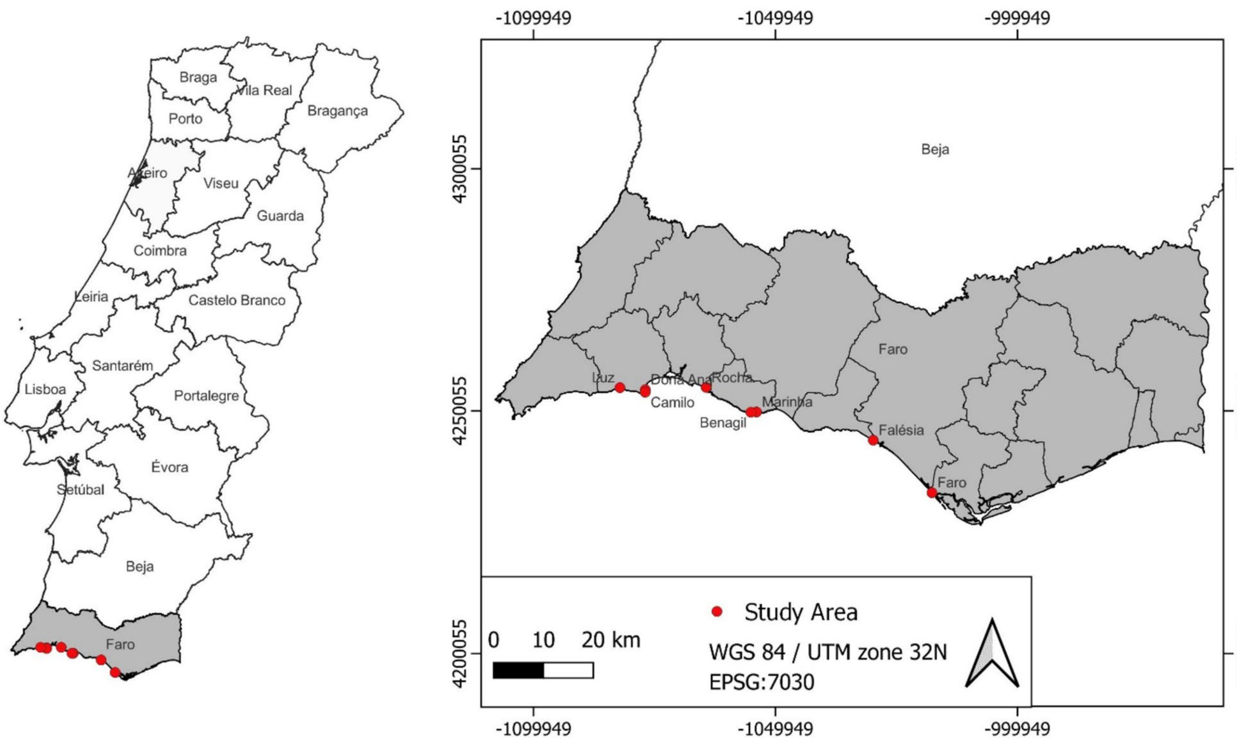

Fig. 6 Location of the study area. Algarve, Southern Portugal. Source of Base: Agência para a Modernização Administrativa. Available at dados.gov.pt

as sand-dunes associated with estuarine-lagoon systems (Teixeira 2009). Regarding the hydrodynamic regime, the tide is semi-diurnal, with amplitude of 2 m (Teixeira 2009); the average waves are 1 m height, with period of 4.7 s and W-SW prevailing direction; the winds approach the coast with angles of 40° and 60° (Costa et al. 2001; Teixeira 2009). The average temperature is 14° in winter and 24° in summer (Semeoshenkova and Williams 2011). The beaches are composed of median to coarse sand and have intermediate to reflective morphodynamic state (Loureiro et al. 2013).

The data for each indicator was scored using information provided by the literature (Reyes et al. 1999; Costa et al. 2001; Antunes and Taborda 2009; Teixeira 2009; Martins et al. 2012; Loureiro et al. 2013; Pinto et al. 2018; Sousa et al. 2018; Moura et al. 2019; Lukoseviciute and Panagopoulos 2021); public databases (Natura 2000, Mesh Atlantic, UNESCO Harmful algae info system, Eurostat, Shark Attack Data, Gel a Vista, DiscoMap EEA); Google Earth; and official government/environmental sites. Experts from the University of Algarve and research centers (CCMAR and CIMA) were consulted by email to clarify some parameters. Fieldwork was also carried out in April and May of 2022 for on-site inspection. The Quality Value for each beach and the final ranking was calculated using a spreadsheet developed by the authors (Online Resource 1). The individual performance of each beach was represented by the proposed graphical output and are shown below (Fig. 7).

The results (Fig. 7) show that all the beaches presented good performance in the 'Sanitary' domain, which contributed to elevate the individual final score. The high quality of the bathing waters is a consequence of the EU Bathing Water Directive (EC 2000), which requires the Member States to monitor and report information on water quality. In addition, the beaches of Faro, Rocha, Falésia, and Luz have the 'Blue Flag' certification, which establishes criteria for sanitary quality and facilities.

Recreation is the domain that varied mostly between the beaches. Rocha, D. Ana and Faro beaches showed the best performance for the 'Recreational' domain as a whole (Table 3), whereas Camilo and Benagil had the lowest, especially for the Carrying Capacity category due to the small beach area. The large beach of Falésia is the only one to achieve the highest score in the Carrying Capacity category. Facilities and Services are higher at urban and village beaches, except for Dona Ana, which, despite being an urban beach, does not have facilities for children, shade provision or adaptions for disabled users.

All beaches obtained similar results for 'Protection', with an overall median performance (Table 3), intercalated with a good to very good result in one specific

Fig. 7 Graphical representation of each beach scored

Table 3 Ranking of the Algarve beaches by domain. The value represents the overall performance of each beach in the specific domain. The beaches are ranked according to performance

Recreation		Protection		Conservation		Sanitary	
Ranking	*Value*	*Ranking*	*Value*	*Ranking*	*Value*	*Ranking*	*Value*
Rocha	0.297	Marinha	0.182	Marinha	0.352	Rocha	0.272
D. Ana	0.238	Camilo	0.175	Camilo	0.339	D. Ana	0.269
Faro	0.191	Benagil	0.174	Benagil	0.312	Luz	0.222
Luz	0.179	Falésia	0.167	Falésia	0.272	Faro	0.216
Falésia	0.088	Luz	0.145	Luz	0.235	Benagil	0.174
Marinha	0.074	Faro	0.133	Faro	0.187	Marinha	0.167
Camilo	0.060	D. Ana	0.124	D. Ana	0.092	Falésia	0.167
Benagil	0.058	Rocha	0.115	Rocha	0.086	Camilo	0.162

category. Marinha and Camilo, per example, showed the highest score for 'induced changes', while Rocha was the better on 'storm buffer'. Marinha and Camilo scored better on the 'Conservation' domain (Table 3), with a very good performance in the Environmental quality category due the absence of noise or exceeding nitrogen, and the excellent air quality. Luz also has the highest score for the category 'Heritage' due the presence of a high number of well conserved sites.

The ranking of best beaches, done through the comparison of the BQV, is shown in Fig. 8. The beaches presented similar BQV despite the variations between the domains and beach typology. The best beach (#1) is Luz, a village beach in the municipality of Lagos. The beach won due the combination of a good performance in the 'Sanitary' and 'Conservation' domains (presence of a Natura 2000 site), aligned with a median performance in the 'Recreation' domain. The beach in the last position, Falésia, had a low performance in the 'Conservation' domain and a good performance in 'Recreation', despite being a rural beach. Since rural beaches have higher weights for conservation and lower for recreation, a mediocre performance in conservation led Falésia to a worse position. Furthermore, the ranking shows different beaches at the three first positions, confirming that the framework is not favoring a unique beach type.

The test-application of the Beach Ranking Framework on the Algarve region was possible and validated the methodology created. The graphics produced confirm that urban beaches have higher performance in the 'Recreational' domain, compared with rural beaches that favor 'Conservation'. This outcome also proves the importance of weightings when the same rating scale is being applied. If equal weights were applied to all beaches, regardless of the typology, the final ranking would not be appropriate, since the beaches do not have the same strength in each area. Rural beaches, for example, would be jeopardized by the lack of infrastructure, even though they would not be expected to have it. Urban beaches, on the other hand, would suffer losses due to their land modification, which is unavoidable, since land modification is needed to provide facilities such as parking and services such as access steps and ramps, which is their main strength.

5 Discussion

The 'Beach Ranking Framework' is a clear, objective methodology composed by indicators that respect the functions and ecosystem services of a beach generating a rating score scheme that enables comparisons. The use of weights allows type-specific differentiation based on the importance of each component for each beach type, avoiding generalization and incorrect classification. The framework provides a holistic view, addresses the main issues and points out the weakness and strengths of each beach. The graphical result summarizes larges amount of information to communicate clearly to the beach-users. Furthermore, the framework standardizes the ranking methodologies, reducing the subjectivity of the existing beach rankings.

The 'Beach Ranking Framework' can support the management of beaches by highlighting the characteristics, assessing the health status of a beach and guiding the response and actions towards the main issues identified. For example, the manager can look at beaches with a lower score in the Protection domain and think of alternative options, such as beach nourishment, dune restoration, permeable access and structures, to increase the beach protection. Managing this beach will then improve the score of specific categories, increasing the future score and raising the position in the ranking. Additionally, the managers can use the result of the ranking to create informative materials such as signs, posters, and brochures for environmental

Fig. 8 Ranking of the beaches analyzed in Algarve using the beach ranking framework. The comparison only includes the eight beaches analyzed in this study case. Source of images: Hélio Ramos, Algarve Beach Guide (2014)

education and raising awareness of beaches as socio-ecological systems. Other stakeholders can also benefit from the outcomes. The tourism industry can divulge their region and the status of their beaches using a 'science-based methodology'. Possible products for dissemination include beach guides, posters, videos, news or social-media content. The scientific community can apply the methodology not only to generate articles and conference presentations, but also to move forward the improvements needed. For the general public, the Beach Ranking Framework allows each-users to compare and identify the beaches that fit their visitation needs and, at the same time, understand why that beach is in a specific position, since the criteria for ranking are explicit in the methodology.

The Beach Ranking Framework is widely applicable and can be used for research on beach quality and for the identification of the management priorities in areas where coastal tourism is an important sector. However, it should always be adapted to local specifics and beach typology. Some of these adaptations may include the revaluation of the access category in countries were private beaches are allowed, and the revision of indicators that depend of levels of standards, like water and air quality, or concentration of nutrients, that should be based on local directives. Additionally, the rating of indicators can vary according to the availability of data, local dynamics, and relevance to the beach quality issues in a given area. Some examples of this variety include beaches located in bays and rivers, which do not fit the morphodynamic nomenclature, and have their own particularities regarding waves, winds and water levels. In this scenario, storm buffer and energy dissipation will need to be readjusted to reflect the local energy characteristics. Touristic beaches may have a seasonality in the tourism influx and in the services provided throughout the year. Hence, the application of the methodology in different times could show variation on the final beach quality value. The choice of the season that most reflects the real status of the beach quality should be decided by a group of stakeholders. The indicator 'vulnerability and risk' may be pointless for locations that do not suffer or do not have a record of harmful events, such as hurricanes. In these regions, the vulnerability to sea level rise or other local hazards should increase importance.

The case-study beaches generated evaluations with final quality values very close to one another. There are three possible explanations. Firstly, differentiating the domains and categories within each beach typology by using weights is helping to balance and compensate the strengths and weakness of each beach. Secondly, the geographical location of the beaches analyzed. The beaches are all from the same climate and economy, and are located in a region known for its coastal tourism, which would make them rate very similar in some of the categories. Finally, the results may have been impacted by the person analyzing it, so there is still a small element of subjectivity. If different researchers, with different expertise, background, and more experience in the area, had applied the methodology at the same beaches, the results may have been different. The perception of the framework user will subject the results to their personal analysis and beliefs. For example, a conservationist and a coastal engineer may evaluate the human modifications of a beach differently. To test this possibility, we are currently implementing the framework on beaches in Latin America with the help of experts from the Proplayas Network. This assessment will allow us to assess how the method responds in countries with different economies and cultures, and how personal background can affect the results of the application.

Developing the framework required some compromises. First, we limited the selection of articles to the ones that proposed a holistic and integrative approach to assess the quality of beaches. Articles focusing on specific management aspects, such as water quality, risk analysis, microplastic or marine litter were not considered. They could have brought updates and recent findings on specific indicators. Secondly, we decided to create one single rating score for all beaches, and have them differentiated by the weights. Even though the weights are helpful to differentiate the beaches, as shown in the case study, the creation and use of a rating score for each beach typology could deliver different results, as it would be more specific to some characteristics. Moreover, the use of a small focus group to weight the framework, instead of a large expert panel consisting of different stakeholders, could still have a bias to one of the domains of the framework, according their perceptions.

Finally, the rating score still has many elements that are incomplete or subjective, such as the color of water or sand. The rating of some indicators, for example parking, only considers the abundance of space, but could also include the location, the material of the paving, and the integration with the environment. The rating of the indicators related with beach protection, e.g. impervious surface and hard coastal defense, could in future incorporate new developments in coastal structures, such as permeable groynes and beach revetments, as well as nature-based solutions, which play an important role in stabilizing the shoreline in urban beaches.

Although the proposed methodology is working, some improvements must be made to strengthen the framework. First, the indicators selected were all extracted from the existing literature. The incorporation of experts and stakeholders at this stage of the project can generate better results by including indicators that are still lacking importance or by restructuring the categories in each domain. The sanitary domain, for example, could evolve to incorporate indicators of human health, such as mortality rate or income per capita, while governance engagement and sustainable practices could be emphasized in the conservation categories. Another future step could be the inclusion of indicators to assess social justice issues, giving support for the historically underrepresented beach towns.

Second, a robust analysis of the rating scores, identifying the best measurement technique and monitoring for each indicator and the clear division between the classes is necessary. The literature on environmental rating scores is scarce. The majority of the measurements suggested in this research are from more than one decade ago, while others are just the opinion of the authors' article. Thus, an up to date, consistent and integrated rating score to measure ecosystem services indicators (what is good or bad) is urgent. Third, stakeholders, beach managers and the expanded peer-community should be more involved in the local adaptation of the framework and in the weight process to amplify the range of perceptions relevant for beach quality ranking. The use of a limited focus group helped to reduce the bias of a single evaluation, but would deliver better results if a bigger group with different interests were involved in the process. Fourth, this study tested the AHP only on three types of beach (urban, village and rural) due the amount of information to be shared with the focus group and the limited time. However, weights should be calculated for all beach types, including resort and remote, to completely respect the attributes of each one.

Additionally, the creation of an application or website to calculate and plot the results should be pursued, since it will facilitate the use of the framework by managers and users worldwide. This could also be developed as App for beach-users to download on a smart phone. Moreover, the research can take advantage of the merging artificial intelligence techniques, which can be used to automatize, filter and display the results, and to retrieve data from public available sources. Finally, the framework should be shared with managers and users to see the acceptance between different groups.

5.1 BRF and sustainability

The promotion of rankings can create a self-destructive cycle for beaches. Once these beaches become the dream of tourists, there is an increase in the influx of visitors to the area, which will require additional facilities and land modification, leading to a decrease in the quality of the landscape, which in turn will decline the number of visitors (Butler 1980; Cristiano et al. 2020). Moreover, Decol (2015) states that after the complete saturation and exhaustion of a beach, the search for new untouched and pristine destinations begins, which will spread the impact across different environments, as the rapid explosion of demand, and the consequent economic return, prevents tourism planning that could lead to sustainable tourism. Additionally, large influxes of tourists can have a major environmental impact on coastal ecosystems and their functionality, as all drivers acting on this vulnerable habitat have a cumulative impact (Halpern et al. 2008; Micheli et al. 2013; Drius et al. 2019).

A good beach quality, according to Li et al. (2023), is critical to the sustainable development of coastal zones and the competitiveness of beach tourism. The World Tourism Organization defines sustainable tourism as "*Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities*" (WTO 2005). According to them, sustainable tourism needs to guarantee viable, long-term economic operations, respect the socio-cultural authenticity of host communities, and make optimal use of environmental resources; it also requires the participation of all relevant stakeholders, strong political leadership, and constant monitoring of impacts. Sustainable Tourism is also highlighted in the 2030 Agenda for Sustainable Development, on targets 8.9, 12.b, and 14.7. The sustainable development goal (SDG) target 12.b aims to "*develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products*". The BRF is in the scope of the sustainable tourism since it is a tool that can help to monitor the quality of beaches in the three main aspects (economic, ecological and cultural). The integration of various components into a holistic assessment is necessary to address complex interconnections, identify effective solutions across multiple systems and scales, clarify environmental responsibilities, mediate trade-offs and enhance of synergies, reduce conflicts, and design harmonious conservation and development policies and practices Liu et al. 2015). Moreover, the framework can offer support for planning, management and development the beaches, as it can assist managers to address complex systems holistically, and help to reduce knowledge compartmentalization (Virapongse et al. 2016).

Finally, the problems of tourism will not be solved until the public is taught all the information they should know about the environment, so they can manage their expectations. It is necessary to promote environmental awareness and teach beach quality if it is to move towards a more sustainable tourism. That is why something is desperately needed to resolve the subjectivity of rankings while bringing science and society closer together. The aim of scientific quality indices up to this point was not to solve this demand. The BRF, despite being a new methodology, which is learning to crawl, has the potential to be this link.

6 Conclusions

The framework provides a robust, holistic, and widely applicable tool for assessment of beach quality. It standardizes the ranking methodologies, reducing the subjectivity of the existing internet-based content, and allowing the tourist to compare the beaches and understand which criteria the ranking was based on.

The BRF embraces three main goals: to assess the quality of beaches based on indicators; to enable beaches to be compared; and to communicate the results for the society. For our first goal, indicators were selected based on the maintenance of the beach's services, guaranteeing the identification of threats that can put the system at risk (such as erosion, sea level rise, loss of biodiversity, pollution). This holistic assessment, which is common in the scientific quality evaluation, is not applied in the beach rankings so far. Regarding our second goal, in order to compare the beaches a scoring system based on the final quality value was created. As the beaches are evaluated using this system, we will be able to compare the final value and rank them according to quality. It is also important to highlight that the use of weights is essential at this stage to ensure the protection of beach typologies, since beaches must be assessed and managed differently according to their characteristics.

To achieve our final goal, to communicate the results for the society, a graphical representation of the results was created. This graphic was designed to allow the user to understand why the beach is at a specific position in the ranking and to help the manager to identify which categories could be improved. The graphical output allows large amounts of information to be communicated clearly and quickly and, even more importantly, provides a holistic view of everything that is important when judging the quality of a beach.

Despite achieving the main goals proposed, the methodology still have a long journey to go. The assumptions assumed so far, as the use of existing beach quality indexes to select and rate the indicators and the use of a limited focus group to weight the structure, need to be improved in the near future. As different authors with different expertise apply the methodology, new limitations and challenges will arise. Some of these challenges include the availability of continuous environmental monitoring data, morphodynamic of beaches located in bays, presence of beach hawkers, macrotidal regime, or seasonality of beach tourism. Future applications will allow exploration of how to improve the BRF. By calling attention to specific gaps in indicators selection and rating, the framework can be stimulated to better assess the system quality, differentiate the beaches, and incorporate sustainable and nature-based solutions for tourism.

Sustainable tourism is a sector of the Blue Economy and a goal of the Ocean Health Index. To achieve sustainable tourism, is necessary to respect the characteristics of different beaches and to inform the public so they understand the principles of resilience and social-ecological systems, to raise the profile of environmental quality with respect to the 'Instagramable' aspects. The proposed beach ranking framework can help achieve these goals and transform the expectations of the tourism sector towards a more sustainable future.

Supplementary Information

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Additional file 1.

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Availability of data and materials
Data will be available under request.

Declarations

Competing interests
The authors have no competing interests to declare that are relevant to the content of this article.

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