

Beach quality index for beach tourism management in small islands

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Abstract. Small island economies rely heavily on beach tourism as a critical economic driver. However, managing beach resources in these contexts poses significant challenges due to limited land, fragile ecosystems, and the need to balance the interests of local communities and visitors. The objectives of this study were to evaluate the water quality of beaches using distinct metrics, including pH and dissolved oxygen levels in the water surface, as well as the amounts of sediment coliform and solid waste. Additionally, the study aimed to develop a Beach Quality Index as a decision support tool for sustainable beach management in small island environments. The results showed that the water quality of the beaches varied across the study sites, with some locations exceeding national standards and thus deemed suitable for beach tourism. The study proposes the Beach Quality Index as a standardized framework to assess beach suitability for recreational use, guide management decisions, and promote sustainable beach tourism in small islands.

1 Introduction

The small island environment furnishes a variety of ecosystem services that benefit humanity, such as the provision of food, natural resources, opportunities for recreation, and tourism activities [1-3]. However, small islands are vulnerable to a combination of natural and anthropogenic disturbances that can undermine the quality of their beaches, which are essential for beach tourism, a pivotal economic engine for numerous small island countries [4] [5] [2] [6]. Sandy beaches are notable among these ecosystems for being affected by a variety of factors, both natural and human-induced, that can impact their suitability for beach tourism [7] [2] [3] [8] [6] [5]. Human occupation and development reduce the environmental quality of sandy beaches, as can marine pollution, coastal erosion, and other environmental stressors that alter the physical, chemical, and biological characteristics of these dynamic systems [1] [8].

Given the escalating threats to small island environments, establishing comprehensive assessment frameworks to evaluate beach quality and inform sustainable management strategies for beach tourism is crucial. Such frameworks would enable island communities to strike a balance between economic development and environmental conservation, ensuring the long-term sustainability and resilience of this critical

natural resource that underpins the livelihoods and well-being of island residents [4]. Implementing robust assessment frameworks to evaluate beach quality and inform sustainable management strategies for beach tourism in small island contexts is crucial [9].

Implementing comprehensive assessment frameworks to evaluate beach quality and guide sustainable management strategies for beach tourism is crucial in small island contexts. Such frameworks can enable island communities to strike a balance between economic development and environmental conservation, ensuring the long-term sustainability and resilience of this critical natural resource that underpins the livelihoods and well-being of island residents [6] [10]. The proximity of beaches to human settlement is a significant factor influencing beach quality, as small island development can degrade beach environments through the introduction of marine litter, poor water quality, loss of natural habitats, and other impacts. The socioeconomic consequences of beach degradation are a pressing concern for small island nations, which often have limited land area and rely heavily on beach tourism as a primary economic driver. Furthermore, tourism associated with recreational activities is one of the main sources of disturbance to beach ecosystems, as increased human presence, activities, and infrastructure can harm the natural functioning of these environments [2].

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Prior research on the environmental condition of sandy beaches has typically relied on a single metric to assess their status, focusing on physical, chemical, and biological indicators that provide a comprehensive evaluation, such as water quality and sediment properties. However, assessing beach quality in small island contexts requires a more holistic approach that incorporates diverse social, economic, and environmental factors [11]. Given the diverse human pressures impacting beaches, evaluating beach quality using a single metric may be inadequate. Instead, a more comprehensive assessment approach that incorporates multiple indicators is necessary to provide a thorough evaluation of beach conditions [7].

This study aimed to assess the water quality of beaches for tourism purposes using specific metrics, such as pH and dissolved oxygen levels in the surface water, as well as the amounts of sediment coliform and solid waste. Additionally, the study sought to develop a Beach Quality Index as a decision-making tool to support sustainable beach management in small island contexts. The underlying hypothesis was that sandy beaches with recreational potential would exhibit better physical and microbiological characteristics compared to those impacted by intensive human activities, such as urban development or mass tourism. To test this hypothesis, the researchers conducted a field survey of beach conditions at multiple locations within a small island environment.

2 Research methods

2.1 Study Area

We conducted a field survey of beach conditions at beaches in a small island environment. Located on Sembilan Beach in Gili Genting Island, East Java, Indonesia. Sembilan Beach, the main tourist beach on the island, offers a range of recreational activities, including swimming, sunbathing, and water sports. The island is located approximately 10 km off the northwest Madura Strait and has an area of 0.61 square kilometers, with a permanent population of around 200 residents. Sembilan Beach display an impacted condition due to the combined effects of local community's daily activities and the influx of mass tourism [12].

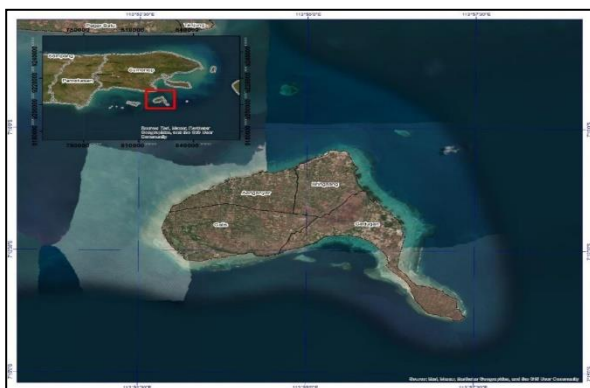


Fig. 1. Beaches studied along the Gili Genting Island.

2.2 Data collection

To comprehensively evaluate the beach's condition, we collected data on several water quality parameters relevant to beach tourism, such as water color, pH, suspended solids, dissolved oxygen levels, sediment coliform content, and the amount of visible solid waste along the shoreline. We then compared the collected water quality data to the standards outlined in Appendix VIII of the Government Regulations of the Republic of Indonesia Number 22 to assess the suitability of the beach for tourism activities.

We measured water pH and dissolved oxygen using a multi-parameter water quality tester, taking measurements at various locations along the beach at a depth of approximately 30 cm [13]. Sediment samples were collected from the upper 5 cm of the beach along transects and analyzed for fecal coliform content using a most probable number method [1]. The amount of solid waste was quantified by counting the number of visible plastic items, glass bottles, and other refuse along the beach's shoreline [3].

Additionally, we developed a Beach Quality Index to comprehensively evaluate the condition of the surveyed beach, drawing upon a previously established analytical framework [1]. This BQI encompassed three component sub-indices: the Recreational Function Index, the Natural Function Index, and the Protective Function Index. Each sub-index incorporated variables relevant to the specific function being assessed for the individual beaches. The final BQI score for each beach was then calculated by integrating these three sub-indices, and the resulting value was standardized on a scale from 0 to 1.

3 Result and discussion

3.1 Environmental quality indicator

The environmental quality of the beaches was determined by measuring the following indicators: water color, transparency, pH, suspended particulates, dissolved oxygen concentrations, sediment coliform levels, and the quantity of visible solid waste along the shoreline. Water quality measurement in Sembilan Beach showed in Table 1.

The study findings indicate that the water quality at Sembilan Beach generally met the standards for recreational use, with the exception of the excessive amount of solid waste observed along the shoreline, which exceeded the acceptable limit. The water at the beach had a light blue to green hue with moderate transparency. The average pH level of 7.8 fell within the acceptable range for recreational water use. However, the suspended particulate levels exceeded the recommended limit for recreational waters, suggesting poor water clarity. Dissolved oxygen concentrations were found to be below the recommended level for swimming activities, potentially due to the accumulation of organic matter and nutrient inputs from nearby human settlements. Additionally, the sediment

samples exhibited high fecal coliform counts, surpassing the regulatory threshold for safe recreational use. Significant quantities of visible solid waste, primarily comprised of plastic items, were observed along the shoreline, indicating suboptimal solid waste management practices in the area.

Table 1. Water quality measurement.

No	Parameter	Unit	Result	
			Observation	Standar*
1	Colour	Pt.Co	35.00	30.00
2	Brightness	m	6.40	>6.00
3	pH		7.80	7.00 - 8,50
4	Dissolved Oxygen	mg/l	6.70	>5.00
5	Total Suspended Solid	mg/l	18.00	20.00
6	Soild Waste	-	20.40	<1.00
7	Fecal coliform	number/ 100 mL	175.00	200.00

*Appendix VIII, Government Regulations of The Republic of Indonesia, Number 22, 2021.

Furthermore, the findings of this study demonstrate the application of a comprehensive Beach Quality Index framework to evaluate the environmental condition of beaches in a small island setting [1] [3]. The results suggest that Sembilan Beach, the primary tourist beach on Gili Gending Island, is experiencing significant environmental degradation due to the combined effects of the local community's daily activities and the influx of mass tourism. The poor microbiological water quality, characterized by high levels of fecal coliform bacteria, indicates the presence of untreated sewage or inadequate sanitation infrastructure, posing potential health risks to beachgoers [14] [7]. The substantial accumulation of solid waste, predominantly comprised of plastic items, not only detracts from the aesthetic appeal of the beach but also has detrimental impacts on the marine ecosystem, potentially harming wildlife and disrupting the natural balance of the coastal environment [15] [3]. Furthermore, the low dissolved oxygen levels observed in the water suggest the accumulation of organic matter and nutrient inputs, which can lead to eutrophication and the degradation of the overall aquatic habitat [16] [6] [3]. These environmental issues collectively suggest that Sembilan Beach is under considerable stress, which could have significant implications for the long-term sustainability of beach-based tourism on the island. The development and implementation of a comprehensive beach management plan, incorporating strategies to address the identified environmental concerns, is crucial for ensuring the continued viability of beach tourism in this small island context [5].

3.2 Beach Quality Index

The Beach Quality Index was computed based on the measured environmental quality indicators and the

assessment of the beach's recreational, natural, and protective functions. The observed findings are presented in Table 2.

Table 2. Beach quality index for Sembilan Beach.

No	Component Index	Score
1	Recreational Function Index	0.73
2	Natural Function Index	0.55
3	Protective Function Index	0.42
<i>Beach Quality Index</i>		0.57

The Recreational Function Index, which captures the beach's suitability for recreational activities, scored 0.73, indicating a moderately high quality. The Natural Function Index, reflecting the beach's ecological integrity, scored 0.55, suggesting a moderate level of natural function. The Protective Function Index, which assesses the beach's capacity to safeguard the adjacent coastal environment, scored 0.42, indicating a relatively low protective function. The overall Beach Quality Index for Sembilan Beach was calculated to be 0.57, signifying a moderate condition of the beach.

The relatively low scores in the Protective Function Index and the Natural Function Index underscore the urgent necessity for enhanced environmental management strategies to safeguard the beach's natural attributes and its capacity to provide crucial ecosystem services. Addressing the significant issue of solid waste accumulation requires a multi-pronged approach. Improving waste collection, recycling, and disposal systems would help mitigate the problem at the source. Simultaneously, promoting public awareness campaigns and encouraging active community participation in regular beach cleanup initiatives could foster a sense of ownership and stewardship among local residents and visitors, leading to more sustainable behaviors [17] [18]. Furthermore, the implementation of comprehensive water quality monitoring programs and the strict enforcement of regulations governing recreational water use, coastal development, and waste management practices are crucial steps to help mitigate the detrimental impacts of human activities on the delicate beach ecosystem. Ultimately, adopting a holistic approach to environmental management, which prioritizes the protection and restoration of the beach's natural functions and ecological integrity, is essential for ensuring the long-term sustainability of beach tourism in this small island destination. Such a multifaceted strategy, combining infrastructure improvements, community engagement, and robust regulatory oversight, is necessary to safeguard the beach's environmental quality and maintain its appeal as a sustainable tourist attraction.

The comprehensive assessment approach employed in this study, which involved the development and application of the Beach Quality Index, demonstrates its significant potential as a valuable tool for evaluating and managing beach resources in small island destinations [1]. The multidimensional nature of the index, encompassing the assessment of recreational, natural, and protective functions, provides a holistic and nuanced understanding of the beach's overall condition.

This enables the identification of specific areas within the beach ecosystem that require targeted interventions and management strategies. The findings from this research can meaningfully inform the development of sustainable, evidence-based beach management strategies, which is crucial for contributing to the long-term viability and resilience of beach tourism in Gili Gending Island and other similar small island destinations facing increased environmental pressures. The comprehensive and multifaceted approach showcased in this study underscores the importance of using robust assessment frameworks to guide the effective and sustainable stewardship of precious coastal resources in fragile island environments.

4 Conclusion

This research developed and applied a comprehensive Beach Quality Index framework to evaluate the environmental state of Sembilan Beach, the primary tourist beach on Gili Gending Island. The findings indicate substantial environmental degradation resulting from the combined effects of local community activities and the influx of mass tourism. The relatively low scores in the Protective Function Index and Natural Function Index underscore the urgent necessity for enhanced environmental management strategies to safeguard the beach's natural attributes and its capacity to provide crucial ecosystem services. The multidimensional assessment approach showcases the significant potential of the Beach Quality Index as a valuable tool for evaluating and managing beach resources in small island settings, which is vital for ensuring the long-term sustainability of beach-based tourism in these fragile ecosystems resources in fragile island environments.

This study was supported by funding from the BIMA KEMDIKBUDRISTEK program of the Indonesian government, which facilitated the research. The authors would like to express their gratitude to the local community and authorities of Gili Gending Island for their cooperation and assistance during the data collection process.

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