Litter management strategies on Sukabumi beaches, Indonesia: implementing the clean coast index and beach typology

[1]Ankiq Taofiqurohman, [1]Mochamad R. Ismail, [1]Mochamad U. K. Agung, [1]Sheila Zallesa, [2]Shafira B. Annida, [3]Putri Wibawanti

[1] Department of Marine Science, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Sumedang, West Java, Indonesia; [2] Vocational Marine Tourism, Universitas Padjadjaran, Sumedang, West Java, Indonesia; [3] Research Center for Climate Studies and Maritime Area Management, Universitas Padjadjaran, Sumedang, West Java, Indonesia. Corresponding author: A. Taofiqurohman, ankiq@unpad.ac.id

Abstract. Indonesia's Sukabumi coast is part of the UNESCO Global Geopark Ciletuh-Palabuhanratu area, which is intensively developed as a marine tourism destination. In the development process, basic research is very necessary to support the development of the Sukabumi coastal area. One of the basic research topics that is needed is to answer the problem of coastal litter originating from tourism and other anthropogenic activities. In the old paradigm, the coast was often considered the first door to the flow of marine litter. Therefore, marine litter has always been a scourge that haunts the sustainable development of coastal areas. This research aims to develop a litter management strategy, especially on the Sukabumi coast, using the clean coast index (CCI) approach with beach typology classification. A total of 1129 litter items were collected from 14 beach tourism locations along the Sukabumi coast. The grouping results show that 85% of the total litter was plastic. Other types found were litter made from rubber, textiles, glass, and metal. Based on the analysis of the beach litter management table, ten beaches were categorized as green, two beaches as orange, and two other beaches as red. This study obtained a practical approach to determine effective solutions for developing coastal management strategies with specific characteristics.
Key Words: clean coast index, environmental management, marine debris, South Coast of Java.

Introduction. Marine debris is a global concern that impacts a variety of coastlines, ranging from expansive sandy beaches to rugged and isolated coastlines. The studies have consistently highlighted the global issue of marine debris, showing its impact even in the most secluded coastal locations. For instance, the study by Duhec et al (2015) revealed that the majority of marine debris on Alphonse Island in Seychelles originates from land-based sources. Similarly, a study by Otley & Ingham (2003) found plastic litter in remote areas such as the Antarctic Peninsula and the Falkland Islands. Grillo & Mello (2021) offer evidence that the marine debris in the Fernando de Noronha Archipelago, a remote region of Brazil, presents a significant threat to the local fauna. The extent of the impact of marine pollution on even the most remote and seemingly pristine environments is emphasized by these findings. The challenge of litter disposal is also prevalent in rural villages in developing countries, where the scarcity of organized waste disposal sites significantly influences residents' disposal behaviors (Wang et al 2018). Litter sources are on the rise as urbanization progresses, and urban and tourist areas, such as Xiamen in East China, are substantial contributors to marine debris (Chen et al 2019).

Indonesia, which has one of the world's longest coastlines, is both directly affected by and contributes to marine debris. Studies conducted in a variety of Indonesian regions have emphasized the severe impact of marine debris on the littoral and marine ecosystems. Some waste problems in Indonesia include the accumulation of plastic litter in mangrove ecotourism areas in Kupang, East Nusa Tenggara, and Makassar, the city of South Sulawesi (Paulus et al 2020; Daris et al 2021). Additionally, there is a correlation between marine debris and the deterioration of water quality, which has a detrimental impact on marine environments in Palu Bay, Central Sulawesi (Walalangi et al 2022). Debris from fishing equipment, such as gillnets, poses a threat to marine life in Central Java (Maksum et al 2023). Additionally, marine debris significantly impacts the remote coastal communities of Indonesia (Phelan et al 2020).

Several studies have investigated the correlation between litter presence and beach typology, revealing that the type and quantity of litter accumulated are significantly influenced by the geographical characteristics and human interaction on each type of beach (Cristiano et al 2018; Rangel-Buitrago et al 2018b; Asensio-Montesinos et al 2019; Er-Ramy et al 2022). The accumulation and management of litter are influenced by the distinct characteristics of each beach typology - remote, rural, village, and urban. For example, the high frequency of tourist visits frequently maintains the cleanliness of urban beaches; however, the large number of visitors also increases the likelihood of waste accumulation. Conversely, remote beaches frequently accumulate debris due to ocean currents or wind, and inadequate remediation initiatives exacerbate these circumstances (Williams et al 2016; Rangel-Buitrago et al 2017). This comprehension is crucial for the development of effective refuse management strategies that are tailored to the unique characteristics of each beach, thereby promoting the ecological and aesthetic sustainability of the area, which in turn supports tourism activities (Corraini et al 2018). The clean coast index (CCI) is an assessment tool that is intended to measure beach cleanliness by considering the quantity of litter, and it can be used to initiate a comprehensive and coordinated approach to addressing coastal litter (Alkalay et al 2007). It is also crucial to conduct beach typology analysis in order to comprehend the physical characteristics and natural dynamics that influence refuse accumulation. The negative influence of litter on beach quality, particularly on Indonesian coasts, can be mitigated through the development of more targeted and efficient strategies through the integration of CCI assessments and beach typology classifications.

The Sukabumi coastal areas, which are part of the Ciletuh-Palabuhanratu UNESCO Global Geopark, are being developed into a marine tourism destination in Indonesia (Giovani et al 2018; Malik 2019; Muslim et al 2019; Rahmawati et al 2021). This area is a significant study area for Indonesia's litter management strategies. However, marine debris has an impact on the coastlines in Sukabumi, as it does in other locations (Juliandri et al 2020; Hengky 2022; Taofiqurohman et al 2024). The beaches in Sukabumi, which are situated on the southern coast of Java Island and are directly exposed to the Indian Ocean, are severely affected by tropical cyclones and monsoon phenomena. These phenomena frequently result in the formation of large waves and storms in the southern waters of Java Island (Mahubessy et al 2018; Nurfaida & Shimozono 2019; Windupranata et al 2019; Aji et al 2021).This condition exacerbates the problem of spreading marine debris along the coast (Lo et al 2020; Marchesiello et al 2020; Azman et al 2021). Therefore, this research aims to develop a litter management strategy, especially on the Sukabumi coast, using the CCI approach and beach typology classification. Other coasts with similar characteristics and problems can use this research's guidance on effective beach cleanliness strategies as a model.

Material and Method

Area of interest (AoI). This research focuses on the outer coastline of Sukabumi Bay (Figure 1). Administratively, the Sukabumi Coast is part of Sukabumi Regency, West Java Province, Indonesia. The number of beaches studied was 14, with a total coastline of approximately 30 km. Beach spots in AoI are taken from Google Maps reviews as user recommendations based on their experiences (Shafqat & Byun 2020). Photos and ratings on Google Maps provide crowdsourcing information that shows a spot has been visited (Li & Hetch 2021; Payne 2021). Table 1 displays the names of the beach spots studied.

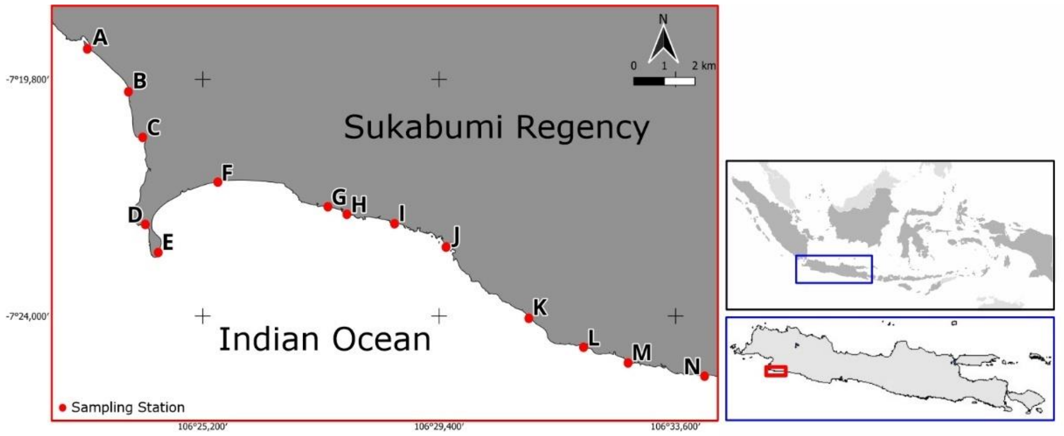

Figure 1. The area of interest.

Table 1

Names of beaches in the Area of Interest

Code	*Beach name*	*Code*	*Beach name*
A	Cipanarikan	H	Taman Pandan
B	Pangumbahan	I	Pamunguan
C	Cibuaya	J	Karang Gantung
D	Ujung Genteng	K	Minajaya
E	Tenda Biru	L	Pasir Minajaya
F	Pasir Hideung	M	Cimandala
G	Karang Panganten	N	Cikaret

Clean coast index (CCI). The CCI is an important indicator for determining the cleanliness of coastal areas. It has also been employed as a comparison instrument to offer a framework for the findings acquired in research on coastal debris, particularly plastic (Perumal et al 2021; Manullang et al 2023; Sukri et al 2023). This research's CCI calculation and classification (Table 2) are based on Rangel-Buitrago et al (2018a), with adaptations from Alkalay et al (2007):

$$\mathrm{CCI} = \frac{\Sigma\ \text{Litter item}}{\text{Length (m)} * \text{Width (m)}} * 20$$

Table 2

Clean coast index classification

Clean coast index	*Very clean*	*Clean*	*Moderate*	*Dirty*	*Very dirty*
Numeric index	0-2	2-5	5-10	10-20	> 20

Although this is a natural process, in some circumstances, the shores may also gather organic material like branches, leaves, and seagrass that some people may consider to be "dirty" (Asensio-Montesinos et al 2021; Er-Ramy et al 2023). In this study, the objects classified as litter were anorganic material with a size of more than 2 cm^2 that was scattered (inadvertently collected) on the beach and dune sample unit (Figure 2). The area of the beach sample unit is 100 meters by 2 meters on the coastline, whereas the area of the dune sampling unit is the width of the dune by 2 meters (Rangel-Buitrago et al 2018a).

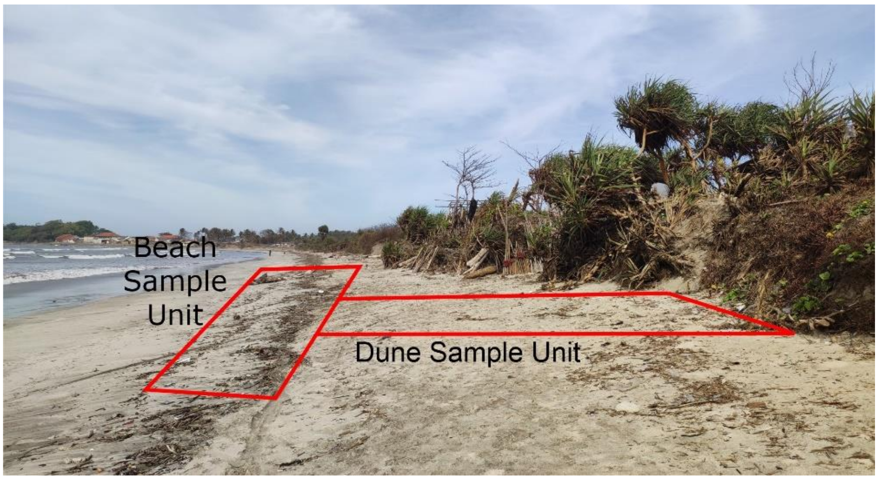

Figure 2. Sampling area.

Beach typology. The typology of beaches is determined through the bathing area registration and evaluation (BARE) scheme, which classifies beaches based on criteria such as facilities, accessibility, and environmental characteristics (Williams & Micallef 2009). This classification helps understand each coastline's specific needs for effective development, conservation, and management. Typologies like this are important to ensure that interventions are carried out in accordance with the unique characteristics of each beach, whether it is remote, rural, urban, or resort, thus maximizing economic and social benefits while minimizing environmental impact (Er-Ramy et al 2023). To determine the coast's typology, the study uses a modified version of the BARE scheme by Asensio-Montesinos et al (2019):

Remote. These places are usually difficult to reach and only accessible by boat or on foot. In Indonesia, where motorcycles are the predominant mode of transportation, some remote areas are accessible by motorcycle even though the roads are sloping and still grounded. The main characteristic of remote area is the absence of permanent residents. Remote beaches can be near rural or village areas, but not in urban areas.

Rural. Similar to a remote, but permanent residents live around it with a small population. The main feature is that there are no community centers or permanent facilities for the population there.

Village. The population has begun to grow, and there are small-scale facilities for the community, such as schools, worship centers, and traditional markets. Public transportation already exists in this area, but not as much in urban areas.

Urban. A region with a large population has established public services such as schools, banks, hospitals, terminals, and government offices, as well as commercial areas such as supermarkets, hotels, ports, and large industries.

Results and Discussion

Litter distribution. The dataset documented the different litter materials identified within the AoI (Table 3). The abundant litter on beaches includes various materials, such as plastic packaging, textiles, glass, and metal. Figure 3 shows the litter distribution in AoI, where plastic is the most prevalent material. Significant plastic litter was at Pamunguan Beach, totaling 279 items, while only 18 were reported at Karang Gantung Beach. The finding reflects a well-known phenomenon often explored in environmental research, highlighting the significant impact of plastic on ocean pollution.

Table 3

The different litter materials identified within the AoI

Code	*Beach*	*Typology*	*Litter type*					*Total litter*	*Sampling area (m²)*	*CCI index*	*Status*
			Plastic	*Rubber*	*Textiles*	*Glass*	*Metal*				
J	Karang Gantung	Remote	21	1	0	0	0	22	230	1.91	Very clean
A	Cipanarikan	Remote	46	0	0	3	7	56	388	2.89	Clean
E	Tenda Biru	Remote	51	1	0	1	2	55	222	4.95	Clean
M	Cimandala	Remote	34	0	0	0	2	36	226	3.19	Clean
F	Pasir Hideung	Remote	98	0	5	0	6	109	306	7.12	Moderate
I	Pamunguan	Remote	286	10	32	1	10	339	250	27.12	Very dirty
G	Karang Panganten	Rural	18	0	0	0	5	23	258	1.78	Very clean
B	Pangumbahan	Rural	29	1	1	1	1	33	364	1.81	Very clean
H	Taman Pandan	Rural	19	0	0	2	3	24	244	1.97	Very clean
L	Pasir Minajaya	Rural	126	4	11	3	7	151	352	8.58	Moderate
N	Cikaret	Rural	87	14	37	2	9	149	260	11.46	Dirty
C	Cibuaya	Village	50	1	0	0	3	54	224	4.82	Clean
D	Ujung Genteng	Village	42	2	0	0	4	48	262	3.66	Clean
K	Minajaya	Village	25	0	2	1	2	30	216	2.78	Clean
	Total litter types		932	34	88	14	61	-	-	-	-

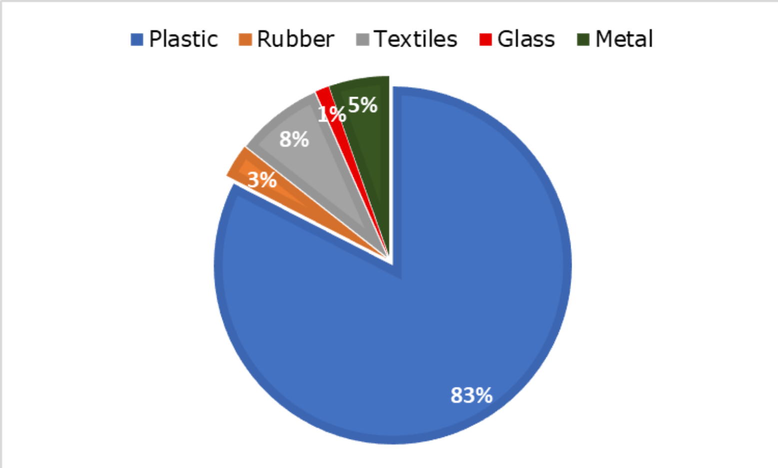

Figure 3. Beach litter distribution in AoI.

Based on observation, there was no significant disparity in litter presence among remote, rural, village and rural beaches. However, plastic is the most abundant litter, mainly comprising food packaging and other consumer products. The main reason for this issue is that plastic usage in daily human activities is continuously increasing; moreover, plastic requires a long time to degrade (Derraik 2002). This not only affects the aesthetics of the beach but also disrupts marine habitats, marine life, and human health, and can worsen when it decomposes into microplastics (Strafella et al 2019). It appeared that rubber, cloth, and textiles were less frequently found, which could indicate that beachgoers may not frequently discard these types of litter. However, even in small quantities, these materials potentially have a negative impact on the environment, especially given their potential to contain dangerous chemicals for organisms (Nowaczyk & Domka 1999; Kamble & Bahera 2021). Glass and metal, including drink cans, are observed in smaller amounts compared to plastic. This could be because glass and metal are recycled more often, or because products packaged with these materials are not very popular among beachgoers in the region.

All beaches within the AoI are classified as non-urban, with remote beaches being the prevailing type. Typically, remote beaches in the AoI are reachable by motorbike, bicycle, or foot and are primarily located far from residential areas. The cleanliness levels of remote beaches in this area vary, with a predominance of "clean" beaches. However, one beach stands out for its significantly dirty condition compared to others in the AoI. From a cleanliness perspective, these classifications of beaches are not always aligned with the amount of litter found. Despite rural beaches having fewer visitors and remote beaches having the fewest visitors due to limited accessibility by public transportation and a smaller local population, the amount of litter found can still vary. The rural beach category in AoI includes areas with few residents and beaches utilized for tourism and non-tourism activities, such as agriculture like those found in Cikaret. This is also because the abundance of litter on beaches is not solely due to beachgoers or other daily activities; wind and ocean currents can also cause and transport massive debris, surprisingly serving as the primary factors in depositing litter in some areas, including remote islands (Duhec et al 2015). For instance, Henderson Island is an uninhabited island so far away from human activities that there are barely significant local pollution sources; however, the presence of litter there undoubtedly comes from the global disposal and distribution of litter (Lavers & Bond 2017). The study by Lavers & Bond (2017) also emphasized the widespread use of plastic debris throughout the oceans, driven by society's growing demand for plastic goods. This implies that even remote and uninhabited islands, far from anthropogenic influence, can still be vulnerable to abundant litter.

The beach litter management table. Maintaining cleanliness in various beach environments, ranging from remote coastlines to urban areas, requires diverse strategies to address the unique challenges in each location. The high accumulation of plastic debris on beaches, particularly in dunes, indicates the necessity of more extensive interventions to restore beach cleanliness from "very dirty" to "very clean" status (Andriolo et al 2020). Cleanliness strategies for remote beaches should take into account the local natural and social conditions, infrastructure, and accessibility (Harwood 2010; Filer et al 2020). Meanwhile, coastal and rural villages require sustainable litter management through effective litter segregation, recycling, and processing facilities to support local and traditional economies (Ngoc & Schnitzer 2009).

Conversely, urban coastal remediation necessitates inventive solutions to confront the challenges of population density and activity, including enhanced infrastructure and litter treatment capacity (Morales et al 2018). The effective management of coastal litter requires the implementation of a robust sanitation and litter management infrastructure, as well as community empowerment programs and active participation in cleanup initiatives, as demonstrated by successful initiatives in a variety of coastal areas (Wyles et al 2017; Portman et al 2019). Additionally, environmental education and awareness are crucial for guaranteeing the sustainability of remediation initiatives (Chen & Teng 2016). Furthermore, these endeavors necessitate the implementation of robust regulations and innovative technologies (Zhang 2020; Cicceri et al 2023).

This study develops a decision-making table approach that combines the CCI and beach typology to effectively prioritize beach cleanliness strategies (Table 4). The table is initially referred to as the Beach Litter Management Table and is divided into four color categories: green, orange, yellow, and red. The extent of intervention required is denoted by each color, ranging from immediate restoration to conservation and prevention. Additionally, the actions that may be implemented are illustrated in Tables 5 and 6. The Beach Litter Management Table provides a structured decision-making method for managing and prioritizing beach cleanup efforts.

Table 4

The beach litter management table

Status	*Beach typology*			
	Remote	*Rural*	*Village*	*Urban*
Very clean				
Clean				
Moderate				
Dirty				
Very dirty				

Table 5

Actions based on cleanliness level

Level of cleanliness	*Actions*	
	Coastal clean up	*Reward*
Very clean	Intensive	More reward
Clean	↕	↕
Moderate		
Dirty		
Very dirty	More intensive	No reward

Table 6

Actions based on beach typology

Actions	Beach typology			
	Remote	*Rural*	*Village*	*Urban*
Conservation	Exclusive	←→	←→	Inclusive
Facilities	Basic	←→	←→	Advance
Supervision	More intensive	←→	←→	Intensive
Education	←	All stakeholder		→
Regulation	←	All condition		→

Green. The green color signifies initiatives to prevent and preserve coasts that are classified as "very clean" or "clean." This status underscores the importance of the coasts in protecting biodiversity and promoting economic value, including fisheries and tourism, as well as the well-being of coastal communities (Barbier et al 2011). To maintain "very clean" and "clean" status on the coast, a series of specific efforts need to be implemented, among others:

- an exclusive conservation approach for remote coasts, focusing on protecting specific areas or species. This approach will effectively restrain environmental damage such as deforestation and area pollution, which can ultimately prevent the extinction of certain species (Brooks et al 2009; Le Saout et al 2013);
- inclusive conservation for non-remote beaches integrates human activities as part of the solution to environmental conservation;
- development of coastal protection zones through preserving dunes and natural coastal boundaries (Kirshen et al 2023). Dunes play a crucial role as an ecological habitat and have high aesthetic value (Richardson & Nicholls 2021). The need for this maintenance is emphasized to combat rapid degradation due to human activity (Lithgow et al 2013);
- increase and renew basic facilities for litter management on remote and rural coasts and upgrade such facilities to village and urban coasts. Using attractive and innovative designs for garbage dumping can reduce the behavior of disposing of garbage unwittingly (Portman et al 2019);
- giving economic incentives or rewards to his community. Economic incentives for and communities to adopt sustainable practices can significantly contribute to conserving coastal and marine resources (Hao & Hill 2022).

Yellow. Yellow covers the status of "moderate", "dirty", and "very dirty" in urban areas. The status of "dirty" and "very dirty" indicates high levels of pollution and ecosystem damage, threatening marine life, public health, and local economies. The "moderate" condition also risks dropping to "dirty" if not handled properly. Therefore, intensive intervention and restoration are needed to correct this condition. Urban coasts face unique challenges associated with high population density, industrial pollution, and many visitors (Chen & Teng 2016). Solutions for urban coasts require a complex approach by combining technology, public policy, and community participation (Guardiola et al 2016). To address the environmental problems on the urban coast, several efforts can be made:

- conducting large-scale campaigns involving schools and the media to spread the message about the importance of beach cleanups and call the public to action. An example is the success of the California Coastal Commission's Public Education Program, which focuses on ocean conservation education through beach cleanups (California Coastal Commission 2019);
- cross-agency cooperation by strengthening cooperation amongst stakeholder groups to coordinate coastal sanitation and rehabilitation efforts. These efforts require effective collaborative cooperation (Wang & Gong 2022), such as collaboration between the Indonesian government and the private sector as well as community participation for the restoration of coastal ecosystems (Yamindago 2015);

- adopting advanced technologies for mass coastal litter treatment, for example, building smart cities to improve litter management efficiency (Zhang et al 2020) or the concept of recycling and bioconversion that supports a circular economy (Satchatippavarn et al 2016);
- sustainable mass tourism development on the coast through innovative marketing, local cultural integration, increased visitor awareness, and an emphasis on the blue economy (Li 2020; Shen 2020);
- zonation and restricting human activity to preserve marine biodiversity due to high human pressure on urban shores (Costa et al 2017).

Orange. The rural and village beaches offer authenticity and ease of access with standard accommodation as an alternative to urban beaches, which provides a different experience for beachgoers (Dodds & Holmes 2020). However, these coasts often face challenges arising from local economic pressures, such as fishing and tourism, as well as human interventions that negatively impact the ecological balance and biodiversity of coastal ecosystems (Amaral et al 2016). The orange color includes "moderate", "dirty" and "very dirty" on the typology of rural and village coasts, indicating that pollution has occurred that could lead to ecosystem degradation. Although developing rural-village coastal tourist destinations based on local potential is important for sustainable local economic development (Wijijayanti et al 2020), there is still a risk of rising litter on rural coasts and villages, especially during the holiday season. Besides, the community activity around it adds to the risk. Some efforts can be made on the rural coast and village, among others:
- rehabilitation programs for damaged areas include habitat restoration, coastal clean-up, and beach nourishment. Replanting coastal vegetation such as seaweed, seagrass, and mangrove effectively prevents abrasion (James et al 2019; Orth et al 2020). Beach nourishment efforts can contribute to the restoration of vegetation and invertebrate communities (Cooke et al 2020);
- community empowerment programs to increase awareness and participation in beach cleanliness, such as community-run recycling programs. In Indonesia, this initiative increases women's awareness in litter management through sustainable economic practices (Wulandari et al 2023). Empowering local communities to clean beaches can improve their perception of environmental conditions (Rayon-Viña et al 2019);
- environmentally friendly economic activities by avoiding major industrial activities on the coast. For example, agricultural practices are integrated with aquaculture, where the use of seagrass for nutrient absorption can improve the efficiency and sustainability of aquacultures while minimizing environmental impact (Chopin et al 2001). Another example is the transition to the services sector in coastal areas, which can reduce pollution and advance environmental protection technologies (Wu et al 2020);
- promote the development of ecotourism on the coast as a sustainable source of income. Protecting the rural-village coastal environment through ecosystem development is one solution to removing the urban-rural gaps in coastal areas (Fan 2020; Li 2020);
- upgrade the sanitation and litter management facilities to deal with the possibility of larger volumes.

Red. The red represents an immediate restoration action compared to other colors, due to the status of "moderate" to "very dirty" on the remote typology. Remote shores are often natural and conservation areas, so pollution and environmental damage must be avoided or repaired immediately. Research shows marine debris, mainly plastic, threatens wildlife conservation on Trindade Island, Brazil (Andrades et al 2018). In five national parks in Alaska, plastic garbage contributes to 60% of the total weight of debris affecting ecological and recreational impacts (Polasek et al 2017). Marine litter threatens biodiversity for at least 17% of species listed as endangered or near-threatened that are largely under conservation (Gall & Thompson 2015). Limitations in remote coastal areas are limited access and lack of infrastructure, which can complicate cleanliness interventions. Therefore, some efforts that can be made for this condition include:

- implement the cleaning of the coast immediately. Cleaning efforts help maintain the attractiveness of the coast (Ballance et al 2000). Organizing coastal cleaning and involving local communities is essential to designing targeted garbage prevention strategies (Lavers & Bond 2017);

- improved basic infrastructure to support sanitation activities, such as road access, sanitation, and litter disposal facilities. The development of sustainable transportation infrastructure is important for remote destinations, as traditional cost-benefit analysis often ignores environmental costs (Dimitriou & Sartzetaki 2016). An example from Greece shows that transporting litter by sea is more economical than building a final disposal site on any island (Zis et al 2013);

- self-management litter systems with local recycling approaches, for example, through biological and physiochemical methods to convert litter into a safe product or energy source without hazardous emissions (Jouhara et al 2017);

- more effective and strict surveillance of vulnerable areas of accumulated garbage by adapting conventional and innovative ways. For example, in Nowshahr, Iran, an effective system makes it easier for people to report marine debris, thus speeding up cleaning action (Fatehian et al 2018). An unmanned aerial vehicle (UAV) allows the identification and estimation of marine debris's spatial and temporal distribution through geo-reference images (Adade et al 2021). This technology is very useful for monitoring pollution in remote and protected areas (Merlino et al 2020);

- development of special interest tourism. Specialized tourism that focuses on alternative, educational, and environmentally responsible forms of tourism can play an important role in diversifying tourism options and promoting sustainability (Novotná et al 2019).

Beach litter management table implementation

Green. According to the CCI and beach typology, there are only three categories of coastal conditions in the AoI (Table 7). The green group is the most common, especially for the remote typology. Karang Gantung, Cipanarikan, Tenda Biru, and Cimandala are among the remote beaches with a very clean status. These four beaches are not very popular because they can only be reached by foot or motorcycle. The most urgent thing for these four areas is the provision of garbage dumps and information boards related to environmental campaigns. Beach information boards serve as an information tool and a key strategy for raising public awareness and involvement in the conservation and management of a responsible coastal environment (Klein & Dodds 2018; Latinopoulos et al 2018). At Tenda Biru Beach, which is in the protected forest area of Ujung Genteng, the application of exclusive conservation and the development of tourism of special interest can be an attempt to maintain this beach's "clean" status.

Table 7

Management classification in AoI (beach name is represented by code)

Level of cleanliness	*Beach typology*			
	Remote	*Rural*	*Village*	*Urban*
Very clean	J	G, B, H		
Clean	A, M, E		K, D, C	
Moderate	F	L		
Dirty		N		
Very dirty	I			

Other beaches in the green classification are Pangumbahan, Karang Panganten, Taman Pandan, Cibuaya, Ujung Genteng, and Minajaya. Figure 4 depicts the beach, which represents the typological conditions in the green categorization. The beaches belong to the rural and village typology, which has been developed as a tourist area by the local community and these beaches are regularly cleaned by the community. Efforts that can be made in this area are providing economic incentives, for example tax cuts or easy access to funding (de Lange & Dodds 2017; Turguttopbas 2019). Other examples of rewards include facilitating licensing, certification, or recognition, as well as marketing and promotional support (de Oliveira 2003; Bramwell & Lane 2010; Costa et al 2019).

Figure 4. Green classification: (a) Cipanarikan and (b) Tenda Biru as remote areas, (c) Cibuaya as a village, (d) Taman Pandan as a rural (original photos).

Orange. The beaches that belong to the orange classification are Pasir Minajaya and Cikaret, where both of these beaches have a rural typology and are not yet developed for tourist areas (Table 7). The status of "moderate" in Pasir Minajaya is possible due to the impact of local community activity, where settlements are very close to the coast, even on dunes (Figure 5). Given these conditions, the level of cleanliness in Pasir Minajaya is at risk of becoming dirty in the presence of occasional visitors to this area. Whereas in Cikaret there are seaweed cultivation ponds, the "dirty" status is most likely due to the activity (Figure 5). The necessary efforts on both shores are primarily focused on community empowerment programs, such as transforming the area into a tourist destination and a sustainable domestic industry. For example, in the Binh Dai district, Ben Tre province, and remote areas of the Mekong Delta in Vietnam, sustainable coastal tourism development promotes economic growth for stakeholders while paying attention to the livelihoods of local communities and environmental protection (He & Mai 2021; Lan & Thanh 2023). Other initiatives include improving litter management infrastructure, particularly seagrass litter. For instance, some alternative seagrash litter management techniques include turning it into biofertilizer (Seghetta et al 2016), using bacteria to break it down (Kim et al 2013), and using it as a bioremediator for shrimp pool litter (Syahrir 2024).

Figure 5. Orange classification: (a) settlement in the dune area, (b) coastal litter in the dune area on Minajaya, (c) seaweed cultivation pond in Cikaret, (d) seaweed cultivation pond waste (original photos).

Red. Pasir Hideung has a status of "medium", and Pamunguan is "very dirty" (Table 7), indicating that cleaners may not frequently visit remote beaches due to their hard-to-reach location. This may lead to garbage collection from visitors or other sources (such as ocean currents) without cleaning. The cove-shaped morphology of Pamunguan Beach (Figure 6) allows marine debris to be trapped inside the bay due to seawater circulation. Circulation within the bay contributes significantly to the distribution of plastic debris, indicating the influence of local hydrological patterns on debris accumulation (Manullang 2019; Goodman et al 2020). Furthermore, Duhec et al (2015) identified that ocean currents can carry debris from distant land sources to remote beaches.

The efforts that must be made on these two beaches are immediate beach cleaning and stricter routine checks for the presence of rubbish, considering that the "dirty" and "very dirty" status of these two beaches is caused more by physical than human factors. Although both of these beaches are not conservation areas, these litter accumulations are considered normal for the surrounding communities. There are many illegal litter transfer stations in developing countries with insufficient economic factors and infrastructure (Henry et al 2006). Besides, bad social habits such as disposing of and burning garbage openly cause environmental impacts (Ferronato & Torretta 2019). Another way to solve the red classification is to develop these two regions into sustainable tourist areas, especially for tourism of special interest. In addition, other efforts, as recommended, are similar to the color red.

Figure 6. Red classification: (a) coastal litter in Pasir Hideung, (b) coastal litter in Pasir Hideung, (c) the cove-shaped morphology of Pamunguan (original photos).

Conclusions. All beaches in AoI are classified as non-urban, with remote coasts predominating. In terms of cleanliness, the beaches in AoI are mostly in good condition, with most of them being "clean" or "very clean". Only one beach has been labeled "dirty" and another "very dirty", while the other two beaches are in "moderate" condition. Eighty five percent of the litter collected in AoI is composed of plastic, while the remaining comprises various materials such as rubber, textiles, glass, and metal. To overcome the garbage disposal problem effectively, the Beach Litter Management Table was created, combining cleanliness status and beach typology. The table is divided into four color classifications, each representing a specific recommendation for action to be taken.

From the classification results of the Beach Litter Management Table, three coast classifications are identified in the AoI, with the green classification dominating. For the classification of the green on the remote coast typology, there are Karang Gantung, Cipanarikan, Tenda Biru, and Cimandala, which stand out for their cleanliness but have limited access. On these shores, the urgent effort is the provision of garbage disposal facilities and information boards. Beaches in other green classifications, which are included in rural and village typologies, namely Pangumbahan, Karang Panganten, Taman Pandan, Cibuaya, Ujung Genteng, and Pasir Minajaya, show community initiatives in maintenance and potential for sustainable tourism development so that the recommended effort is an economic incentive. Meanwhile, beaches with orange classifications, among others Pasir Minajaya and Cikaret, face specific cleanness and litter management challenges, which require the empowerment of communities and innovative litter management.

On the other hand, red-classification beaches, Pasir Hideung and Pamunguan require immediate cleaning measures and stricter litter management to prevent adverse environmental impacts. The Beach Litter Management Table offers a practical and effective solution by customizing coastal management strategies according to diverse beach typologies, ensuring targeted and efficient interventions that address specific challenges unique to each type of beach. With the clean coast index integration, the table provides a detailed overview of setting measured cleanness targets. The color code system facilitates the identification of actions required, from conservation to restoration. Illustrative examples of communities actively participating in coastal cleanup initiatives and sustainability efforts highlight the significant positive impact of community involvement in maintaining coastal cleanliness and long-term sustainability.

The table also suggested a variety of measures, including infrastructure development, technological innovation, and educational campaigns, to address coastal pollution. The complexity of implementing strategies that require substantial resources, including funds, labor, and technology, may prove challenging to acquire in less developed regions, which is the primary weakness of the Beach Litter Management Table. Sustained monitoring and enforcement are essential for its efficacy, but they can be complex to implement in remote or difficult-to-access regions. Furthermore, the success of the table is contingent upon the local community's participation and compliance, as their resistance or unattractiveness may obstruct this initiative.

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Authors:
Ankiq Taofiqurohman, Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: ankiq@unpad.ac.id
Mochamad Rudyansyah Ismail, Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: m.rudyansyah@unpad.ac.id
Mochamad Untung Kurnia Agung, Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: Mochamad.Untung@unpad.ac.id
Sheila Zallesa, Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: sheila.zallesa @unpad.ac.id
Shafira Bilqis Annida, Vocational Marine Tourism, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: shafira.bilqis@unpad.ac.id
Putri Wibawanti, Research Center for Climate Studies and Maritime Area Management, Universitas Padjadjaran, Universitas Padjadjaran, Bandung-Sumedang Highway, km 21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumedang, Jawa Barat 45363, Indonesia, e-mail: putriwibawanti3004@gmail.com

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