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Analysis of the Relationship Between the Abundance of Marine Debris and the Number of Visitors at Three Tourist Beaches in Malang Regency, East Java

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Abstract: Marine debris refers to items that are no longer in use and are either deliberately or unintentionally left in marine areas by humans. Beaches, which serve as the boundary between land and sea, are areas vulnerable to pollution by marine debris. High visitor activities in beach areas can affect the abundance of marine debris in those areas. This study examined the composition and abundance of marine debris at three tourist beaches in Malang Regency, East Java, and its correlation with visitor numbers. Sampling was divided into two times intervals according to school holidays: high season (June-July) and low season (August). The marine debris collected was macro marine debris, which was collected from quadrat transect measuring 5x5 m, spaced 20 m apart. Number of visitors from each sampling beach were collected from the counter staff at each beach on the day before the marine waste samples were taken. The results of this study showed that plastic waste was the dominant type of marine debris with a value greater than 70%. The average abundance of marine debris on low season was 1.5 ± 0.3 items/m^2 and during the high season was 2.5 ± 0.2 items/m^2, while the weight abundance recorded was 2.3 ± 0.5 grams/m^2 on low season and 5.6 ± 1.8 grams/m^2 during the high season. There is a strong and positive correlation between marine debris abundance and the number of visitors (R^2 = 0.901). The results of this study emphasized the importance of waste management, particularly during the high season.

Keywords: Coastal Environment, Marine litter, Plastic Waste, Pollution, Tourism

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Introduction

As an archipelagic country, Indonesia has possessed vast natural resource potential due to its rich marine biodiversity. Nevertheless, the quality of Indonesia's marine environment has been progressively declining as a consequence of various anthropogenic activities that contribute to environmental pollution (Adyasari et al., 2021). One of the threats to the marine environment is marine debris (Azharil & Paskah, 2023). Marine debris can be defined as the remains of materials or items that are no longer in use and are either deliberately or unintentionally left in marine areas by humans (GESAMP, 2015). Marine debris can originate from land-based activities, carried by river flows, or directly discarded into the ocean (Tuahatu et al., 2022). Indonesia is the second-ranked country with the largest amount of marine pollution after China, followed by the Philippines, Vietnam and Sri Lanka (Jambeck et al., 2015). The accumulation of marine debris is a global threat that continues to rise (Mghili et al., 2020). In addition to diminishing the visual appeal of coastal environments, marine debris can negatively impact marine ecosystems, harm coral reefs, and potentially contaminate the food chain (Arifianti et al., 2024).

Marine litter pollution in coastal areas is a widespread issue (Sari et al., 2020). Beaches that serve as a transition zone between the ocean and land, have a high level of tourism activity, which greatly influences the presence of marine debris in the area (Akbar & Pratiwi, 2023; Yona et al., 2024). It is generally caused by tourists disposing of waste improperly (Toruan et al., 2021). The number of visitors affects the abundance of marine debris on tourist beaches (Suteja et al., 2021). Tourist visits tends to be higher during high season or holiday periods compared to low season or regular days (Wati & Sudarti, 2022). The high season refers to periods with increased visitors activity, while the low season is characterized by a lower number of visitors compared to holiday periods (Dikara et al., 2022). High visitors activity, when not properly managed, have the potential to degrade coastal ecosystems and contribute to elevated levels of marine debris pollution during the high season (Garcés-Ordóñez et al., 2020). The difference in visit frequency between these periods may lead to variations in the abundance of marine debris during the high and low seasons.

A study conducted at Digha Beach, India, found that the average amount of marine debris reached 12 tons of solid waste per day, while during peak holiday seasons, it could increase to 17 tons per day, with the majority consisting of bottles, Styrofoam cups, tote bags, and food wrappers (Mugilarasan et al., 2021). According to research at Ujong Blang Beach, Lhokseumawe, the high number of visitors on Sundays, which is a holiday, is one of the factors contributing to the increased abundance of marine debris (Andika et al., 2023). This finding is also supported by Satriawan et al., (2024) in their study at Pangandaran Beach, where plastic waste dominated the marine debris composition, with the highest percentage occurring on holidays. Therefore, further research is needed to better understand the connection between visitor numbers and marine debris abundance.

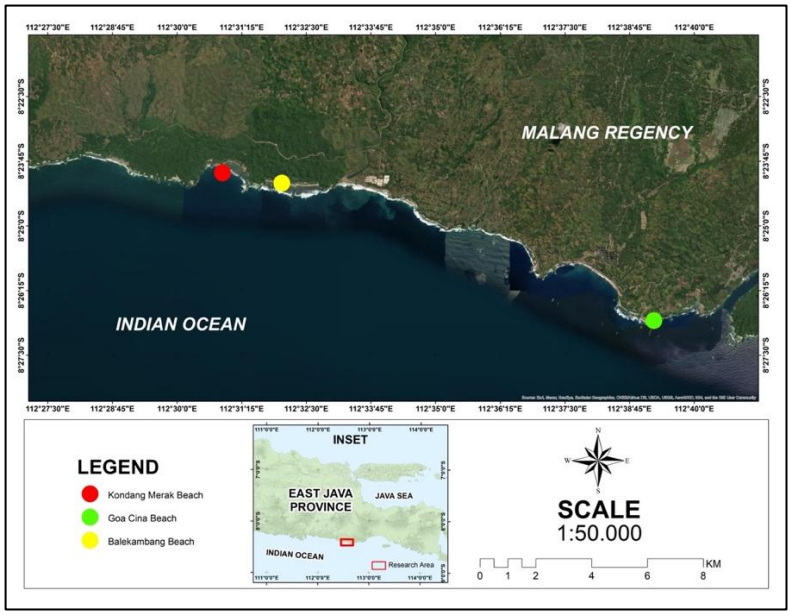
Malang Regency is known as the "Land of a Thousand Beaches" due to its numerous coastal attractions, with a shoreline stretching 102.5 km (Putri & Amalia, 2020). Some of the most popular tourist beaches in South Malang, especially during holidays, include Balekambang Beach, Kondang Merak Beach, and Goa Cina Beach (Yona et al., 2023). The selection of these three locations considers human activities, development, and the geographical characteristics of the beaches. The three beaches have different characteristics in terms of human activity, development, and geography. Balekambang Beach is a highly touristic beach with high visitor volume, where visitors constituting the majority of its visitors. Various tourism infrastructures are presents, including resorts and souvenir shops. Kondang Merak Beach is a village beach, identified by its association with small settlements.

Goa Cina Beach located outside urban and village areas, typically marked by limited public transportation access.

While tourism provides economic benefits, increasing visitor numbers may also contribute to marine debris accumulation on coastal beaches. Previous studies in Indonesia have primarily focused on the composition, sources, and spatial-temporal distribution of marine debris (e.g, (Toruan et al., 2021; Yona et al., 2023, 2024). However, studies examining the relationship between visitor numbers and marine debris abundance, particularly on the southern coast of Malang, remain limited. Therefore, this study addresses this gap by analyzing the composition and abundance of marine debris and examining their relationship with visitor numbers across three tourist beaches in Malang Regency, East Java.

Research Methods

This research was conducted at Balekambang Beach, Kondang Merak Beach, and Goa Cina Beach in Malang Regency as shown in Figure 1. The sampling locations were selected using the purposive sampling method, considering the influence of anthropogenic activities, development, and the geographical characteristics of the beaches. the study sites were classified using the Bath Registration and Evaluation (BARE) classification based on the level of urbanization, accessibility (Asensio-Montesinos et al., 2020) . Balekambang Beach is categorized as a rural beach with high tourism intensity, where the majority of beach users are visitors. Kondangmerak Beach is classified as a village beach, where in addition to visitor activities, local settlements also contribute to human presence along the shoreline. Goa Cina Beach, also categorized as a rural beach, is situated outside urban and densely populated village areas and is characterized by relatively lower visitor frequency compared to the other two sites. All three beaches are well-known tourist destinations in Malang Regency.



Source: Author's Analysis, 2025

Figure 1. Study Location

Field sampling was conducted during two tourism activity periods: the high season (starting 26 June, corresponding to the school holiday period) and the low season (starting 14 August, after the school holiday period). Sampling was repeated three times within each season at each beach, resulting in repeated temporal observations across sites. For

statistical analysis, the dataset was aggregated at the sampling session level, resulting in 18 observations (3 beaches × 2 seasons × 3 repeated sessions). The marine debris data focuses on macro debris, which was classified into three size categories: small (2.5–5 cm), medium (5–10 cm), and large (10 cm–1 m). The method for collecting marine debris data was based on a modification of the Marine Debris Monitoring Guidelines issued by Kementerian Lingkungan Hidup dan Kehutanan (KLHK, 2020). Marine debris data collection was conducted before any beach cleaning activities took place.

The marine debris data were collected by placing a transect line parallel to the shoreline in the backshore area. The backshore zone was chosen as the sampling location because this study aimed to evaluate the abundance of marine debris related to visitor activities. This zone is the area most frequently used by visitors for various recreational activities, such as relaxing, camping, picnicking, and other visitor activities, making it a potential primary site for the deposition of debris directly derived from human activities. Furthermore, debris accumulated in the backshore zone tends to be more stable and less subject to intense movement due to wave and tidal dynamics compared to the foreshore zone or the intertidal zone. Therefore, the debris found in the backshore zone is more representative of the contribution of visitor activity to coastal debris accumulation.

A total of 168 transect-based quadrat samples were collected across all study sites. At Balekambang Beach, 12 quadrat transects were established, while 8 quadrat transects were used at Kondang Merak Beach and 8 quadrat transects at Goa Cina Beach. The number of transects at each beach was adjusted according to beach length to ensure representative spatial coverage. This transects line then divided into several lanes, each with an interval of 20 m. In each lane, a 5x5 m quadrat transect was randomly placed. The marine debris within the quadrat transects was collected and identified based on type and size. The percentage composition of marine debris was measured by determining the percentage of each type of debris relative to the total amount of debris. The abundance of marine debris was calculated by determining the number of debris collected for each type per unit area of the quadrat transect.

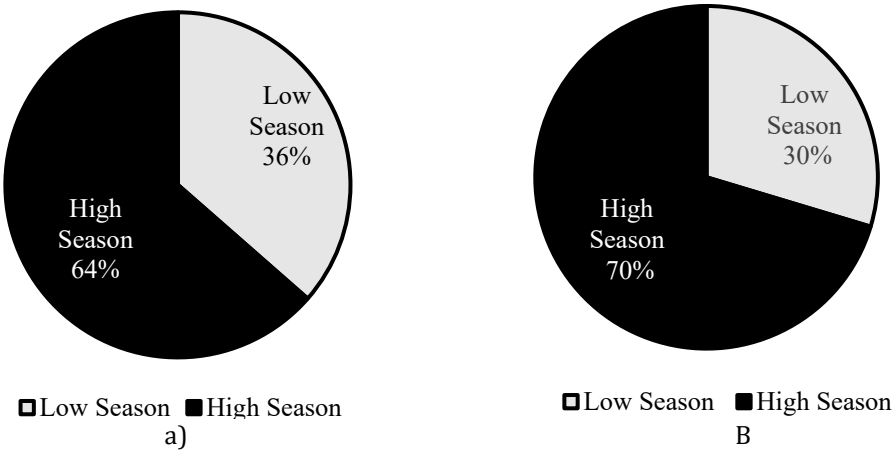
The number of visitors data were obtained from official ticket counter records managed by beach authorities at each study site preceding marine debris sampling. It was assumed that the collected debris originated from visitors present on the previous day. The recording system is standardized across all three beaches, where visitor numbers are recorded daily based on ticket sales. These data were aggregated to match the field sampling periods. Each sampling session represents a summary of multiple quadrat measurements within transects, and both marine debris abundance and visitor numbers were recorded for each sampling session. Statistical analysis in this study was conducted using IBM SPSS software. The number of visitors and marine debris data were then analyzed using a simple linear regression test to determine the relationship between these two variables. Simple linear regression was chosen because it is capable of explaining the effect of the independent variable on the dependent variable.

Results

Marine Debris Composition

The composition of marine debris includes total composition, plastic and non-plastic composition, composition based on material type, and size composition. The total composition of marine debris was divided into the total quantity composition of marine debris (Figure 2a) and the total weight composition of marine debris (Figure 2b). In general, the total quantity of marine debris collected was higher during the high season compared to the low season. The total number of marine debris items collected across the three

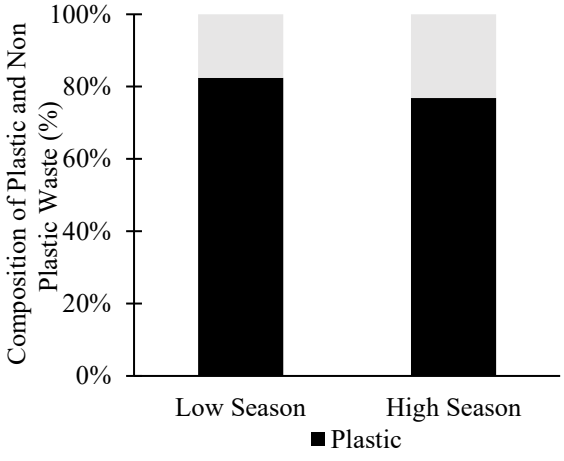
research sites reached 8,946 items. Of this total, 64% (5,685 items) were recorded during the high season, while the remaining 36% (3,261 items) were found during the low season. Similarly, the total weight of marine debris collected from the three locations amounted to 17,488 grams (17.5 kg). A significant proportion of this, approximately 70% (12,303 grams), was recorded during the high season, whereas the remaining 30% (5,185 grams) was collected during the low season.

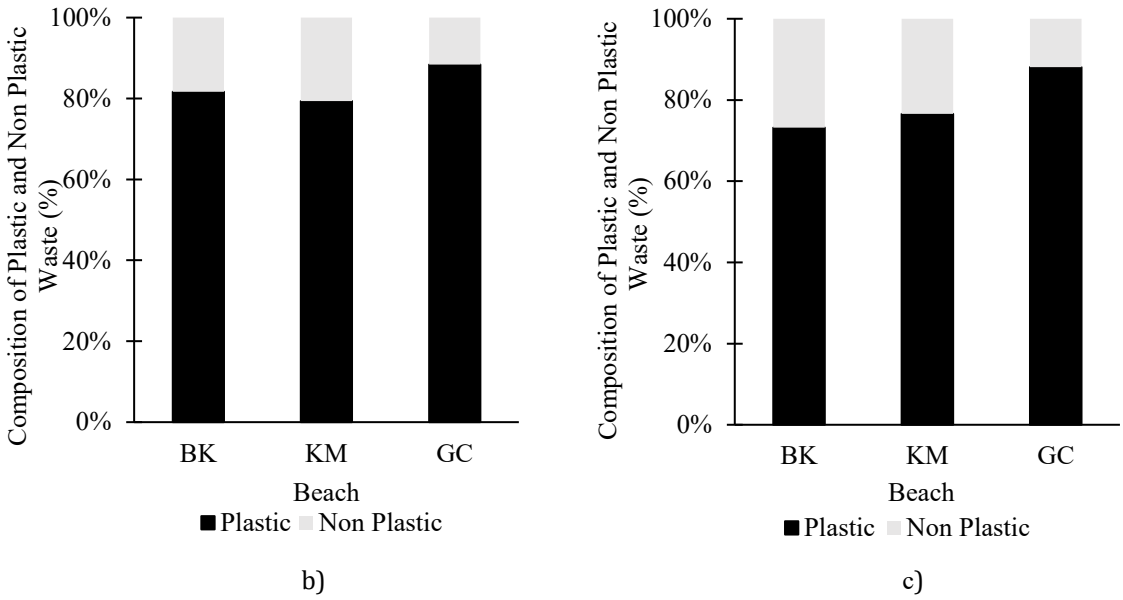


Source: Author's Analysis, 2025

Figure 2. Percentage of Marine Debris Composition at Three Tourist Beaches in Malang Regency: a) Marine Debris Quantity; b) Marine Debris Weight

The collected marine debris was classified into two broad categories: plastic waste and non-plastic waste. Plastic waste encompasses all debris primarily composed of plastic materials. This category includes various commonly discarded items such as plastic bottles, bottle caps, cigarette butts, ropes, different types of plastic packaging, Styrofoam fragments, and plastic bags. On the other hand, non-plastic waste consists of debris made from materials other than plastic. This category includes paper-based waste, wooden debris, rubber materials, textile fragments, metal objects, glass shards, ceramic pieces, and hazardous or toxic materials. The overall composition of plastic and non-plastic waste collected during the study at Balekambang (BK), Kondangmerak (KM), and Goa Cina (GC) is illustrated in Figure 3a. Specifically, the composition of plastic and non-plastic waste found at each surveyed beach during the low season is shown in Figure 3b, and the composition of plastic and non-plastic waste at each beach during the high season is shown in Figure 3c.



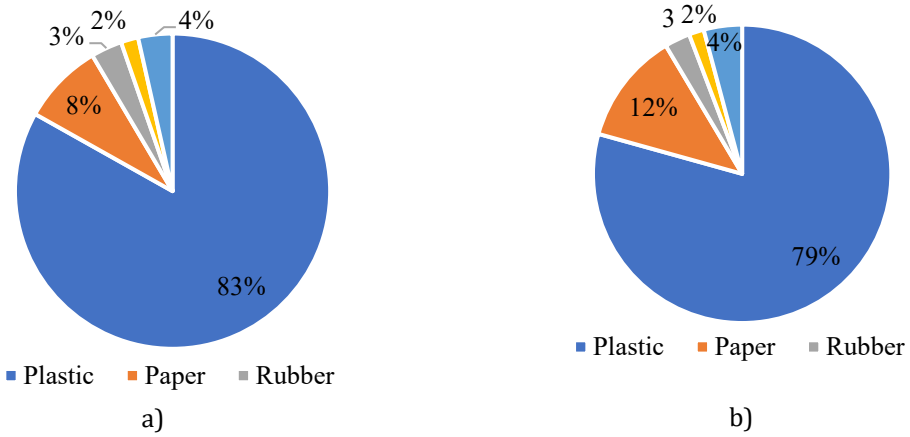


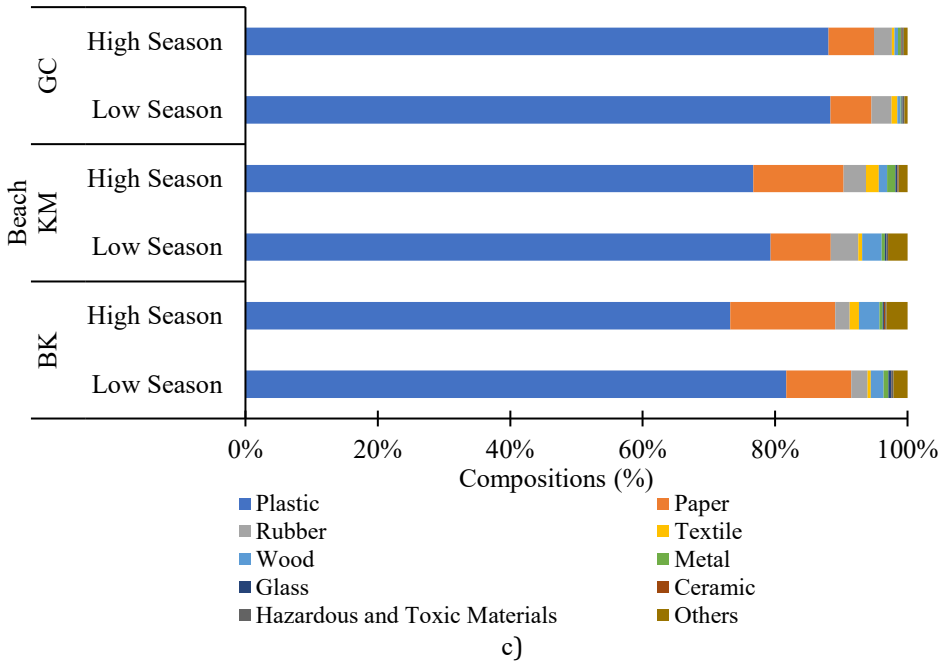
Source: Author's Analysis, 2025

Figure 3. a) Composition of Plastic and Non-Plastic Waste; b) Percentage at Each Beach during Low Season; and c) High Season at Balekambang (BK), Kondangmerak (KM), Goa Cina (GC)

Overall, plastic waste was found to be the dominant category compared to non-plastic waste. During the low season, plastic waste accounted for 82% (2,688 items), while non-plastic waste contributed only 18% (573 items). A similar pattern was observed during the high season, where plastic waste comprised 77% (4,368 items) of the total marine debris, whereas non-plastic waste made up 23% (1,317 items). Data analysis of marine debris at each beach indicates that all beaches were dominated by plastic waste compared to non-plastic waste, with plastic waste dominance exceeding 70% at each location, both on low season and high season.

The marine debris samples were classified into several categories based on their material composition. These categories included plastic, paper, rubber, textiles, wood, metal, glass, ceramics, hazardous and toxic materials, and others. The overall composition of marine debris based on material type during the low season is illustrated in Figure 4a, whereas the composition during the high season is depicted in Figure 4b. Furthermore, Figure 4c presents the marine debris composition by material for each beach surveyed.



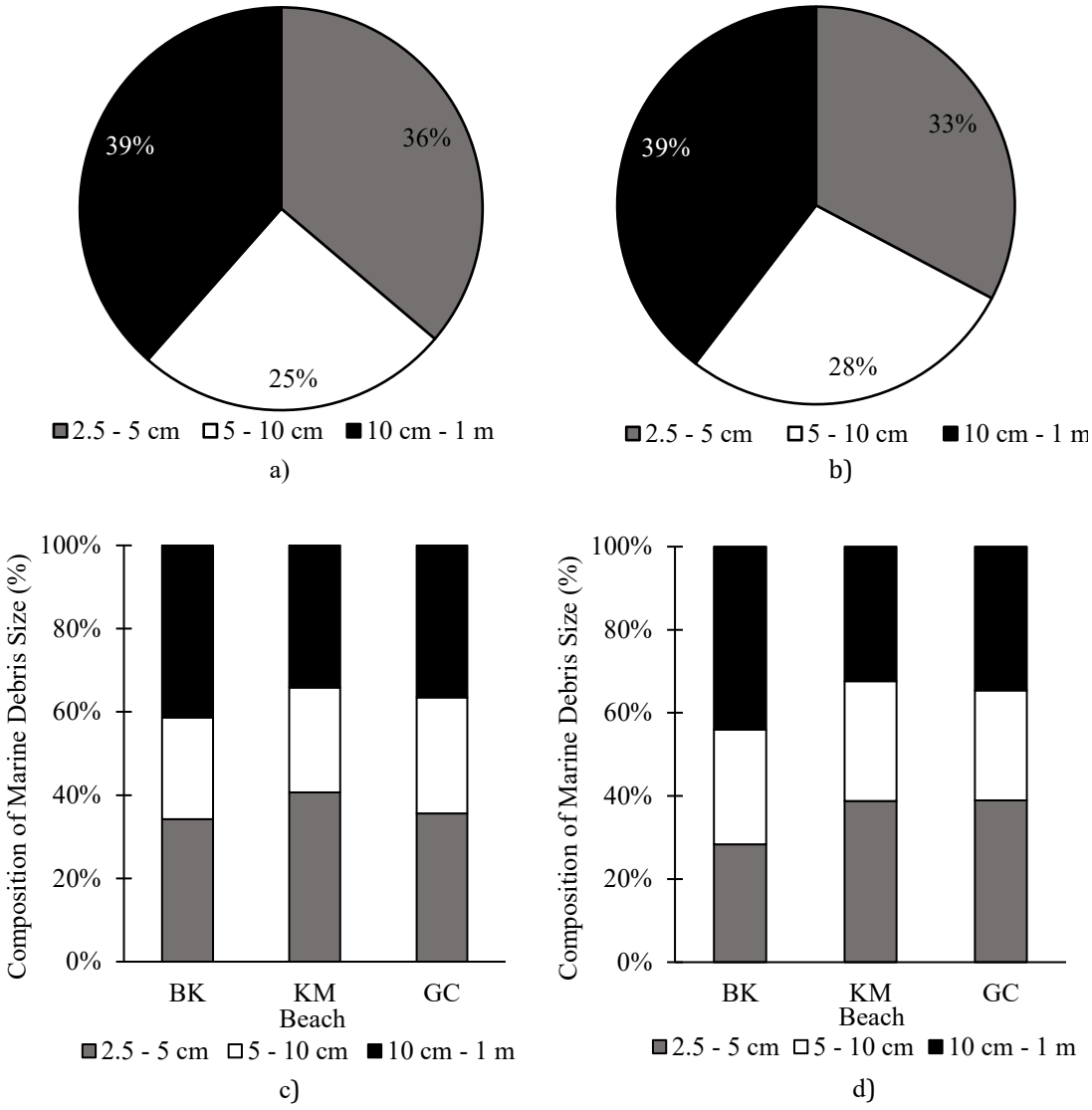


Source: Author's Analysis, 2025

Figure 4. Composition of Marine Debris Based on Material at Three Tourist Beaches in Malang Regency: a) Low Season; b) High Season; c) Composition at Each Beach

The total composition of marine waste based on its materials on low season showed that the most dominant waste category was plastic waste (83%), followed by paper (8%), others (4%), rubber (3%), and wood (2%). A similar thing also happens during the high season, with the most dominant waste category being plastic waste (79%), followed by paper (12%), others (4%), rubber (3%), and wood (2%). Another category of waste is the marine debris category, which has a percentage below 2%, including textiles, metal, glass, ceramics, and hazardous and toxic materials. The results of data processing on the three beaches, both on low season and in the high season, show that the waste found is dominated by plastic waste, followed by paper waste.

The marine debris taken was divided into three sizes, including small size (2.5-5 cm), medium size (5-10 cm), and large size (10-100 cm). Overall composition of marine debris by size during low season is presented in Figure 5a, while in high season is shown in Figure 5b. The composition of marine debris by size at each beach during the low season is presented in the Figure 5c, while during the high season is presented in the Figure 5d.



Source: Author's Analysis, 2025

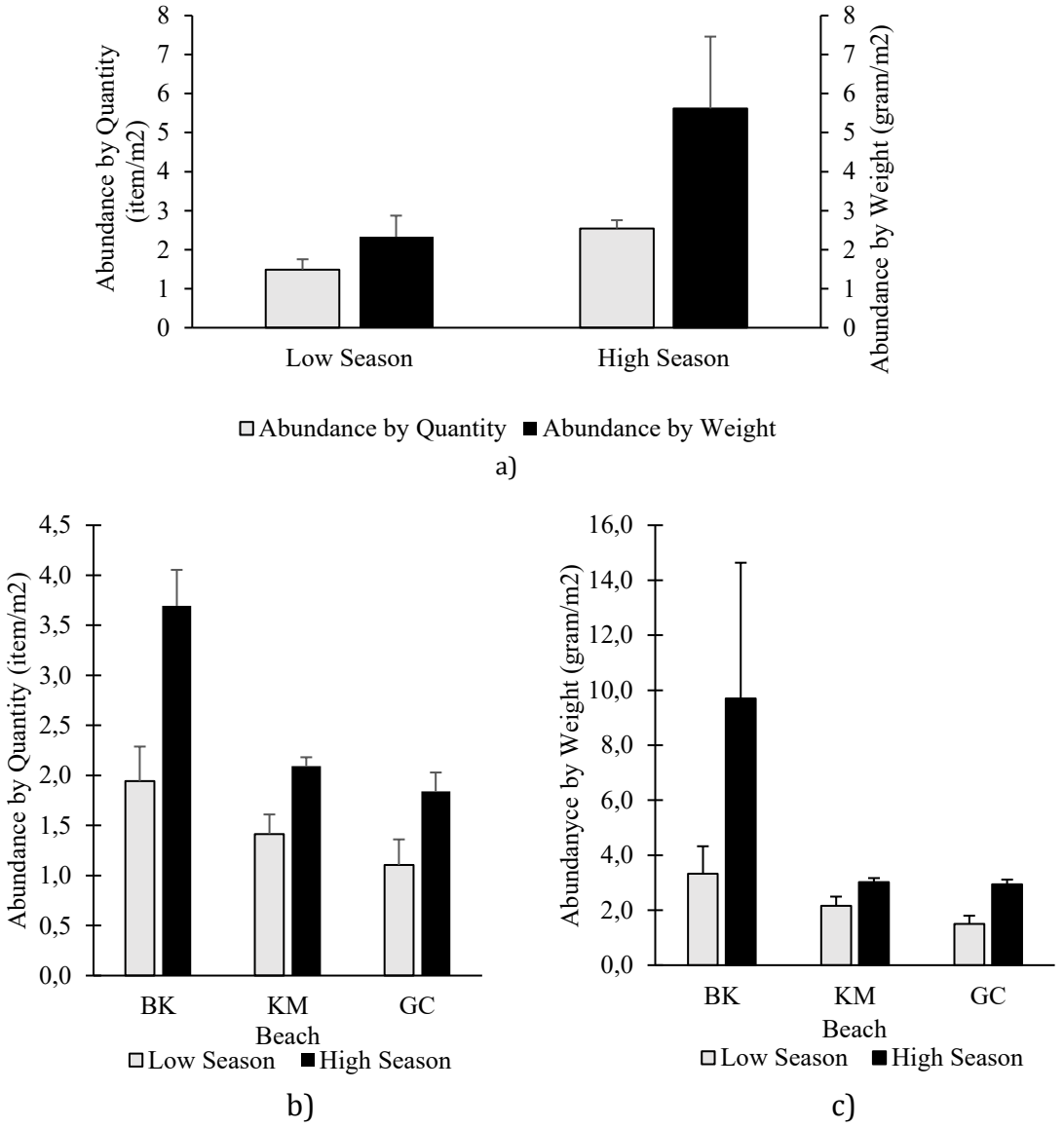
Figure 5. Composition of Marine Debris by Size at Three Tourist Beaches in Malang Regency: a) Low Season; b) High Season; Percentage at Each Beach During the: c) Low Season; and d) High Season

The composition of marine debris sizes tended to be evenly distributed, both during the low season and the high season. During the low season, large-sized debris accounted for 39%, while small-sized debris comprised 36%, followed by medium-sized debris at 25%. A similar pattern was observed during the high season, with large and small-sized debris making up 39% and 33%, respectively, while medium-sized debris accounted for 28%. The composition of marine debris sizes at each beach followed the same trend in both the low season and the high season, showing a relatively even distribution across all size categories.

Marine Debris Abundance

The abundance of marine debris is categorized into two types: abundance based on quantity and abundance based on weight. The overall graph depicting marine debris

abundance is presented in Figure 6a. The average abundance of marine debris quantity at each beach is illustrated in Figure 6b, while the average abundance of marine debris weight at each beach is shown in Figure 6c.



Source: Author's Analysis, 2025

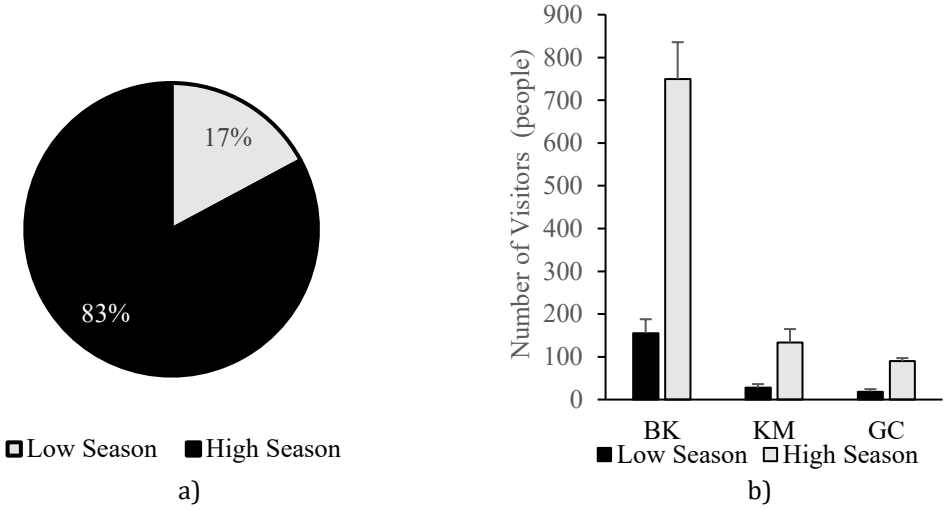
Figure 6. Marine Debris Abundance at Three Tourist Beaches in Malang Regency: a) Overall Abundance; b) Abundance by Quantity at Each Beach; c) Abundance by Weight at Each Beach

In general, the abundance of marine debris, both in terms of quantity and weight, was higher during the high season. The average abundance of marine debris quantity across all three beaches during the low season was recorded at 1.5 ± 0.3 items/m^2, which increased to 2.5 ± 0.2 items/m^2 during the high season. Similarly, the average abundance of marine debris weight across all three beaches followed the same trend, with 2.3 ± 0.5 grams/m^2 recorded in the low season and 5.6 ± 1.8 grams/m^2 in the high season. At three study sites,

marine debris accumulation was higher during the high season compared to the low season, both in terms of quantity and weight. Balekambang Beach recorded the highest abundance of marine debris in both quantity and weight among the three study sites, followed by Kondangmerak Beach, while Goa Cina Beach showed the lowest accumulation. This pattern was consistent across both seasons.

Number of Visitors

The number of visitors was recorded one day prior to marine debris sampling. It was assumed that the marine debris collected at each site was generated by visitors from the previous day. The visitor data were then analyzed together with the marine debris data to examine the relationship between visitor numbers and marine debris accumulation. The total number of beach visitors at the three study sites varied significantly between the low and high seasons. During the low season, the total number of visitors was recorded at 603 people, whereas during the high season, this number surged to 2,918 people, reflecting a substantial increase in visitors activity. The percentage of visitors during both seasons is illustrated in Figure 7a, providing a comparative overview of the percentage of total visitors. Additionally, the variation in the average number of visitors across the three beaches is depicted in Figure 7b, offering further insight into the differences in visitor trends at each location.



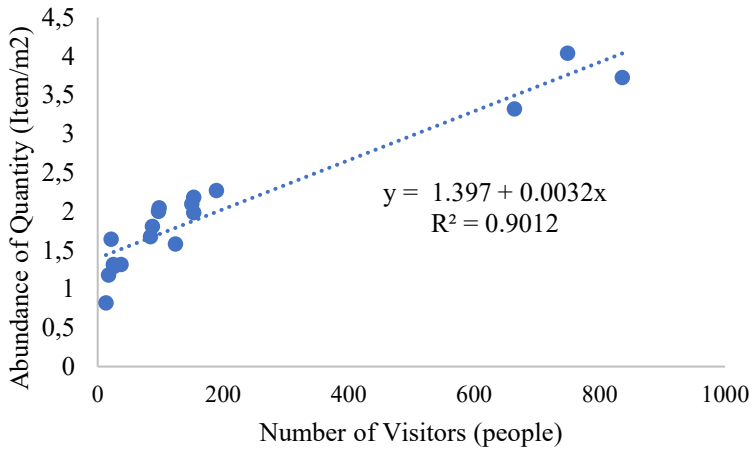
Source: Author's Analysis, 2025

Figure 7. Tourist Visits at Three Tourist Beaches in Malang Regency During Low Season and High Season: a) Overall Percentage; b) Averages Number of Visitors at Each Beach

Tourist visits were significantly higher during the high season compared to the low season, with 83% of total visits occurring during the high season and only 17% during the low season. A similar pattern was observed for each beach category, where visits were consistently higher during the high season at each location. Based on data, among the three beaches surveyed, Balekambang Beach recorded the highest number of visitors, making it the most popular destination. Kondangmerak Beach ranked second in visitor numbers, while Goa Cina Beach had the lowest visitor turnout. The higher influx of visitors during the

high season can have direct implications for environmental conditions, including increased waste generation and pressure on coastal ecosystems.

Relationship Between Marine Debris Abundance and Number of Visitors



Source: Author's Analysis, 2025

Figure 8. Relationship Between Marine Debris Abundance and Number of Visitors at Three Tourist Beaches in Malang Regency

The linear regression analysis between tourist numbers and marine debris abundance produced the equation y = 1.397 + 0.0032x. This indicates a positive relationship between the two variables, where an increase in visitor numbers is associated with an increase in marine debris abundance. The model yielded a coefficient of determination (R^2) of 0.901, based on 18 observations (n = 18). Given the relatively small dataset, the interpretation of R^2 should be considered with caution. Overall, the results indicate a strong association between visitor numbers and marine debris abundance, whereby higher tourist visitation tends to correspond with higher levels of marine debris.

Discussion

The higher composition of marine debris during the high season (Figure 2) is attributed to the increased number of visitors during this period. This finding aligns with previous research conducted at Santa Maria Beach, Colombia, which reported a higher abundance of marine debris during holiday seasons (Garcés-Ordóñez et al., 2020). A surge in tourist numbers can lead to an increase in marine debris (Panwanitdumrong & Chen, 2022). The rise in marine debris volume also contributes to an increase in debris weight during the high season. Additionally, variations in waste composition, such as the presence of organic waste generated during the high season, further contribute to the increase in waste weight (Enggara et al., 2019). The presence of marine debris is primarily caused by visitors behavior, where waste is either intentionally or unintentionally disposed of improperly, rather than in designated disposal areas (Toruan et al., 2021).

The composition of plastic waste is generally higher than non-plastic waste during both the low season and high season (Figure 3a). In all three study areas (Figure 3b, Figure 3c), plastic waste remains the dominant type of debris regardless of the season. Plastic materials are widely used by visitors due to their practicality and durability (De Ramos et al., 2021). This finding aligns with previous research conducted on several beaches in the

southern region of Java, which also reported plastic waste as the most dominant type of marine debris (Yona et al., 2023). Plastic waste undeniably remains the most dominant type of marine debris globally (Sari et al., 2024). Plastic waste has become a persistent issue in Indonesia due to improper disposal habits. It often enters marine environments as a result of poor waste management, both from land-based and ocean-based sources (Lestari & Trihadiningrum, 2019).

Based on its material composition, the overall pattern of marine debris remains consistent across both time periods, whether on low season (Figure 4b) or during the high season (Figure 4c). Marine debris is predominantly composed of plastic waste, a trend that is also observed at each beach, both on low season and during the high season. Across all locations, plastic waste is the most dominant category, followed by paper waste. This prevalence is largely due to the widespread use of single-use plastics and the high consumption of plastic-based products (Yona et al., 2023). Plastic waste constitutes a major portion of the debris generated by anthropogenic activities (Firdausi et al., 2024). Interestingly, plastic waste composition is higher on low season compared to the high season. This can be attributed to the increased tourism and commercial activities during high seasons, which lead to a greater variety of waste types (Putri et al., 2024). During peak visitor periods, tourism-related activities contribute not only plastic items but also paper-based food packaging, tissues, clothing, metal cans, and glass bottles. Therefore, increases in visitor numbers may lead to a more diverse waste stream, causing the relative proportion of plastics to decrease despite continued increases in plastic abundance. Among the three beaches, Balekambang Beach generates the highest amount of paper waste especially during the high season. This is attributed to Balekambang Beach being the most popular beach among the three study sites, attracting a larger number of visitors, which results in a more diverse composition of waste, including paper waste which commonly found at tourist beaches. The most commonly found paper waste in the study areas includes tissues and rice wrappers.

The overall distribution of marine debris sizes tends to be relatively even across all three size categories, both on low season (Figure 5a) and during the high season (Figure 5b. This is due to the relatively consistent input of marine debris across both sampling periods, particularly from tourism-related activities. The most frequently observed waste, mainly food-related packaging, is generated in a wide range of sizes, which contributes to a relatively balanced distribution of debris size classes. In addition, both large and small sized debris were continuously introduced during the study periods, including plastic packaging, food containers, wrappers, utensils, and non-degraded tissues, resulting in no clear dominance of any specific size category between the two periods. Medium-sized debris commonly found in the study areas consists of food packaging and torn tissue fragments. Meanwhile, small-sized debris includes cigarette butts, candy wrappers, bottle caps, and pieces of plastic packaging. Furthermore, small debris can accumulate within coastal vegetation, where it becomes trapped and remains undetected during beach cleaning processes (Cozzolino et al., 2020). This entrapment contributes to the persistence of small plastic waste in vegetated areas along the coastline.

The abundance of marine debris, both in terms of quantity (Figure 6a) and weight (Figure 6b), was found to be higher during the high season. The increased tourism activities at the coastal tourist destinations in Malang Regency during high season have led to a rise in marine debris accumulation. Beach tourism activities are predominantly conducted during holidays (Wati & Sudarti, 2022), resulting a significant increase in waste volume within tourist areas, aligning with the surge in visitor numbers (Tassakka et al., 2019). Consequently, are considerably higher during the high season compared to the low season, leading to increased marine debris accumulation. Among all the three study sites,

Balekambang Beach being the most popular destination, receives the highest number of visitors, particularly during the high season. The large influx of visitors contributes to a significant increase in marine debris accumulation compared to the other two beaches, Kondangmerak and Goa Cina.

The three study beaches, classified under the BARE framework (Asensio-Montesinos et al., 2020). Balekambang Beach, classified as a rural beach with the highest tourism intensity among the three sites, recorded the greatest abundance of marine debris, particularly during the high season. This beach has the most adequate tourist facilities with the availability of resorts and shops as well as a temple which is the icon of the beach, making it the beach with the most visitors compared to the other two beaches. The large influx of visitors to Balekambang contributes to a significant increase in marine debris accumulation compared to the other two beaches. Kondangmerak Beach, classified as a village beach, exhibited a different debris dynamic. In addition to tourist-generated waste, the presence of local settlements along the shoreline introduces a domestic waste component that persists regardless of seasonal tourism fluctuations. This suggests that debris accumulation at village beaches may be driven by a combination of tourism pressure and everyday household activities, making waste management more complex compared to purely tourist-oriented sites. Goa Cina Beach, also classified as a rural beach but with comparatively lower visitor frequency, generally recorded lower marine debris abundance. However, it does not entirely insulate it from debris inputs, as marine-transported litter and occasional visitor waste were still observed.

This highlights that even low-traffic beaches are not immune to marine debris pollution, and that oceanographic factors may play a secondary role alongside direct human activity (Rangel-Buitrago & Gracia., 2026). Although both sampling periods in this study generally occurred within the dry season in southern Malang, and therefore rainfall-related differences in land-based runoff are expected to be minimal, residual variation in marine debris abundance may still be affected by other processes. These include coastal hydrodynamic dynamics such as wave, wind, and currents, which may redistribute floating debris and contribute to spatial and temporal variability across sites (Bettim et al., 2021; Li et al., 2023).

Based on the findings of this study (Figure 8), a simple linear regression was conducted with 18 data points (3 beaches × 2 season periods × 3 replicates), yielding a coefficient of determination (R^2) of 0.901 (Adjusted R^2 = 0.895), with a statistically significant result ($F(1.16) = 145.889$, $p < 0.001$), indicating that visitor numbers explain a large proportion of the variation in marine debris levels within the study sites. However, this result does not imply causation, and other environmental and anthropogenic factors may also contribute. A previous study conducted on several beaches in Padang, West Sumatra, found a similar correlation, where visitors numbers affected waste production with a coefficient of determination of 0,941(Aditya et al., 2019) . The presence of marine debris on tourist beaches is strongly influenced by tourism activities, as waste is generated by visitors who leave litter behind, leading to environmental pollution (Cordova et al., 2021). Similarly, a study on the Great Barrier Reef coastline in Australia identified tourism activities as the largest contributor to marine debris in the area (Wilson & Verlis, 2017). The high influx of visitors negatively impacts the coastal ecosystem by exacerbating marine debris pollution, particularly during peak holiday seasons (Garcés-Ordóñez et al., 2020; Ghosh, 2011).

This pattern suggests that human activities, particularly tourism, are strongly linked to marine debris abundance in the study areas. Direct consumption associated with tourism activities, such as family picnics, camping, and large group events, often involves the extensive use of disposable items. Visitors frequently bring food and beverages packaged in single-use materials such as plastic wrappers, styrofoam, plastic bottles, and straws, and subsequently leave these items behind. Across the three study sites, single-use packaging

waste was identified as the most commonly found type of litter. In addition, high smoking activity contributes to litter generation, as a substantial number of cigarette butts were observed in the study areas.

The contrast between Balekambang's tourism-driven accumulation, Kondangmerak's mixed anthropogenic sources, and Goa Cina's lower but persistent debris presence demonstrates that a single management approach is insufficient across different beach types. Among the three study sites, Balekambang Beach has a more structured management system compared to the other two beaches. Beach cleaning at Balekambang Beach is conducted daily. At Kondangmerak Beach, beach cleaning is conducted twice per week, whereas at Goa Cina Beach, cleaning is not carried out on a regular basis, especially when visitor numbers are low. Although beach management authorities have implemented cleaning efforts, marine litter is still present, mainly due to lack of awareness of the visitors and other oceanographic influences.

The high abundance of marine debris in coastal areas constitutes a significant threat to safety and negatively affects the tourism industry (Boahen, 2024). To address this issue, effective waste management practices and regulatory measures should be implemented. At Balekambang Beach, with high visitor density, priority should be given to strengthening waste management infrastructure through the provision of additional bins and improved waste segregation in high-use areas. At Goa Cina Beach, where accessibility is more limited and visitor regulation is less intensive, environmental education and clear signage at entry points are expected to be more effective in mitigating littering behavior. Furthermore, at Kondang Merak Beach, where tourism activities coexist with nearby local settlements, waste inputs are likely derived from both recreational visitors and residential areas, necessitating a combined approach that includes improved waste facilities in tourist zones, enhanced household waste management in surrounding settlements, and community-based clean-up and awareness programs. Overall, these findings emphasize the importance of adaptive management strategies that consider differences in accessibility, visitor pressure, and surrounding land-use characteristics to effectively reduce marine debris across coastal environments.

Conclusion

The composition of marine debris during both the school holiday period and the school term period is predominantly plastic waste, with no specific dominance in waste size across the two periods. This finding indicates that temporal variation between the two periods does not significantly affect the type and size structure of marine debris, but primarily influences its quantity and total weight. However, the abundance of marine debris, in terms of both quantity and weight, was higher during the high season, indicating a potential association with increased tourism-related activities during this period. A strong positive correlation was also observed between marine debris abundance and visitor numbers, indicating that increased visitor presence may contributes to higher debris accumulation across the three study beaches in Malang Regency. This pattern reflects the role of direct consumption and littering behavior as major sources of coastal pollution, particularly during peak visitation periods. It is important to note that this study has several limitations, including the regression analysis based on a finite dataset and the temporal scope of the study, which was limited to two comparable observation periods (school holiday and non-holiday seasons). Therefore, the findings should be interpreted with caution in terms of generalizability. Future studies are recommended to validate these results using larger datasets, as well as to incorporate additional environmental variables such as rainfall patterns, hydrodynamic conditions, and coastal current dynamics, which may also influence marine debris distribution and transport.

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