JoMS | Journal of Marine Studies

Research article

OPEN ACCESS

Characterization of marine debris at Bluka Teubai Beach, North Aceh, Indonesia: Composition, density, and temporal patterns

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Abstract

Marine debris consists of materials discarded or unintentionally introduced into the marine environment by human activities. The increasing volume of marine debris is largely attributed to human activity near coastal areas. Bluka Teubai Beach, North Aceh, a popular visitor destination, has a high potential for waste accumulation. This study, conducted in May 2024, employed a purposive sampling method to assess marine debris. The research area was divided into three stations with distinct characteristics, using the line transect method. Results from Bluka Teubai Beach identified two primary waste categories: organic and inorganic. Organic waste included wood, bamboo, and coconut husk, while inorganic waste consisted of plastic, glass, metal, and rubber. Among organic waste, wood exhibited the highest absolute density (0.456 items/m^2) and relative density (53.950%), followed by bamboo (0.317 items/m^2, 39.641%) and coconut husk (0.049 items/m^2, 6.409%). The overall density of organic waste at Bluka Teubai Beach was highest for wood (0.23 items/m^2), with an average relative density of 58.640%. For inorganic waste, plastic had the highest absolute density in pieces (2.24 items/m^2) and relative density in pieces (96.968%). The highest absolute density and relative mass of inorganic waste were also found in plastic (99.94 g/m^2 and 64.36%, respectively). Temporal analysis revealed that organic waste accumulation peaked on Fridays, while inorganic waste was most abundant on Tuesdays in terms of count and on Sundays in terms of mass. The results underscore the urgent need for targeted waste management strategies and continuous monitoring to mitigate marine debris pollution and protect the coastal ecosystem of Bluka Teubai Beach.

Keywords: Coastal pollution, organic debris, inorganic debris, plastic pollution, marine environmental monitoring

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Citation:
Imamshadiqin, I., Andika, Y., Syahputra, A., Erniati, E., & Salmarika, S. (2025). Characterization of macro-sized marine debris at Bluka Teubai Beach, North Aceh, Indonesia: Composition, density, and temporal patterns. *Journal of Marine Studies, 2*(1), 2102. https://doi.org/10.29103/joms.v2i1.19487.

Received: November 24, 2024
Revised: February 9, 2025
Accepted: February 10, 2025
Published: February 11, 2025

Subject areas:
Marine pollution; coastal management

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Introduction

Marine debris, defined as waste materials discarded by humans into the marine environment, intentionally or unintentionally, has emerged as a critical environmental issue with far-reaching implications (Johan et al., 2020). This debris is primarily categorized into two types: organic and inorganic waste. Organic waste, including materials such as wood, fruits, and vegetables, is biodegradable and can be broken down by microorganisms over time. In contrast, inorganic waste—comprising plastics, foam, cloth, styrofoam, ceramics, glass, rubber, and metal—resists natural decomposition processes. The persistence of inorganic waste in marine ecosystems is particularly concerning, as many materials can take centuries to degrade, creating long-lasting environmental impacts. The continuous increase in the volume of marine debris further exacerbates the problem, resulting in the accumulation and dispersion of waste across the world's oceans and coastal areas.

The global spread of marine debris has reached alarming levels, with an estimated 14 billion pounds of waste being dumped into the marine environment annually (Hetherington et al., 2005). Among the worst affected regions, Indonesia is identified as one of the most significant contributors of marine plastic waste, second only to China (Jambeck et al., 2015). Indonesia's coastal population, which exceeds 187 million people, plays a central role in this crisis, with each person contributing an average of 0.52 kg of plastic waste per day, leading to an annual total of 3.22 million metric tons of plastic waste entering the oceans (Jambeck et al., 2015). The increase in marine debris directly results from rising population densities, urbanization, industrial activities, and changing consumption patterns. Furthermore, ocean currents significantly transport debris across vast distances, with currents frequently carrying waste toward coastal regions, where it accumulates and contributes to local pollution (Manik et al., 2016). This large-scale contamination represents an immediate and growing threat to marine ecosystems, disrupting biodiversity and compromising the health of aquatic species. In addition, the socio-economic impact on coastal communities is profound, as pollution impairs livelihoods, damages fisheries, and undermines the potential for sustainable tourism (Lippiat et al., 2013).

As one of the popular tourist destinations in this region, Bluka Teubai Beach, located in Dewantara District, North Aceh Regency, faces significant challenges related to marine debris. Known for its picturesque landscape, including a vast expanse of brownish-white sand and coconut trees, Bluka Teubai Beach attracts a large number of visitors throughout the year. While tourism is an important economic activity for the region, it also brings a high potential for waste accumulation. Despite the increasing presence of debris, there is limited research and data on marine waste types, quantities, and distribution patterns at this particular beach. Understanding the sources and composition of marine debris in this area is essential for developing effective management strategies to reduce waste and mitigate its impact on the environment.

Given the growing concern over marine pollution and the need for more localized data (Mahmud et al., 2024), this study aims to assess marine debris at Bluka Teubai Beach comprehensively. By identifying the types and densities of both organic and inorganic waste and temporal variations in accumulation, this research will contribute crucial baseline data that can inform future waste management policies and initiatives by local authorities. Additionally, this study will offer insights into the broader implications of marine debris on coastal ecosystems and communities, facilitating better-informed decisions and actions for sustainable coastal management.

Methods

Study area and sampling approach

This study was conducted in May 2024 at Bluka Teubai Beach, Dewantara District, North Aceh Regency (Figure 1). A mixed-methods approach, combining both qualitative and quantitative techniques with a purposive sampling strategy, was employed. Data collection involved direct observations to assess waste type, weight, density, and the rate of accumulation, with a focus on tourism-related activities.

Observation stations were selected based on an initial survey of the area's characteristics. Sampling took place at three observation stations, each 150 meters apart, during low tide. The line transect method was used for marine debris sampling, with each station comprising one transect of 50 meters. Each transect was subdivided into three 10 x 10 meter plots, spaced 10 meters apart (Kahar, 2020) (Figure 2). Only macro-sized marine debris (>2.5 cm to 1 m) visible above the substrate/sediment surface was collected, following the guidelines of Ningsih (2020).

Type of waste analysis

The collected marine debris was analyzed to determine waste type, size, quantity, and mass. The marine debris was categorized into several types, including plastic, metal, glass, rubber, textiles/fibers, wood, and others, following the classification outlined by NOAA (2013). ´

Marine debris density analysis

Waste data were recorded according to type, quantity, and weight. The absolute and relative density of waste pieces and mass were determined using the method outlined by Walalangi (2012). Density was calculated in two forms: number density (items/m^2) and mass density (g/m^2).

Absolute density of waste pieces (item/m^2) = Number of waste pieces in each category (item) / area (m^2) .... (*1*)

Absolute density of the waste mass (g/m^2) = Weight of the waste pieces in each category (g) / area (m^2) .... (*2*)

Relative density (number of trash pieces) = (number of waste in each category (g) / total amount of discount per category in all categories (item)) x 100 .... (*3*)

Relative density (mass waster) = (Weight of waste in each category (g) / total weight of waste pieces in all categories (g)) x 100 .... (*4*)

Results

Type of marine debris

The study results indicate significant variation in the types of macro-sized organic marine debris observed at different stations along Bluka Teubai Beach, Dewantara District, North Aceh Regency. The identified organic debris primarily consists

https://doi.org/10.29103/joms.v2i1.19487

of wood, bamboo, and coconut husk (Table 1). As shown in Table 1, these organic waste materials were consistently present across all observation stations.

The macro-sized inorganic marine debris observed at Bluka Teubai Beach consists of plastic, glass, metal, and rubber (Table 2). Plastic waste includes items such as plastic bottles, plastic bags, food packaging, plastic spoons, plastic straws, ropes, styrofoam, and plastic bottle caps. Glass waste primarily comprises beverage bottles and medicine bottles. Metal waste is predominantly derived from cans, while rubber waste consists solely of discarded sandals.

Table 1. Classification of macro-sized organic marine debris observed at Bluka Teubai Beach, North Aceh Regency. (+): found, (-): not found.

Types of debris	Station 1	Station 2	Station 3
Wood	+	+	+
Bamboo	+	+	+
Coconut husk	+	+	+

Table 2. Classification of macro-sized inorganic marine debris observed at Bluka Teubai Beach, North Aceh Regency. (+): found, (-): not found.

Types of debris	Station 1	Station 2	Station 3
Plastic	+	+	+
Glass	+	+	+
Metal	+	+	+
Rubber	+	+	+

Density of marine debris

The absolute and relative density of organic marine debris at Bluka Teubai Beach, measured based on the number of individual items (Table 3). The data indicate that wood exhibits the highest density (1.36 items/m^2 and 95.59%), followed by bamboo (0.94 items/m^2 and 100.34%) and coconut husk (0.13 items/m^2 and 99%) (Table 3). The total density of organic debris at Bluka Teubai Beach reveals that wood constitutes the highest proportion of debris by count (0.23 items/m^2), with an average relative density of 58.64%. Furthermore, the absolute and relative density of organic debris based on mass indicates that coconut husk contribute the highest density (66.13 g/m^2 and 50.76%), surpassing wood (54.26 g/m^2 and 38.41%) and bamboo (9.72 g/m^2 and 10.81%) (Table 4). These findings suggest that while wood is the most frequently occurring organic debris, coconut husk account for the highest mass contribution.

The absolute and relative density of inorganic marine debris at Bluka Teubai Beach, measured based on the number of individual items, indicates that plastic waste is the

Figure 1. Satellite image of the research location (modified from www.googleearth.com).

Table 3. Absolute and relative density of organic marine debris pieces.

Types of waste	Density of organic waste pieces			Total
	Station 1	Station 2	Station 3	
Absolute density of organic waste pieces (item/m^2)				
Wood	0.21	0.69	0.46	1.36
Bamboo	0.19	0.42	0.33	0.94
Coconut husk	0.03	0.06	0.04	0.13
Total	0.147	0.392	0.282	0.821
Relative density of organic waste pieces (%)				
Wood	11.219	50.48	33.9	95.599
Bamboo	20.35	44.56	35.43	100.34
Coconut husk	0.25	0.43	0.31	99
Total	100	100	100	100

Table 4. Absolute and relative density of organic marine debris mass.

Types of waste	Density of organic waste mass			Total
	Station 1	Station 2	Station 3	
Absolute density of organic waste mass (g/m^2)				
Wood	8.4	29.4	16.46	54.26
Bamboo	3.28	0.48	5.96	9.72
Coconut husk	18.83	30.2	17.1	66.13
Total	30.51	60.08	39.52	130.11
Relative density of organic waste mass (%)				
Wood	15.47	54.17	30.34	38.416
Bamboo	23.31	34.31	42.36	10.815
Coconut husk	28.47	45.66	25.83	50.769
Total	100	100	100	100

Furthermore, the absolute and relative density data of inorganic marine debris at Bluka Teubai Beach, measured based on mass, indicate that plastic waste has the highest density (99.94 g/m^2 and 64.35%), followed by glass (79.98 g/m^2 and 27.47%), metal (10.00 g/m^2 and 4.09%), and rubber (8.09 g/m^2 and 4.11%) (Table 6). Among all observation stations, the highest waste density was recorded at Station 2, where plastic waste reached 4,033 g/m^2 with an average relative density of 70.76%. This substantial accumulation is likely influenced by local anthropogenic activities and environmental factors that contribute to debris retention in this area.

Composition of marine debris

The organic waste data from Bluka Teubai Beach indicate that the highest number of organic debris items was recorded on Friday, totalling 148 items/day, with a corresponding mass of 7,790 g/day. In contrast, the lowest number of organic waste items was observed on Sunday, amounting to 76 items/day with a total mass of 3,300 g/day (Figure 2).

For inorganic waste, the highest number of debris items was recorded on Sunday, totalling 128 items/day, while the highest mass of inorganic waste was observed on Tuesday, reaching 2,530 g/day. The lowest number of inorganic waste items was found on Thursday (76 items/day),

most dominant, with a density of 2.24 items/m^2 and a relative proportion of 96.968%. This is significantly higher than the densities of glass (0.013 items/m^2, 1.841%), metal (0.006 items/m^2, 0.721%), and rubber (0.003 items/m^2, 0.470%) (Table 5). Among all observation stations, Station 2 exhibited the highest absolute and relative density of inorganic debris, with values of 0.341 items/m^2 and an average relative density of 97.46%. The elevated debris accumulation at Station 2 is likely attributed to its proximity to a fishing boat manufacturing area, where waste materials tend to concentrate due to human activities and local environmental factors.

Table 5. Absolute and relative density of inorganic marine debris pieces.

Types of waste	Density of inorganic waste pieces			Total
	Station 1	Station 2	Station 3	
Absolute density of inorganic waste pieces (item/m^2)				
Plastic	0.48	1.02	0.74	2.24
Glass	0.013	0.016	0.001	0.03
Metal	0.003	0.006	0.006	0.015
Rubber	0.003	0.003	0.001	0.01
Total	0.67	1.27	0.748	2.295
Relative density of inorganic waste pieces (%)				
Plastic	96.053	97.46	97.391	96.968
Glass	2.632	1.587	1.304	1.841
Metal	0.658	0.635	0.87	0.721
Rubber	0.658	0.317	0.435	0.47
Total	100	100	100	100

https://doi.org/10.29103/joms.v2i1.19487

Table 6. Absolute and relative density of inorganic marine debris mass.

Types of waste	Density of inorganic waste mass			Total
	Station 1	Station 2	Station 3	
Absolute density of inorganic waste mass (g/m^2)				
Plastic	15.66	47.34	36.94	99.94
Glass	42.34	37.36	20.28	79.98
Metal	10	50	40	100
Rubber	21.27	42.55	21.27	85.09
Total	89.27	177.25	118.49	385.01
Relative density of inorganic waste mass (%)				
Plastic	47.24	70.76	75.06	64.35
Glass	46,85	15.11	15.11	27.47
Metal	1.96	4.87	5.3	4.4
Rubber	3.93	3.89	4.5	4.11
Total	100	100	100	100

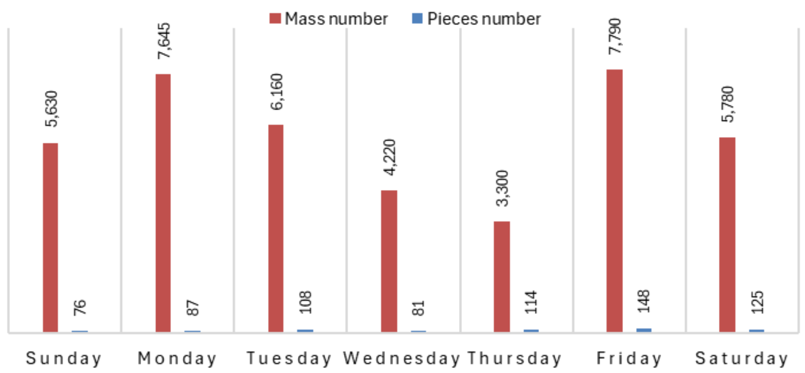

Figure 2. Quantity (pieces) and mass of organic marine debris at Bluka Teubai Beach.

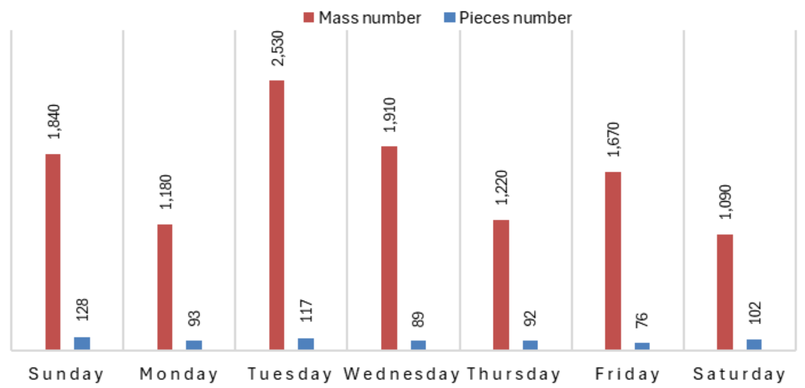

Figure 3. Quantity (pieces) and mass of inorganic marine debris at Bluka Teubai Beach.

whereas the lowest waste mass was recorded on Saturday at 1,090 g/day (Figure 3). The significant increase in inorganic waste mass on Tuesday (2,530 g/day) is attributed to the presence of discarded jerrycans, which are commonly used as containers for fishing boat fuel, as well as ropes frequently utilized for securing boats while docked.

Discussion

The availability of all kinds of organic waste (wood, bamboo, and coconut husk) at every observation station can be linked to the varied vegetation along the coastline of Bluka Teubai Beach. In particular, coconut husk come from naturally growing coconut trees, as well as from trash leftover from coconut beverages consumed by visitors. Bamboo wastage is a result of the decomposition of tourist facilities constructed from bamboo, which are brought to the research location by tidal currents. According to Sejati (2009), organic wastage found in aquatic ecosystems is typically from natural sources like leaves, branches of trees, and domestic refuse (such as vegetable and fruit peels) carried by water currents during tidal events or runoff resulting from rainfall.

Likewise, the presence of all forms of inorganic waste (plastic, glass, metal, and rubber) in all stations is believed to be due to human activities in the nearby areas. These wastes are carried by tidal currents and alongshore and deposited on the coastline. Coe and Rogers (1971) attributed human activities as the major source of inorganic waste, both on land and sea.

From the density analysis, wood waste was the densest among the organic types of waste. Ayuningtyas et al. (2019) reported that wood waste is very buoyant and can be carried by water currents and deposited in huge amounts in the marine environment. The high density of organic waste in Station 2 can be attributed to the high abundance of trees along the shoreline, resulting in a higher input of organic trash such as wood, bamboo, and coconut husk being carried by river flow downstream. In contrast, Station 1 had the lowest density of organic waste because of the minimal occurrence of trees in the vicinity. Subekti (2017) and Johan et al. (2020) highlighted that the trash is carried into aquatic environments during the rainy season via surface runoff, which will finally end up at river mouths and coatal areas.

The highest absolute and relative mass density of organic waste at Bluka Teubai Beach was exhibited by coconut husk, which had 10.067 g/m^2 and a mean relative density of 46.06%. Coconut wastes mostly come from tourist spots, where young coconuts are being sold by vendors as part of their commodities. Stevenson (2011) identified two general sources of organic waste: wastes that are disposed of from domestic activities and those brought by riverine systems from terrestrial ecosystems to marine waters.

The density of inorganic waste is different at different stations, with the lowest absolute and relative density being at Station 1. This can be explained by the fact that there is little human activity in this area and there are pond gates to prevent water from flowing, thus inhibiting the transportation of inorganic trash to this point. Windsor et al. (2019) emphasized that recreational and tourist sites often face serious waste deposition as a result of inadequate disposal methods. Also, Irawan et al. (2020) documented that food packaging debris is a prevalent category of litter along coastal tourist regions because it is extensively used and is resistant to degradation. Desi et al. (2018) similarly observed that coastal areas with estuaries of rivers have compounded waste management issues, given that these zones are natural trap points for trash carried from upstream locations.

Table 6 shows that Station 2 recorded the highest absolute density of marine debris. Johan (2021) explained that marine debris comes mainly from human activities, whereby trash is usually recklessly thrown into water bodies. Plastic was defined by Derraik (2002) as a synthetic organic polymer with characteristics that render it extremely versatile for daily usage, which has resulted in its widespread occurrence in marine litter. Also, Yogiesti et al. (2010) identified that the inorganic trash on the coastline is mostly made up of plastic, and NOAA (2015) identified that poorly managed household trash significantly contributes to marine contamination.

The daily variations in the number and weight of organic trash are most probably affected by the changes in tourist activities in Bluka Teubai Beach. Megawan and Surayawan (2019) attested that activities related to tourism, such as those of visitors and vendors, are major sources of coastal trash. Among the marine wastes, the wood waste category was the most common, both from natural sources and human activities like deforestation and careless disposal of wood items along the coastline. In the same manner, inorganic trash, especially from fishermen, added greatly to the overall volume of waste. Irawan et al. (2020) observed that fishermen commonly dispose of trash, such as jerrycans and ropes, into the ocean prior to, during, and after fishing activities. These wastes are then carried to the coastal region by ocean currents and wind-driven surface circulation.

The maximum amount of inorganic waste was observed on Sundays, coinciding with the highest tourist visits to Bluka Teubai Beach. Greater tourist numbers mean greater consumption and disposal of plastic waste, especially plastic bags, which were found in abundance at the study location. Derraik (2002) explained that plastic debris makes up the biggest portion of marine trash because of its widespread application across human activities. The ongoing use of plastic bags in Aceh is also likely caused by the lack of regulatory prohibitions, meaning vendors are free to give them out during daily transactions.

Conclusions

The study identified two main categories of marine debris at Bluka Teubai Beach, Dewantara District, North Aceh Regency: organic waste (wood, bamboo, and coconut husk) and inorganic waste (plastic, glass, metal, and rubber). Among organic waste, wood exhibited the highest absolute density in pieces (1.36 items/m^2), while bamboo had the highest relative density in pieces (100.34%). The highest absolute density and relative mass values for organic waste were recorded for coconut husk at 66.13 g/m^2 and an average relative density of 50.796%, respectively.

For inorganic waste, plastic accounted for the highest absolute density (2.24 items/m^2) and relative density (96.968%). Additionally, plastic waste exhibited the highest absolute mass density (99.94 g/m^2) and an average relative density of 64.357%. Temporal variations in waste accumulation were also observed, with the highest number and mass of organic waste recorded on Friday, while inorganic waste peaked on Tuesday in terms of quantity and on Sunday in terms of mass.

These findings highlight the dominant role of plastic waste in inorganic pollution and the significant contribution of organic waste from natural sources and human activities. Further research and targeted waste management strategies are essential to mitigate marine debris accumulation and its environmental impacts on coastal ecosystems.

Acknowledgements

The authors would like to express their sincere gratitude to the vendors, tourists, and village officials at Bluka Teubai Beach, Dewantara District, North Aceh, for their valuable contributions and support in providing data and information essential to the successful completion of this study.

Authorship contribution

Imamshadiqin Imamshadiqin: Conceptualization, methodology, investigation, sample processing and analysis, visualization, supervision, writing - review and editing. **Yudho Andika:** Methodology, sample processing and analysis. **Andika Syahputra:** Conceptualization, sample processing and

analysis, visualization, writing, original draft preparation, review and editing. **Erniati Erniati:** Methodology, review and editing, supervision. **Salmarika Salmarika:** Original draft preparation, writing - review and editing.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

Funding

No external funding or financial support was received while conducting this research.

References

Ayuningtyas, W. C., Yona, D., Julianda, S. H., & Irnawati, F. (2019). Kelimpahan mikroplastik pada perairan di Banyuurip, Gresik, Jawa Timur. *Fisheries and Marine Research, 3*(1), 41–45. https://doi.org/10.21776/ub.jfmr.2019.003.01.5.

Coe, J. M., & Rogers, D. B. (1997). *Marine debris: Sources, impacts, and solutions* (pp. 161–170). Springer. https://doi.org/10.1007/978-1-4613-8486-1.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin, 44*(1), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5.

Hetherington, J., Leous, J., Anziano, J., Brockett, D., Cherson, A., Dean, E., Dillon, J., Johnson, T., Littman, M., Lukehart, N., Ombac, J., & Reilly, K. (2005). *The Marine Debris Research, Prevention and Reduction Act: A policy analysis*. Columbia University.

Irawan, F., Novita, Y., & Soeboer, D. A. (2020). Limbah dari aktivitas penangkapan ikan di PPN Palabuhanratu. *Marine Fisheries, 11*(1), 61–73. https://doi.org/10.29244/jmf.v11i1.33961.

Jambeck, R. J., Roland, G., Chris, W., Theodore, R. S., Miriam, P., Anthony, A., Ramani, N., & Kara, L. (2015). Plastic waste inputs from land into the ocean. *Science, 347* (6223), 768–771. https://doi.org/10.1126/science.1260352.

Johan, Y., Renta, P. P., Muqsit, A., Purnama, D., Maryani, L., Hiriman, P., & Yunisti, T. (2020). Analisis sampah laut (Marine debris) di Pantai Kualo Kota Bengkulu. *Enggano, 5* (2), 273–289. https://doi.org/10.31186/jenggano.5.2.273-289.

Johan, Y., Renta, P. P., Purnama, D., Muqsit, A., & Hariman, P. (2019). Jenis dan bobot sampah laut (Marine debris) Pantai Panjang Kota Bengkulu. *Enggano, 4*(2), 243–256. https://doi.org/10.31186/jenggano.4.2.243-256.

Kahar, G. M. (2020). Identifikasi sampah anorganik pada ekosistem mangrove Desa Talawaan Bajo Kecamatan Wori Kabupaten Minahasa Utara. *Pesisir & Laut Tropis, 8* (1), 1–6. https://doi.org/10.35800/jplt.8.1.2020.27200.

Lippiat, S. M., Arthur, D. C., & Wallace, E. N. (2013). Assessing the abundance and types of marine debris on shorelines and surface waters in Chesapeake Bay tributaries stratified by land use. Presentation at the Ocean Sciences Meeting, 20–24 February 2012, Salt Lake City, USA.

Mahmud, M. N., Rahman, M. O., & Jahan, R. (2024). Abundance and distribution of anthropogenic marine litter in Hatiya and Nijhum Dwip Island, Bangladesh. *Journal of Marine Studies, 2*(1), 2101. https://doi.org/10.29103/joms.v1i3.19198.

Manik, K. H. T. R., Indrajaja, M., & Amanda, S. (2016). Sistem pengelolaan sampah di Pulau Bunaken. *Spasial: Perencanaan Wilayah dan Kota, 3*(3), 15–24. https://doi.org/10.35793/sp.v3i1.11630.

Megawan, M. B., & Surayawan, I. B. (2019). Pengelolaan sampah di daya tarik wisata Pantai Candikusuma, Desa Candikusuma, Kecamatan Melaya, Kabupaten Jembrana. *Destinasi Wisata, 7*(2), 239–244. https://doi.org/10.24843/JDEPAR.2019.v07.i02.p05.

Ningsih, W. N., Putra, A., Anggara, R. M., & Suriadin, H. (2020). Identifikasi sampah laut berdasarkan jenis dan massa di Perairan Pulau Lae Lae Kota Makassar. *Pengelolaan Perikanan Tropis, 4*(2), 10–18. https://doi.org/10.29244/jppt.v4i2.32186.

National Oceanic and Atmospheric Administration (NOAA). (2013). *Programmatic environmental assessment (PEA) for the NOAA Marine Debris Program (MDP)*. NOAA. Maryland: NOAA.

National Oceanic and Atmospheric Administration (NOAA). (2015). *Turning the tide on trash: A learning guide on marine debris*. NOAA Marine Debris Division.

Sejati, K. (2009). *Pengolahan Sampah Terpadu Dengan Sistem Node, Sub Point dan Center Point*. Kanisius.

Subekti, S. (2017). Pengelolaan sampah rumah tangga 3R berbasis masyarakat. *Prosiding Seminar Nasional Sains dan Teknologi*, 24–30. http://dx.doi.org/10.36499/psnst.v1i1.326

Stevenson, C. (2011). Plastic debris in the California marine ecosystem: A summary of current research, solution efforts, and data gaps. In *Sea Grant*. University of Southern California Sea Grant, California: Ocean Science Trust.

Walalangi, J. Y. (2012). *Analisis komposisi sampah organik serta dampak terhadap lingkungan pesisir Kota Palu, Sulawesi Tengah* (Master's thesis). Institut Pertanian Bogor.

Windsor, F. M., Tilley, R. M., Tayler, C. R., & Ormerod, S. J. (2019). Microplastic ingestion by riverine macroinvertebrates. *Science of the Total Environment, 646*, 68–74. https://doi.org/10.1016/j.scitotenv.2018.07.271.