EREM 78/2

Journal of Environmental Research, Engineering and Management
Vol. 78 / No. 2 / 2022
pp. 49–57
DOI 10.5755/j01.erem.78.2.28933

Distribution and Composition of Marine Debris in the Shoreline Area of Bone Bay Indonesia

Received 2021/04 | Accepted after revision 2022/01

http://dx.doi.org/10.5755/j01.erem.78.2.28933

Distribution and Composition of Marine Debris in the Shoreline Area of Bone Bay Indonesia

Ridha Alamsyah*, Andi Tenriawaruwaty A.R. Zulkifli, Irfan Fauzi, Andi Liswahyuni, Armita Permatasari, Hamzah Wahab

Aquatic Resources Management, Faculty of Agriculture, Muhammadiyah University of Sinjai, Indonesia

***Corresponding author:** ridhaalamsyah@umsi.ac.id

Indonesia is the world's second greatest producer of plastic waste after China. The bulk of waste produced accumulates in metropolitan regions due to the increasing population, and the situation has spread to rural areas with a limited population. The residents of the Sinjai Regency have felt the impact of the growing amount of debris, and it is expected to worsen without immediate action. Coastal locations that accommodate waste from land and water are mostly affected by debris. The study was conducted in Bone Bay, Sinjai Regency's coastline area. The bay's condition is sheltered to decrease the current strength, but it varies from season to season. Furthermore, it used shoreline survey methodology, where debris grouping consisted of plastics, metal, rubber, glass, clothing, and others. The debris data were calculated and analyzed based on the seasons of the west (January) and east (July). The data were associated with the current pattern model in Bone Bay waters based on the season. In January and July, 86% of waste was plastic, 3% was metal, 4% was rubber, 2% was clothing, while 5% and 4% were glass. No other types of waste were identified in January, while 1% was detected in July. Garbage that enters through rivers, garbage deposited by local residents, and tourism activities at the four observation areas are all contributing to the presence of waste in Sinjai's coastal area.

Keywords: litter, marine debris, bone bay, west season, east season.

Introduction

Debris is a growing worldwide problem in Indonesia's cities and remote areas. It is a serious hazard on land and is subsequently carried into the ocean by river flows, affecting the survival of various marine habitats. The accumulated debris in the world has increased, especially in the last few decades. Every year, we produce 1.3 billion tons of garbage, enough to cover the entire globe. It is predicted to reach 2.2 billion by 2025 at the current rate of urbanization and population growth (David et al., 2019). Indonesia is the second plastic debris-producing country in the world after China (Jambeck et al., 2015; Purba et al., 2020; Vriend et al., 2021).

Marine debris (MD) consists of solid, long-lasting materials generated or processed and allowed to enter the marine environment, either purposefully or inadvertently. Debris occurs in various shapes and sizes, ranging from microscopic microplastics to huge ships. MD is a significant and expanding worldwide concern, presenting a danger to marine life preservation. It negatively influences the marine environment and human health. Subsequently, MD has negative consequences for species, habitats, environmental processes, ecosystem services, and human activities, including tourism, fishing, navigation, and aquatic productivity (Djaguna et al., 2019; Hardesty et al., 2017; UNEP, 2016).

Debris is generated as a result of human activity on land, and the variation of MD depends on its proximity to the city center with the nature of its activities. According to available data, plastic is the most prevalent kind of waste detected, particularly in the ocean (Jang et al., 2018; Pieper et al., 2019). Due to the material's durability, it may accumulate in large amounts over time and pose new problems for ocean health (Maximenko et al., 2019). Therefore, understanding MD derived from plastic and other materials is critical in developing strategies to stop the flow (Chen et al., 2019).

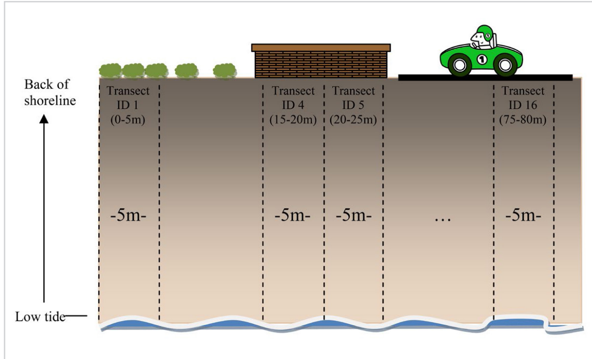
The distribution of MD differs in each location and is influenced by various factors. At least the wind, ocean currents, and tides are closely related to the accumulation of debris in a place (Purba et al., 2021). According to Uhrin et al. (2020), seasons influence debris loads on the United States west coast and occur more frequently in winter and spring (downwelling). In the context of Indonesia, with a wet and dry season, the outcomes will be different. The difference in season (temporal) and place (spatial) shows different results of waste accumulation. Every year, the patterns of ocean currents are influenced by seasonal patterns strongly tied to wind movements (Jasmin et al., 2019). Therefore, it was important to understand local oceanographic processes driving seasonal changes. Furthermore, other environmental and anthropogenic factors are also related to the amount of waste, such as the type of beach access and the distance from city to beach (Uhrin et al., 2020).

Monitoring Indonesian marine debris has given some results, but they should be linked to current circumstances and location characteristics. Information on the condition and density of MD is needed, especially for areas that have not been reported. Data from marine debris monitoring at several locations are needed for policymaking and improving waste management. According to Purba et al. (2019), future studies on the impact of marine debris should be comprehensively conducted on ecosystem impacts, distribution patterns, invasive species, human health, and economic losses. Gulf waters with different coastal characteristics from other places give different results. Therefore, this study aims to determine the relationship between the amount and type of debris in the bay area at different seasons. It provides information about waste characteristics in the coastal area with a limited population. Furthermore, it adopts a more comprehensive policy and provides important information for protection targets in coastal areas.

Methods

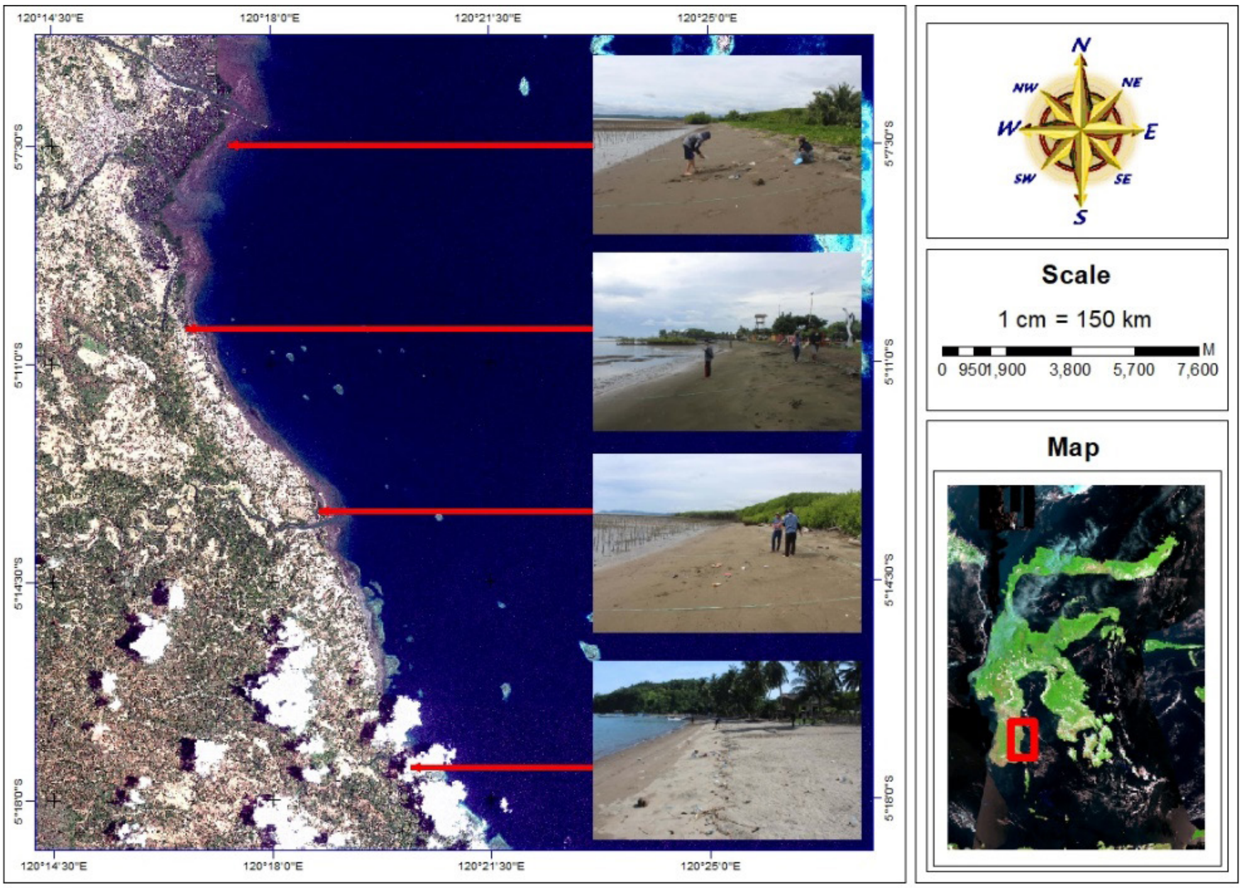
Marine debris was sampled twice in the west (January) and east season (July). Generally, Indonesia has four seasons: the west season, the west to east transition season, the east season, and the east to west transition season. Sampling was performed during the west and east seasons because of the large changes in wind direction and speed. The same factors determined the observation station, a popular tourist destination, close to the river mouth and the Bone Bay area. Determination of the sampling station refers to Opfer et al. (2012), Lippiatt et al. (2013), and KLHK (2019). The observation area with a length of 100 m was divided into four transects perpendicular to the coastline. Each transect was 5 meters wide, where transect 1 was 0–5 meters, transect 2 was 15–20 meters, transect 3 was 20–25 meters, and transect 4 was 75–80 m. The material debris was classified as meso and macro debris based on the size or diameter greater than 2.5 cm (Opfer et al., 2012). The categories were based on waste material consisting of plastics, metal, rubber, glass, clothing, and others (Opfer et al., 2012; Lippiatt et al., 2013; NOAA, 2013; KLHK, 2019). The debris in the transect at each station is calculated based on the type of waste. Meanwhile, the waste types per station were analyzed by calculating the percentage two times. *Fig. 1* shows the shape of the transect at each station, while *Fig. 2* depicts the locations of the four observation stations. The obtained data were correlated with the current pattern model in Bone Bay waters based on the season. Subsequently, the flow pattern model used processed data from https://marine.copernicus.eu/ using the Ocean Data View (ODV) Program.

Fig. 1. *Marine debris sampling technique for shoreline survey methodology*



Source (Opfer et al., 2012)

Fig. 2. *Marine debris sampling locations*



Results and Discussion

Based on the observations, the percentage of debris at two different times was obtained, as shown in *Fig. 3.*

January is considered the west season, while July is the east season. Therefore, there were differences in the amount and type of debris in the January and July observations. However, the debris in the two months was almost the same because the observation location is in a relatively protected bay area. The winds delivering garbage from the sea do not differ significantly during seasonal changes. The characteristics of the location are sites in the bay area, close to the river mouths, tourist attractions, and sea-level currents among the four stations. Plastic made up the majority of the debris, accounting for 86% in both January and July. Glass generated the second-highest quantity of waste, accounting for 5% in January and 4% in July. Several sites, such as the coasts of Takalar Regency and Makassar City, South Sulawesi, indicate a significant volume of plastic debris, with 62%–86% (Tahir et al., 2019). Plastic was also identified in 86.62% of western and southern Aceh (Fitria et al., 2019). Renjaan et al. (2020) found this debris on the coast of Dullah Island, Kei archipelago, to be 46%, but on Banda Aceh, it was 92% (Ondara and Dhiauddin 2020).

Fig. 4 shows the average number of debris types collected. Observations were only made on the number of items and did not weigh the waste mass. Plastic debris was obtained in a very high amount compared with other types of debris. For January, the average amount of plastic waste per m^2 was 2.5 (2.5 ± 2.296), while for July, it was 4.59 (4.59 ± 2.709). The density of other types of debris was just under 0.26 item/m^2. Although the amount of plastic debris collected was relatively high compared with other types, debris in other locations was also higher than in the study location. In other places with similar qualities, such as the Mangrove Ecosystems of Sungai Rawa Village, Sungai Apit Subdistrict, Siak Regency, Riau Province, a high density of plastic debris up to 8.786 item/m^2 was discovered (Fajriah et al., 2020). In contrast, Mardiatno and Wiratama (2021) found that the density of non-degradable waste in the Parangtritis coastal area, Yogyakarta, was 341–883 items/m^2. In Manado Bay, North Sulawesi Province, in the dry and rainy season, the density was 6.25 items/m^2 and 9.18 items/m^2, but it was 1.64 items/m^2 and 1.95 items/m^2 for glass and ceramics (Lasut et al., 2021).

Metal, rubber, glass, textiles, and other garbage come in nearly equal numbers. There was no metal at the

Fig. 3. *The average amount of marine debris on the observation shoreline was compared*

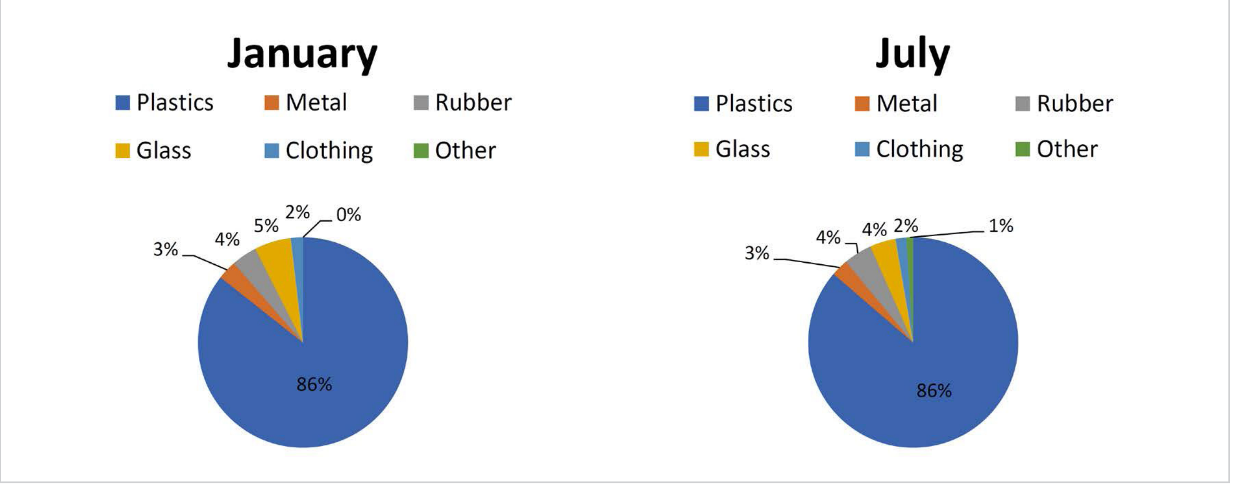
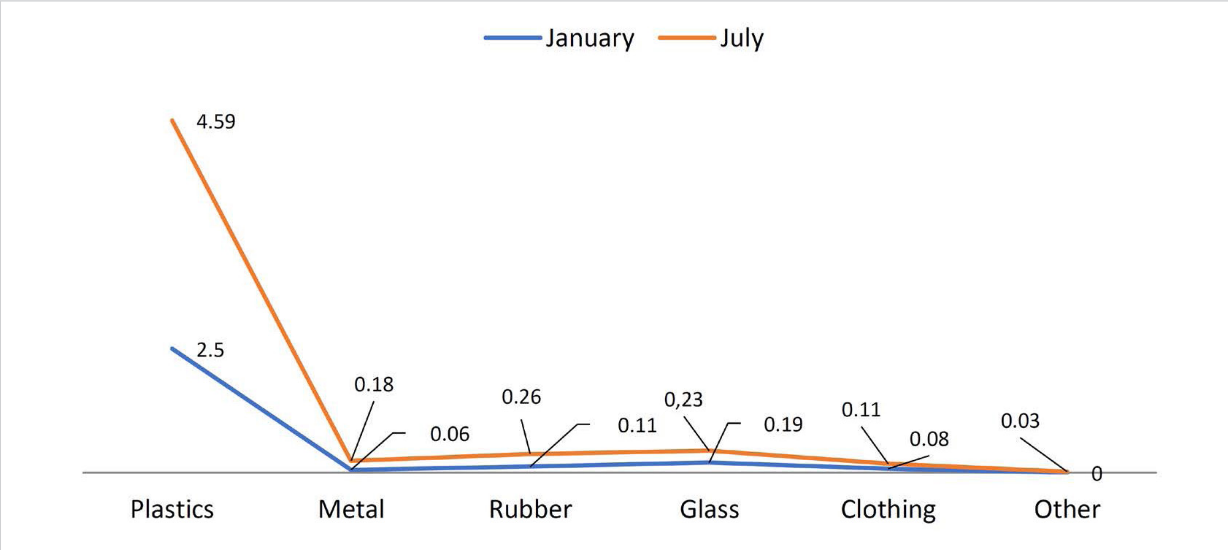


Fig. 4. *Comparison of the average amount of marine debris (item/m²) in January and July*



first and third stations in January or July, and at station 3, the types of cloth debris and others were not discovered. Meanwhile, other types of waste were only obtained at the first and third stations in July and were not obtained in January. Plastic and rubber were also dominant in other locations (Djaguna et al., 2019; Isyrini et al., 2019; Rahmayanti et al., 2020). Observational data for the territory have been more focused on Java Island and big cities. Another study found that plastic garbage is prevalent in the islands of Sumatra, Bali, and Sulawesi, as well as the city of Makassar (Vriend et al., 2021). Therefore, accurate information about the condition of debris in the coastal waters of Bone Bay was also important.

Marine debris in the coastal region is caused by strong waves carried by currents and waste input from the mainland. The role of rivers in transporting debris from land to sea is inextricably linked to the accumulation of garbage. The quantity of rivers that run into the sea, especially close to the observation area, adds to trash, particularly plastic waste. Furthermore, 51 of the 1000 most contaminated rivers were on the Indonesian island of Java, which contributes 14.2% plastic to the seas each year (Lebreton et al., 2017; Meijer et al., 2021). Plastic debris was found not only in Indonesian waters but also in other parts of the world, including South Eleuthera (Ambrose et al., 2019), east China (Chen et al., 2019), Ecuador (Gaibor et al., 2020), Sri Lanka (Jang et al., 2018), Northern Gulf of Mexico (Wessel et al., 2019) East Coast of India (Arun Kumar et al., 2019), Moroccan Mediterranean Sea (Loulad et al., 2019), and Penang Island in Malaysia (Yin et al., 2020). Plastic debris is the biggest problem in Indonesia and throughout the world.

The accumulation and increase in the debris are detected with continuous observations and inventories. This observation and inventory data are useful for formulating good management. Plastic trash severely influences land and marine ecosystems, putting humans at risk, and the existence for a long time in an ecosystem affects organisms' lives. According to Vriend et al. (2021), plastic waste in the marine environment negatively influences the tourist industry, pollutes seafood with microplastics, and has a long-term effect on human health and safety. Plastic consumption by aquatic organisms causes their death and entangle their body parts for a long time. Furthermore, high waste accumulation has caused damage and increased the risk of flooding, especially in urban areas (Hantoro et al., 2019; Honingh et al., 2020; Van Emmerik et al., 2019; Vriend et al.,

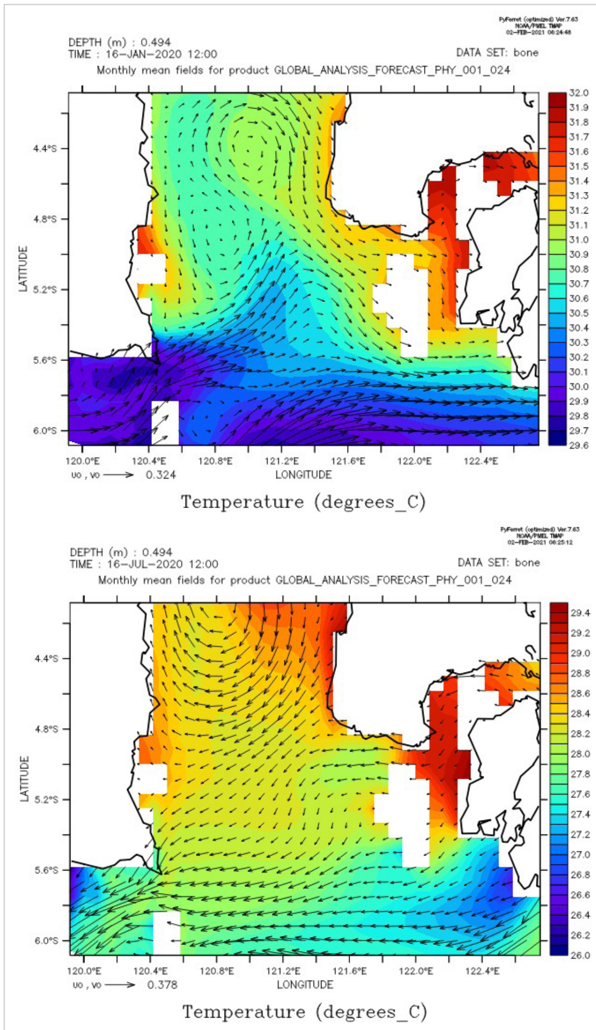
The seasonal variance in waste accumulation is because debris is transferred from land to sea through rivers, especially plastic, spreads very quickly via surface currents. Purba et al. (2021) state that monsoon winds have been proved to have a significant effect on the distribution of marine debris. This is because currents easily move plastic debris on the sea surface but may be stranded in the shoreline area. Due to Indonesia's archipelagic status, marine debris should be transported slowly to filter the MD flow. The results also show that the Indonesian Sea has been a dumping ground for waste from Indonesia and other countries surrounded by the Pacific and Indian Oceans. MD fluctuations have also been caused by debris trajectories on the sea surface, influenced by wind and currents. However, the direction of ocean currents has not always been exactly parallel to the direction of the wind, and vice versa (Rachmayani et al., 2018).

Different wind patterns in each season affect the direction and speed of currents, which impacts the movement and accumulation of debris. There are four seasons in Indonesia, namely the west season, west to east transition, east season, and east to west transition. January represents the west season, and July represents the east season (Siregar et al., 2017). In the east season *(Fig. 5, bottom)*, the current direction is towards the mainland. Therefore, the current carries debris collected from the land resulting in a bigger buildup of waste in July than in January. Meanwhile, the current pattern is visible parallel to the mainland in January *(Fig. 5, top)*, indicating that debris moves towards the bay's mouth. In the east season, winds and currents move from the southeast to the waters of Bone Bay. In this season, the current velocity tends to be higher than in the west season since the mainland of Sulawesi Island blocks the wind. As a result, the wind speed and wind currents were relatively low.

Shoreline debris fluctuations are related to seasonal changes. According to Brennan et al. (2018), MD that migrates inland has been deposited in coastal vegetation, and this, together with inputs from land, has resulted in the buildup of significant volumes of debris. Accumulation of debris has been influenced by various factors such as wind, currents, and population areas (Wessel et al., 2019). Meanwhile, according to Isyrini et al. (2019), coastal morphology and wave direction patterns have a significant role and contribute to the increasing volume of marine debris. Observation of garbage, particularly along the seashore, is critical since various variables are unknown. The disparities in the location's features, population density, and the degree of consciousness of the people living along the shore necessitate continual monitoring.

Effective waste observation methods for complex marine areas should be continuously developed with sophisticated and accurate methods to get better results. Information related to spatiotemporal debris in several observation areas also needs improvement.

Fig. 5. *The sea current patterns in January (top) and July (bottom)*



This spatiotemporal data formulate appropriate policies in handling marine debris in Indonesia. Furthermore, reliable data on plastic pollution eliminate plastics to overcome global MD problems and mitigate disasters caused by the debris. Observations focused on environmental systems in diverse MDs by specific timescales and environments increasingly lead to more prudent and sustainable management.

Conclusions

MD was detected in the coastline region of Sinjai Regency between January and July in the following percentages: plastic 86%, metal 3%, rubber 4%, glass 5% in January and 4% in July, clothing 2% in January and 1% in July. For plastic waste, 4.59 items/m^2 and 2.5 items/m^2 were generated in July and January, respectively. One of the factors is the element of ocean currents that flow to the mainland in July. Additionally, debris entering through rivers, local waste, and tourism activities at the four observation areas contribute to the existence of MD in Sinjai's coastal area.

Acknowledgements

The authors are grateful to the Universitas Muhammadiyah Sinjai, Indonesia, (Research Fund 2020-2021) for supporting this study.

References

Ambrose, K. K., Box, C., Boxall, J., Brooks, A., Eriksen, M., Fabres, J., Fylakis, G., and Walker, T. R. (2019). Spatial Trends and Drivers of Marine Debris Accumulation on Shorelines in South Eleuthera, The Bahamas Using Citizen Science. Marine Pollution Bulletin, 142, 145-154. https://doi.org/10.1016/j.marpolbul.2019.03.036

Arun Kumar, A., Sivakumar, R., Sai Rutwik, Y., Nishanth, T., Revanth, V., and Kumar, S. (2019). Marine Debris in India: Quantifying Type and Abundance of Beach Litter Along Chennai, East Coast of India. Springer Singapore. https://doi.org/10.1007/978-981-13-6148-7_23

Brennan, E., Wilcox, C., and Hardesty, B. D. (2018). Connecting Flux, Deposition and Resuspension in Coastal Debris Surveys. Science of Total Environment, 644, 1019-1026. https://doi.org/10.1016/j.scitotenv.2018.06.352

Chen, H., Wang, S., Guo, H., Lin, H., Zhang, Y., Long, Z., and Huang, H. (2019). Study of marine debris around a tourist city in East China: Implication for waste management. Science of the Total Environment, 676, 278-289.https://doi.org/10.1016/j.scitotenv.2019.04.335

David, A., Thangavel, Y. D., and Sankriti, R. (2019). Recover, Recycle and Reuse: An Efficient Way to Reduce the Waste. International Journal of Mechanical and Production Engineering Research and Development, 9(3), 31-42. www.tjprc.org https://doi.org/10.24247/ijmperdjun20194

Djaguna, A., Pelle, W. E., Schaduw, J. N. W., Hermanto, W. K., Rumampuk, N. D. C., and Ngangi, E. L. A. (2019). Identifikasi Sampah Laut Di Pantai Tongkaina dan Talawaan bajo (Identification of Marine Debris on Tongkaina and Talawaan Bajo Beach). Jurnal Pesisir Dan Laut Tropis, 7(3), 174-182. https://doi.org/10.35800/jplt.7.3.2019.24432

Fajriah, N., Fauzi, M., and Sumiarsih, E. (2020). Composition and Density of Marine Debris in the Mangrove Ecosystems of the Sungai Rawa Village, Sungai Apit Subsdistrict, Siak Regency, Riau Province. Asian Journal of Aquatic Sciences, 2(1), 29-38. https://doi.org/10.31258/ajoas.2.1.29-38

Fitria, R., Diana, F., Riani, E., Yulianto, G., and Najmi, N. (2019). Analysis of sources and composition of marine debris in western and southern Aceh, Indonesia. IOP Conference Series: Earth and Environmental Science, 404(1). https://doi.org/10.1088/1755-1315/404/1/012059

Gaibor, N., Condo-Espinel, V., Cornejo-Rodríguez, M. H., Darquea, J. J., Pernia, B., Domínguez, G. A., Briz, M. E., Márquez, Lady, Laaz, E., Alemán-Dyer, C., Avendaño, U., Guerrero, J., Preciado, M., Honorato-Zimmer, D., and Thiel, M. (2020). Composition, abundance and sources of anthropogenic marine debris on the beaches from Ecuador - A volunteer-supported study. Marine Pollution Bulletin, 154(September 2019), 1-6. https://doi.org/10.1016/j.marpolbul.2020.111068

Hantoro, I., Löhr, A. J., Van Belleghem, F. G. A. J., Widianarko, B., and Ragas, A. M. J. (2019). Microplastics in coastal areas and seafood: implications for food safety. Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment, 36(5), 674-711. https://doi.org/10.1080/19440049.2019.1585581

Hardesty, B. D., Lawson, T. J., van der Velde, T., Lansdell, M., and Wilcox, C. (2017). Estimating quantities and sources of marine debris at a continental scale. Frontiers in Ecology and the Environment, 15(1), 18-25. https://doi.org/10.1002/fee.1447

Honingh, D., van Emmerik, T., Uijttewaal, W., Kardhana, H., Hoes, O., and van de Giesen, N. (2020). Urban River Water Level Increase

Through Plastic Waste Accumulation at a Rack Structure. Frontiers in Earth Science, 8(February), 1-8. https://doi.org/10.3389/feart.2020.00028

Isyrini, R., Nafie, Y. A. L., Ukkas, M., Rachim, R., and Cordova, M. R. (2019). Marine Macro Debris from Makassar Strait Beaches with Three Different Designations. IOP Conference Series: Earth and Environmental Science, 253(1), 1-12. https://doi.org/10.1088/1755-1315/253/1/012039

Jambeck, J. R., Ji, Q., Zhang, Y.-G., Liu, D., Grossnickle, D. M., and Luo, Z.-X. (2015). Plastic waste inputs from land into the ocean. In Marine Pollution (Vol. 347, Issue 6223). http://www.sciencemag.org/cgi/doi/10.1126/science.1260879 https://doi.org/10.1126/science.1260352

Jang, Y. C., Ranatunga, R. R. M. K. P., Mok, J. Y., Kim, K. S., Hong, S. Y., Choi, Y. R., and Gunasekara, A. J. M. (2018). Composition and Ambundance of Marine Debris Stranded on the Beaches of Sri Lanka: Results from the First Island-wide Survey. Marine Pollution Bulletin, 128, 126-131. https://doi.org/10.1016/j.marpolbul.2018.01.018

Jasmin, H. ., Purba, N. P., Harahap, S. A., Pranowo, W. S., Syamsuddin, M. L., and Faizal, I. (2019). The model of macro debris transport before reclamation and in existing condition in jakarta bay. Jurnal Ilmu Dan Teknologi Kelautan Tropis, 11(1), 131-140. https://doi.org/10.29244/jitkt.v11i1.24777

KLHK. (2019). Pedoman Pemantauan Sampah Laut. Kementerian Lingkungan Hidup dan Kehutanan.

Lasut, M. T., Pane, L. R., Doda, D. V.D., Kumurur, V. A., Warouw, V., and Mamuaja, J. M. (2021). Seasonal variation of marine debris at Manado Bay (North Sulawesi, Indonesia). IOP Conference Series: Earth and Environmental Science, 744(1). https://doi.org/10.1088/1755-1315/744/1/012038

Lebreton, L. C. ., van der Zwet, J., Damsteeg, J., Slat, B., Andardy, A., and Reisser, J. (2017). River Plastic Emissions to the World's Oceans. In Nature Communications (Vol. 8, Issue 15611). https://doi.org/10.1038/ncomms15611

Lippiatt, S., Opfer, S., and Arthur, C. (2013). Marine Debris Monitoring and Assessment. In NOAA Technical Memorandum. NOAA Technical Memorandum NOS-ORandR-46. http://marinedebris.noaa.gov/sites/default/files/Lippiatt_et_al_2013.pdf

Loulad, S., Houssa, R., Ouamari, N. EL, and Rhinane, H. (2019). Quantity and spatial distribution of seafloor marine debris in the Moroccan Mediterranean Sea. Marine Pollution Bulletin, 139(August 2018), 163-173. https://doi.org/10.1016/j.marpolbul.2018.12.036

Mardiatno, D., and Wiratama, H. (2021). Spatiotemporal Analysis of Marine Debris Existence in Parangtritis Coastal Area, Yogyakarta, Indonesia. Journal of Fisheries and Marine Research, 5(1), 91-98. https://doi.org/10.21776/ub.jfmr.2021.005.01.14

Maximenko, N., Corradi, P., Law, K. L., Sebille, E. V., Garaba, S. P., Murphy, L. G., and Moller, D. (2019). Toward the Integrated Marine Debris Observing System. In Frontiers in Marine Science (pp. 1-25). www.frontiersin.org https://doi.org/10.3389/fmars.2019.00447

Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., and Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Science Advances, 7(18), 1-14. https://doi.org/10.1126/sciadv.aaz5803

NOAA. (2013). Programmatic Environmental Assessment (PEA) for the NOAA Marine Debris Program (MDP).

Ondara, K., and Dhiauddin, R. (2020). Indonesia Marine Debris: Banda Aceh Coastal Environment Identification. Jurnal Kelautan Tropis, 23(1), 117. https://doi.org/10.14710/jkt.v23i1.6238

Opfer, S., Arthur, C., and Lippiatt, S. (2012). NOAA Marine Debris Shoreline Survey Field Guide. In NOAA Marine Debris Programm (Issue January). National Oceanic and Atmospheric Administration.

Pieper, C., Amaral-Zettler, L., Law, K. L., Loureiro, C. M., and Martins, A. (2019). Application of Matrix Scoring Techniques to evaluate marine debris sources in the remote islands of the Azores Archipelago. Environmental Pollution, 249, 666-675. https://doi.org/10.1016/j.envpol.2019.03.084

Purba, N.P., Faizal, I., Abimanyu, A., Zenyda, K. ., Jaelani, A., Indrawan, D., Priadhi, M. ., and Martasuganda, M. . (2020). Vulnerability of Java Sea marine protected areas affected by marine debris Vulnerability of Java Sea marine protected areas affected by marine debris. International Conference on Fisheries and Marine, 1-9. https://doi.org/10.1088/1755-1315/584/1/012029

Purba, Noir P, Faizal, I., Cordova, M. R., Abimanyu, A., Afandi, N. K. A., Indriawan, D., and Khan, A. M. A. (2021). Marine Debris Pathway Across Indonesian Boundary Seas. Journal of Ecological Enginering, 22(3), 82-98. https://doi.org/10.12911/22998993/132428

Purba, Noir P, Handyman, D. I. W., Pribadi, T. D., Syakti, A. D., Pranowo, W. S., Harvey, A., and Ihsan, Y. N. (2019). Marine debris in Indonesia : A review of research and status. Marine Pollution Bulletin, 146(March), 134-144. https://doi.org/10.1016/j.marpolbul.2019.05.057

Rachmayani, R., Ningsih, N. S., Ramadhan, H., and Nurfitri, S. (2018). Analysis of ocean wave characteristic in Western Indonesian Seas using wave spectrum model. MATEC Web of Conferences, 147, 1-12. https://doi.org/10.1051/matecconf/201814705001

Rahmayanti, F., Diana, F., Najmi, N., Riani, E., Yulianto, G., and Munandar. (2020). Analisis Kelimpahan, Komposisi dan Sumber SampahLaut : Studi Kasus Pada Pantai Kuala Batu Desa Pulau Kayu Kabupaten Aceh Barat Daya. 2(2012), 49-59. https://doi.org/10.35308/jlaot.v2i1.2361

Renjaan, E. A., Silubun, D. T., Latar, D. I., and Makailipessy, M.

(2020). Beach orientation and exposure accumulate types of marine debris on the coast of Dullah Island, kei archipelago, Indonesia. IOP Conference Series: Earth and Environmental Science, 517(1). https://doi.org/10.1088/1755-1315/517/1/012015

Siregar, S. N., Sari, L. P., Purba, N. P., Pranowo, W. S., and Syamsuddin, M. L. (2017). Pertukaran massa air di Laut Jawa terhadap periodisitas monsun dan Arlindo pada tahun 2015. Depik, 6(1), 44-59. https://doi.org/10.13170/depik.6.1.5523

Tahir, A., Werorilangi, S., Isman, F. M., Zulkarnaen, A., Massinai, A., and Faizal, A. (2019). Short-Term Observation on Marine Debris At Coastal Areas of Takalar District and Makassar City, South Sulawesi-Indonesia. Jurnal Ilmu Kelautan SPERMONDE, 4(2), 48-53. https://doi.org/10.20956/jiks.v4i2.7061

Uhrin, A. V., Lippiat, S., Herring, C. E., Dettloff, K., Bimrose, K., and Butler-Minor, C. (2020). Temporal Trends and Potential Drivers of Standed Marine Debris on Beaches Within Two US National Marine Sanctuaries Using Citizen Science data. Frontiers in Environmental Science, 8(November 2020), 1-19. https://doi.org/10.3389/fenvs.2020.604927

UNEP. (2016). Marine Plastic Debris and Microplastics Global Lessons and Research to Inspire Action and Guide Policy Change. United Nations Environment Programme.

Van Emmerik, T., Loozen, M., Van Oeveren, K., Buschman, F., and Prinsen, G. (2019). Riverine plastic emission from Jakarta into the ocean. Environmental Research Letters, 14(8). https://doi.org/10.1088/1748-9326/ab30e8

Vriend, P., Hidayat, H., Leeuwen, J. Van, Cordova, M. R., Purba, N. P., and Löhr, A. J. (2021). Plastic Pollution Research in Indonesia : State of Science and Future Research Directions to Reduce Impacts. 9(June), 1-12. https://doi.org/10.3389/fenvs.2021.692907

Wessel, C., Swanson, K., Weatherall, T., and Cebrian, J. (2019). Accumulation and distribution of marine debris on barrier islands across the northern Gulf of Mexico. Marine Pollution Bulletin, 139(July 2018), 14-22. https://doi.org/10.1016/j.marpolbul.2018.12.023

Yin, C. S., Chai, Y. J., Danielle, C., Yusri, Y., and Barry, G. J. (2020). Anthropogenic Marine Debris Accumulation in Mangroves on Penang Island, Malaysia. Journal of Sustainability Science and Management, 15(6), 36-60. https://doi.org/10.46754/jssm.2020.08.004