Spatial Distribution of Marine Debris Pollution in Mangrove-Estuaries Ecosystem of Kendari Bay

Saban Rahim1,3,*, Weka Widayati1, Kangkuso Analuddin2, Fitra Saleh1, Alfirmam1, and Safruddin Sahar1

1Department of Geography, Faculty of Earth Science and Technology, Halu Oleo University, Kendari 93232, Indonesia
2Department of Biology, Faculty of Mathematics and Natural Sciences, Halu Oleo University, Kendari 93232, Indonesia
3Postgraduate Student of Department of Agricultural Sciences, Postgraduate Program, Halu Oleo University, Kendari 93232, Indonesia

* sabanrahim27@gmail.com

Abstract. Marine debris is a solid material that is either accidentally or accidentally disposed of in a river that empties into the sea or is left directly in the sea. The research on marine debris is carried out in the estuary and mangrove forest areas of Kendari Bay which is assumed to be accommodated garbage sites that enter the coastal area. The purpose of this study is to identify the types of composition and potential sources of marine waste contributors found in several river estuaries and mangrove forest areas, to know the density of marine debris and to mapping the distribution of marine debris from several river estuaries and mangrove forest in Kendari Bay. This research was conducted by survey method and using 5x5 quadratic plots in a random sampling. The data obtained were analyzed statistically and map overlays. The results showed that the composition of marine debris types in mangrove ecosystems and estuaries in Kendari Bay generally consisted of plastic (plastic bottles, plastic bags, ropes, pipettes, plastic cups), metals (beverage cans), rubber, glass (glass bottles) and others (cloth, paper and others) with the dominant amount of plastic waste. The highest total density of waste types in the four locations in the mangrove ecosystem and river estuary in Kendari Bay is at station 1 (Lahundape Mangrove Tracking Area). The density of plastic waste dominates the four locations in the mangrove ecosystem with the highest value of 3,024 items/m2 in the mangrove ecosystem around the estuary of Mandonga and Lahundape. The high distribution of marine debris in the mangrove ecosystem is found at station 1 and station 2 because it is directly related to the river flow which contributes greatly to marine debris input in Kendari Bay.

1. Introduction
Coastal areas and estuaries are important areas of biological productivity, geochemistry, and human activities. This area is very important as a provider of food, recreation, and transportation that supports economic activities. Coastal areas and river estuaries are said to be the most productive of the world's biomass and serve important life support systems for humans [1]; [2]. Coastal ecosystems and river estuaries are some of the most widely used and threatened natural systems globally [3]; [4]; [5]; [6], and setbacks due to human activities are very intense and increasing [6]. One activity in coastal areas that has the potential to disrupt the health of the oceans and change the quality of the waters is the presence of marine debris caused by anthropogenic activities [7]. Various kinds of problems arise due to the presence of marine debris such as reduced beauty of coastal areas, causing various kinds of diseases, affecting food networks, reduced productivity of fish resources and can affect the balance of ecosystems in coastal areas. If this happens and continues, then the influence on the food chain, economy, and health of the people in the area cannot be avoided [8].

The high human activity, it is feared will produce landfills in residential areas on the banks of the river. Along with the increasing population in this region, garbage in coastal areas is one of the complex problems faced by cities that are right or adjacent to the beach or riverbank [8]. [9] describes marine debris as a persistent solid, produced or processed by humans, directly or unintentionally dumped or abandoned in the marine environment. Types of marine waste include plastic, cloth, foam, styrofoam, glass, ceramics, metal, paper, rubber, and leather. The most widely produced marine debris...
from the community is plastic waste that is often used in daily life. However, discarded plastic waste can cause other problems, namely soil contamination, and disturbing environmental aesthetics. The spread of marine debris in coastal areas is strongly influenced by currency movements. Movement of water masses/currents can carry waste in the waters at a considerable distance [10]. Flow in coastal areas or events of movement of water masses is strongly influenced by winds and tides [11].

The problem of marine debris also appears in the waters of Kendari Bay especially if it is the rainy season. The increasing in human populations has resulted in the high production of garbage in Kendari Bay. Some of the rivers that flow into Kendari Bay will contribute to marine debris because people living around the river use the river as a garbage dump. This affects the condition of coastal areas and the sea as a place to move these rivers. Marine debris that arrives in coastal areas will be trapped in the mangrove community and will disturb the growth of mangrove tillers when covered by plastic waste. Such conditions will cause ecological instability where the community as resource users is in the ecological system. The potential of marine debris is the main problem of coastal and marine pollution, but there is little quantitative information regarding pollution of marine waste in river mouths and mangrove ecosystems. Besides, marine debris problems have not been a concern in determining ecosystem management strategies. The spatial distribution of marine debris in mangrove ecosystems and estuaries is quantitative information in determining the strategy for management and planning for Kendari Bay development.

The purpose of this study was to determine the composition and abundance of marine debris, to determine the density of marine debris, and to mapping the spatial distribution of marine debris in the mangrove ecosystem and estuaries in Kendari Bay.

2. Materials and Methods
The present study of mangrove ecosystems and estuaries at the Kendari Bay, which is located at the four stations (Fig. 1) with coordinate of station 1 (E: 03°58′16.77″ and S: 122°31′48.56″), station 2 (E: 03°58′35.08″ and S: 122°31′56.06″), station 3 (E: 03°53′42″ and S: 122°32′3.37″) and station 4 (E: 03°59′93″ and S: 122°32′45.07″). The location of the study can be found in the picture below in

| Station | Characteristic area |
|---------|---------------------|
| 1       | Lahundape mangrove tracking area, Lahundape, Mandonga and Malik Raya river estuary |
| 2       | Mangrove forest behind Pertamina Horse Footprint, Wanggu river estuary |
| 3       | Mangrove forest between the Wanggu river estuary and the Kambu River estuary |
| 4       | Mangrove forest in front of Kendari City DPRD Office |
Figure 1. Study Site of Kendari bay

This research was carried out by using a survey method by determining plot sampling squares (5x5 m$^2$) in each station in a random sampling. The collection of marine debris at the estuaries uses net by stretching net on the surface of the water in the estuary area of the river to calculate the mass of garbage that will enter the sea during high tides every day for one week of observation. Data on the composition and abundance of marine debris are analyzed statistically because the number of marine debris collected cannot be represented by weights. Waste density is calculated by referring to the transect method proposed by[12], was calculated using the equation:

$$D = \frac{n}{A}$$

where density (D) is the amount of marine debris (kg/km$^2$) per station. n is the number of debris collected per haul for a given category and A is area swept per (m$^2$). To analyze the spatial distribution of marine debris used two land cover map of Kendari Bay in 2017.

3. Results and Discussion

3.1 The Condition of mangrove forests in Kendari Bay

Based on the results of overlaying mangrove changes into buildings, it can be seen how much mangrove has been reduced due to land use for buildings. The area of mangrove was reduced due to development activities along the Kendari bay, which amounted to 105.58 ha, while the green area which was reduced due to changes in mangroves to buildings was from 113.7 ha to 103.2 ha. Extensive land use of mangrove forests in Kendari Bay area in 1990, 2003 and 2017 (Table 2).

| Year | Area (ha) |
|------|-----------|
| 1990 | 220.03    |
| 2003 | 141.12    |
| 2017 | 103.32    |

Table 2 above shows the mangrove forest area in 1990 amounted to 220.03 ha, in 2003 it was 141.12 ha and in 2017 it was 103.32 ha. Changes in the area of mangrove forests in the Kendari Bay region can be seen in Table 5, showing that the largest decrease in mangrove forest area occurred.
between 1990-2003 in a period of thirteen years, a decline of up to 78.91 ha while in the period of mangrove forest in 2003-2017 in fourteen years there was a decline of up to 37.8 ha, then the total decrease in mangrove forest in 1990-2017 was 116.71 ha.

3.2 Composition and density of marine debris in Kendari Bay

The types of waste identified in the mangrove ecosystem in Kendari Bay according to the [13] classification found several types of marine debris including plastic, metals, rubber, glass, and others. The composition and number of types of waste in the mangrove ecosystem in Kendari Bay area at station 1 (Lahundape mangrove tracking area) are plastic waste (378 items / m²), metal waste (3 items / m²), rubber waste (7 items / m²), garbage glass (2 items / m²), and other waste consisting of cloth, paper and organic (8 items / m²). The composition of the type of waste at Station 2 (mangrove forest behind Pertamina Horse Footprint) is plastic waste (234 items / m²), metal waste (2 items / m²), rubber waste (6 items / m²), glass waste (3 items / m²) and other waste consisting of cloth (3 items / m²). The composition and number of types of waste at station 3 (mangrove forest between the Wanggu river estuary and the Kambu River estuary) are plastic waste (159 items / m²), metal waste (2 items / m²), rubber waste (2 items / m²), glass waste (2 items / m²), and other waste consisting of cloth (3 items / m²). Meanwhile, the composition and number of types of waste at station 4 (mangrove forest in front of Kendari City DPRD Office) are plastic waste (220 items / m²), rubber waste (2 items / m²), glass waste (4 items / m²), and other waste consisting of cloth (5 items / m²). The type of plastic waste dominates all observation stations with the type of plastic waste found including straps, buoys, pipettes, matches, plastic bags and plastic bottles. A large number of types of plastic waste found to dominate the Kendari Bay mangrove ecosystem shows that plastic waste is easily carried away by water through river flows or carried by tides. Besides, the presence of plastic waste is suspected due to the dumping of plastic waste carelessly in the river and the mangrove ecosystem. For more details, the composition and amount of marine debris in the mangrove ecosystem can be seen in figure 2 below.

The density of marine debris found in the mangrove ecosystem in Kendari Bay appears to be a plastic waste with the highest density value per station. Based on observational data shows that the highest density of plastic waste was found at station 1 (Lahundape mangrove tracking area) of 3,024 types / m², then respectively at station 2 (mangrove forest behind Pertamina Tapak Kuda) of 1,872 types / m², then station 4 (mangrove forest in front of Kendari City DPRD Office) of 1.76 species / m², and the lowest at station 3 (mangrove forest between the estuary of the Wanggu river and the Kambu river estuary) of 1,272 types / m². The high density of waste found at station 1 (the Lahundape mangrove tracking area) shows that in the area is the distribution of marine debris originating from rivers and those carried by the tides. Also, the high density of marine debris at station 1 in the mangrove tracking area of Lahundape is thought to have originated from land carried by the river flow, namely from the Malik Raya and Mandonga rivers and the Kemaraya river flow which empties into Lahundape Kendari Bay around the Tracking Lahundape mangrove area. For more details, the density of marine debris types in the mangrove ecosystem in Kendari Bay is shown in figure 3 below.

![Figure 2](image1.png)  
**Figure 2.** Composition and Number of Types of Marine Debris in Mangrove Ecosystem in Kendari Bay

![Figure 3](image2.png)  
**Figure 3.** The Density of Marine of Mangrove Ecosystem in Kendari Bay
The high density of waste at station 1 is caused by the presence of mangroves where the mangrove roots become traps inorganic trash that is carried or disposed of directly by the surrounding community. The presence of waste in the mangrove area can disturb organisms associated with mangroves, especially the resources of mollusks. The closure of the mangrove substrate by inorganic waste will disturb the resource habitat that lives in the base area. Plastic waste has a very large influence on the environment, especially on the growth of seagrass and mangroves, causing death [14].

The highest total density of waste types in the four locations in the mangrove ecosystem and two river estuaries in Kendari Bay are at station 1 (Lahundape mangrove tracking area). The density of plastic waste dominates the four locations in the mangrove ecosystem and two river estuaries with the highest value of 3,024 species / m² in the mangrove ecosystem around the estuary of Mandonga and Muara Lahundape. This is due to the location of the river which is directly adjacent to the trade and residential areas so that the waste disposal activity will be concentrated in the river, which causes a buildup of garbage at the river mouth. Also, the location has a high density and density of mangrove forests so that trash can easily be trapped in the mangrove roots and mangrove tillers. Oceanographic factors also have an important role in the spread of pollutants (garbage) in water such as seasons and currents [15]. The rainy season that continues will cause waste to be carried away. At that time a large amount of waste will be carried away by the current and will accumulate in a place so that it has a negative impact on the system ecology of the area. Wood waste that enters the river will be held on the river body with a small current speed.

3.3 The Weight of marine debris in the mangrove-estuaries of Kendari Bay

The total mass of marine debris collected at four observation station locations in the mangrove ecosystem with a total sampling area of 500 m² was 22,157 kg. Generally collected marine debris is trash that has long been trapped in the mangrove ecosystem both in sediments and that is caught in mangrove trees. The mass of marine debris at station 2 (mangrove forest behind Pertamina Tapak Kuda) is the highest with a weight of 9,138 kg. Subsequently, the marine debris mass at station 1 (Lahundape mangrove tracking area) amounted to 6,253 kg, marine debris mass at station 3 (mangrove forest between the Wanggu river estuary and the Kambu river estuary) at 3,385 kg and marine debris mass at station 4 (forest mangrove in front of Kendari City DPRD Office) of 3,381 kg. For more details, the mass of marine debris in the mangrove forest ecosystem of Kendari Bay can be seen in picture 4 below.

![Figure 4. The Weight of Marine Debris in the Mangrove Ecosystem of Kendari Bay](image_url)
3.4 The Spatial distribution of marine debris pollutions in Kendari Bay

The distribution of marine debris found in the mangrove and estuarine ecosystems in Kendari bay is 5 types in general (Figure 5). The highest amount of waste found at station 1 is then station 2, station 4 and station 3. Station 1 has a high amount of marine debris compared to other islands. It is suspected that the distribution of waste originating from rivers is trapped in the estuary and mangrove ecosystem in both sediments and the stems of mangrove plants. Also, marine debris is also carried by tidal waves and trapped in the mangrove ecosystem both in mangrove trees and in roots and sediments. Also, there is human activity because in the 1st Pension is the mangrove tracking area of Lahundape which is the tourist area of Kendari City.

![Figure 5. The Distribution of Marine Debris Pollutions in Kendari Bay](image)

The amount of plastic waste in the sea originates and is influenced by the activity and number of human populations, such as in high population areas namely China, Indonesia [16] and the Republic of the Marshall Islands [17]. The accumulation of rubbish fragments originating from humans is significantly correlated with the growth of human populations such as in the equator to the poles [18] and Manabi, Ecuador [19]. Furthermore, according to [17], waste increases along with the per capita income of the middle and low population.

Spatial maps of the density of marine debris pollution can be seen in figure 6 below.
4. Conclusion
The distribution of marine debris pollution in the mangrove ecosystem and estuary in Kendari Bay is caused by the activity of dumping garbage from the land carried through the river flow and tides condition so that transported marine debris material is trapped in the mangrove ecosystem. The distribution of marine debris in the high mangrove ecosystem is found at Station 1 and Station 2 because it is directly related to the river flow which contributes greatly to the contribution of marine debris in Kendari Bay.

Acknowledgment
We thank Halu Oleo University for support and give opportunities for this research. We would also like to thank general volunteers who helped during field working.

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