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### Sustainable Tourism Mitigation Strategy on Plastic Waste Problems in Mangrove Forests

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**Abstract:** Mangrove forests play an important role in maintaining biodiversity and global climate balance, as well as providing various ecological and economic benefits. However, plastic pollution, especially microplastics, is increasingly threatening this ecosystem. The main causes of damage are increased plastic production, irresponsible human behavior, and inadequate waste management infrastructure. The accumulation of microplastics in mangrove areas impacts flora and fauna and poses a risk to humans through the food chain. Indonesia, as a country with the largest mangrove area in the world, is also the largest contributor of plastic waste to the ocean. To address this problem, a comprehensive approach is needed, including more effective waste management, education, and increasing public awareness. Sustainable tourism strategies can play an important role in mitigating plastic waste, including the "No Plastic Straw" and "No Plastic Bag" campaigns, training programs for communities and tourists, and waste management that involves local communities. Collaboration between the government, NGOs, and communities is key to preserving mangrove forests. Implementing these steps is expected to support sustainable tourism, reduce pollution, and maintain the sustainability of mangrove ecosystems in the long term.

**Keywords:** Mangrove Forests, Plastic Pollution, Microplastics, Sustainable Tourism.

#### 1. Introduction

Mangrove Forest Areas have a very vital role in maintaining the biodiversity that lives in them and for humans. Mangrove forests have various benefits such as protecting coastlines from erosion, holding back floods, tsunamis, and hurricanes, providing wood products, providing food sources (Deng et al., 2021; Kulkarni et al., 2018), improving water quality, and absorbing carbon dioxide (Agarwal et al., 2017; Alongi, 2014; Cullen, 2024). These Mangrove forests cover about 0.1% of the earth's surface but play an important role in providing wildlife habitat and regulating global climate stability. These mangrove soils contain three to four times the mass of carbon commonly found in boreal, temperate, or tropical forests (Agarwal et al., 2017; Alongi, 2014; Cullen, 2024).

Mangrove forests are coastal resources that also play an important role in the development of a region or a country. One of these developments is the existence of Mangrove ecotourism. With this ecotourism, in addition to being beneficial for the environment and tourists who come, this mangrove ecotourism is also useful in increasing community income, providing business opportunities for the surrounding community, and providing other benefits for the surrounding community (Heriyanto et al., 2023).

Despite the socio-ecological benefits of the Mangrove ecosystem, the destruction of the Mangrove ecosystem is increasing in several regions of the world. One of the causes of the destruction of the Mangrove ecosystem is plastic waste and plastic waste has been recognized as a major threat to Mangrove forests (Ovuare et al., 2019). Mangrove areas appear to have more microplastics than the surrounding non-mangrove areas (Zhou et al., 2020). Of the total waste in the ocean, 80-85% is plastic waste (Deng et al., 2021; Derriak, 2002). In recent decades, there has often been a problem of plastic waste accumulation in the sea, one of which is in the Mangrove area. This is due to the mass production of plastic and increasing every year (Geyer et al., 2017), coupled with inefficient disposal and recycling systems, which has resulted

in more and more waste entering the marine environment (Lebreton et al., 2017; Jambeck et al., 2015). In addition, it is also exacerbated by the behavior of the community and tourists who still often throw garbage into water areas (Saifi & Susanto, 2024).

Mangrove water pollution by microplastic particles is coastal plastic waste pollution that has become a major water pollution problem in developing countries, especially Southeast Asia (van Bijsterveld et al., 2021) and one of them is Indonesia. Mangrove forests in Indonesia have a total area of around 3 million hectares or around 23% of global mangrove forests (Thomas et al., 2017) and are ranked first in the largest mangrove forests in the world (Rahadian et al., 2019; Widyumingsih, 2021), but Indonesia is the largest contributor of plastic pollutants to the sea in the world after China (Y. Wang & Karasik, 2022).

Mangrove forests appear to be free of plastic waste, but there are still microplastics that dominate the mangrove sediments. This is because only 1% of the plastic that enters the marine environment is still floating on the water surface, and the stock of this plastic is mainly reduced in sizes <1 mm. This is due to a series of size-dependent removal processes, such as consumption by fauna, sinking to deeper layers of the water column, and sequestration in sediments (Martin et al., 2020).

Waste pollution in the Mangrove Area has an impact on flora and fauna in the Mangrove ecosystem. Other pollution such as heavy metals and domestic waste also have an impact on the accumulation of contamination in seafood species. When viewed from the aspect of food safety, seafood contaminated with microplastics is not safe for consumption (Hamono & Widiamarso, 2018). If microplastics enter and are digested by marine biota, then the body of the biota may also contain toxins from chemicals. Because of its microscopic size, microplastics can enter not only marine biota, but also the human body, either directly or indirectly through the food chain, where both processes will cause pathological changes (Hamono & Widiamarso, 2018).

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# Sustainable Tourism Mitigation Strategy on Plastic Waste Problems in Mangrove Forests

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**Abstract:** Mangrove forests play an important role in maintaining biodiversity and global climate balance, as well as providing various ecological and economic benefits. However, plastic pollution, especially microplastics is increasingly threatening this ecosystem. The main causes of damage are increased plastic production, irresponsible human behavior, and inadequate waste management infrastructure. The accumulation of microplastics in mangrove areas impacts flora and fauna and poses a risk to humans through the food chain. Indonesia, as a country with the largest mangrove area in the world, is also the largest contributor of plastic waste to the ocean. To address this problem, a comprehensive approach is needed, including more effective waste management, education, and increasing public awareness. Sustainable tourism strategies can play an important role in mitigating plastic waste, including the "No Plastic Straw" and "No Plastic Bags" campaigns, training programs for communities and tourists, and waste management that involves local communities. Collaboration between the government, NGOs, and communities is key to preserving mangrove forests. Implementing these steps is expected to support sustainable tourism, reduce pollution, and maintain the sustainability of mangrove ecosystems in the long term.

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## 1. Introduction

Mangrove Forest Areas have a very vital role in maintaining the biodiversity that lives in them and for humans. Mangrove forests have various benefits such as protecting coastlines from erosion, holding back floods, tsunamis, and hurricanes, providing wood products, providing food sources (Deng et al., 2021; Kulkarni et al., 2018), improving water quality, and absorbing carbon dioxide (Agarwal et al., 2017; Alongi, 2014; Cullen, 2024). These Mangrove forests cover about 0.1% of the earth's surface but play an important role in providing wildlife habitat and regulating global climate stability. These mangrove soils contain three to four times the mass of carbon commonly found in boreal, temperate, or tropical forests (Agarwal et al., 2017; Alongi, 2014; Cullen, 2024).

Mangrove forests are coastal resources that also play an important role in the development of a region or a country. One of these developments is the existence of Mangrove ecotourism. With this ecotourism, in addition to being beneficial for the environment and tourists who come, this mangrove ecotourism is also useful in increasing community income, providing business opportunities for the surrounding community, as a place for employees to reduce unemployment, and providing other benefits for the surrounding community (Heriyanto et al., 2023).

Despite the socio-ecological benefits of the Mangrove ecosystem, the destruction of the Mangrove ecosystem is increasing in several regions of the world. One of the causes of the destruction of the Mangrove ecosystem is plastic waste and plastic waste has been recognized as a major threat to Mangrove forests (Owuor et al., 2019). Mangrove areas appear to have more microplastics than the surrounding non-mangrove areas (Zhou et al., 2020). Of the total waste in the ocean, 80–85% is plastic waste (Deng et al., 2021; Derraik, 2002). In recent decades, there has often been a problem of plastic waste accumulation in the sea, one of which is in the Mangrove area. This is due to the mass production of plastic and increasing every year (Geyer et al., 2017), coupled with inefficient disposal and recycling systems, which has resulted

more and more waste entering the marine environment (Lebreton et al., 2017; Jambeck et al., 2015). In addition, it is also exacerbated by the behavior of the community and tourists who still often throw garbage into water areas (Saifi & Susanto, 2024).

Mangrove water pollution by microplastic particles is coastal plastic waste pollution that has become a major water pollution problem in developing countries, especially Southeast Asia (van Bijsterveldt et al., 2021) and one of them is Indonesia. Mangrove forests in Indonesia have a total area of around 3 million hectares or around 23% of global mangrove forests (Thomas et al., 2017) and are ranked first in the largest mangrove forests in the world (Rahadi et al., 2019; Wahyuningsih, 2021), but Indonesia is the largest contributor of plastic pollutants to the sea in the world after China (Y. Wang & Karasik, 2022).

Mangrove forests appear to be free of plastic waste, but there are still microplastics that dominate the mangrove sediments. This is because only 1% of the plastic that enters the marine environment is still floating on the water surface, and the stock of this plastic is mainly reduced in sizes <1 mm. This is due to a series of size-dependent removal processes, such as consumption by fauna, sinking to deeper layers of the water column, and sequestration in sediments (Martin et al., 2020).

Waste pollution in the Mangrove Area has an impact on flora and fauna in the Mangrove ecosystem. Other pollution such as heavy metals and domestic waste also have an impact on the accumulation of contamination in seafood species. When viewed from the aspect of food safety, seafood contaminated with microplastics is not safe for consumption (Hantoro & Widianarko, 2018). If microplastics enter and are digested by marine biota, then the body of the biota may also contain toxins from chemicals. Because of its microscopic size, microplastics can enter not only marine biota, but also the human body, either directly or indirectly through the food chain, where both processes will cause pathological changes (Hantoro & Widianarko, 2018).

Oliveira et al. (2020) stated that successful measures at the

local level or addressing one product stream are often undermined or offset by the emergence of new types of plastic, new exposure pathways, and new additives. Therefore, a more comprehensive approach is needed, namely an approach that considers various regulatory tools, education, awareness raising, and encouraging voluntary actions throughout the life cycle of plastic products and materials, which is more likely to be successful. Therefore, strategic steps are needed, one of which is sustainable tourism so that ecotourism activities do not further worsen pollution conditions in the Mangrove area, but can reduce and even protect mangrove forests while making Mangrove forests generate income for the surrounding community so that economic benefits can be felt by the community without destroying the Mangrove forest.

## 2. Research Methods

The research approach used in this study is a qualitative research approach with a systematic literature review method. A systematic literature review (SLR) is a way to synthesize scientific evidence to answer specific research questions in a transparent and reproducible manner. This review aims to cover all published evidence on the topic while assessing the quality of this evidence (Lame, 2019). Data sources used as references in the study are relevant library sources including journals, research reports, proceedings, laws and regulations, books, and so on. Data are analyzed by data reduction, data presentation, drawing conclusions and verification, and final conclusions.

## 3. Results And Discussion

### 3.1 Causes of Plastic Waste Problems in Mangrove Area

There are several causes of plastic waste polluting mangrove forests. The first cause is the increasing mass production of plastic (Deng et al., 2021; Lebreton et al., 2017). Mass production of plastic began in the 1950s and has grown by 8.1% per year (Geyer et al., 2017). Primary microplastics (MPs) are intentionally made as microfibers used in textiles, microbeads in cosmetic products and scrubbers for cleaning abrasive materials, and microparticles used in various industrial processes (Cole et al., 2011; Naik et al., 2019). One such industry is the hospitality industry, which is a major source of single-use plastics (straws, lids, takeaway packaging, food packaging, etc.) that often escape into the waste stream and contribute to the plastic pollution problem (Sujai & Juwana, 2021), with a survey of street litter finding that 57% was caused by food and beverages (Siagian et al., 2021). The most common plastic waste found was plastic straws, styrofoam takeaway containers, cutlery bags, condiment wrappers, plastic drink bottles, and plastic bags (McGovern, 2020).

The second cause of plastic waste pollution in mangrove areas is due to irresponsible human activities (Latarissa et al., 2023), distance from residential centers (Garcés-Ordóñez et al., 2019), and exacerbated by population density (Lebreton et al., 2017). Plastic waste in the Mangrove area from human activities comes from terrestrial sources (e.g., sewage treatment plants, coastal waste caused by tourism and fisheries activities, and urban and agricultural runoff) and maritime activities (marine aquaculture and shipping). The largest contributor to plastic waste pollution from land comes from household waste produced by residents (Deng et al., 2021). In

addition, the largest contributor to plastic waste pollution from the sea comes from nearby marine aquaculture due to the intensive use of equipment consisting of polystyrene (PS), polypropylene (PP), and PE plastic during the fisheries aquaculture process (Q. Wang et al., 2020). Low public awareness of the dangers of plastic waste and the importance of responsible waste management practices also contribute to the pollution problem. With low awareness, people tend to litter carelessly, which will ultimately pollute the mangrove forests and threaten their ecosystems. Irresponsible human activities such as the behavior of people and tourists who still often throw garbage into water areas that enter at high tide have an impact on the flora and fauna in the mangrove ecosystem (Latarissa et al., 2023). Household waste disposal, including plastic bags, plastic bottles, and styrofoam, is the main source of plastic pollution in mangrove forests due to a lack of awareness of the importance of waste management. In addition, plastic waste from industry, such as plastic packaging and microplastics from cosmetic products, also pollutes mangrove forests. Agricultural activities that use plastic in the form of fertilizers and plastic mulch also contribute to the problem of plastic pollution in mangrove forests (Latarissa et al., 2023).

Plastic waste pollution in mangrove areas is also caused by the lack of good waste management (Lebreton et al., 2017). Inadequate waste management systems, especially the lack of infrastructure and effective waste management systems in coastal areas, result in plastic waste tending to accumulate and pollute the mangrove environment.

Plastic waste pollution in mangrove areas is also caused by surface currents and ocean waves. Surface currents and waves are known to be the main driving forces for transporting waste from the sea to mangrove areas (Martin et al., 2020). Of the total waste in the ocean, 80–85% is plastic waste (Ding et al., 2021; Derraik, 2002), which is estimated to be at least 8 million tons of plastic dumped into the ocean every year (Deng et al., 2021; Jambeck et al., 2015).

Plastic waste pollution in mangrove areas is also caused by plastic waste flowing from rivers to the sea. This plastic waste is carried through rivers or drainage systems and enters the mangrove area, most of which are maintained by mangrove forests for a long period (Ivar do Sul et al., 2014). 1.15 tons and 2.41 million tons of plastic waste flow from rivers to the sea each year. In this case, 20 rivers have been identified that carry the most waste and contribute around 67% of the total annual input of global waste (Lebreton et al., 2017). Some of these rivers are Xi, Yangtze, Huangpu, Hanjiang, Zhuijiang, and Dong which are located in China; then the Brantas, Serayu, Progo, and Solo Rivers which are located in Indonesia; the Pasig Rivers in the Philippines; the Irrawaddy river which is located in Myanmar; the Mekong River in Southeast Asia and several others are located in Africa, South Asia, and Latin America (Lebreton et al., 2017; Löhr et al., 2017). Meanwhile, as many as 103 rivers in the world contribute around 490% of plastic input with 103 rivers located in Asia, eight in Africa, eight in South and Central America, and one in Europe (Lebreton et al., 2017).

Floods and high tides can also cause plastic pollution in mangrove areas. Strong currents during floods and high tides can carry plastic waste from land to mangrove forests, exacerbating pollution levels in the ecosystem. This results in

the accumulation of plastic waste in mangrove forests which can damage the ecosystem and threaten the survival of the flora and fauna there. Evidence shows that microplastics in the ocean are easily spread or transported long distances through surface currents, wind, and tides, even reaching coastal areas (Barnes et al., 2009; Deng et al., 2021).

Although there are mangrove forests that appear to be free of plastic waste, there are still microplastics that dominate the mangrove sediments. This is because microorganisms in the Mangrove area can break down plastic waste into MP, but with a slow degradation rate, thus supporting the emergence of large amounts of MP in the mangrove ecosystem (Deng et al., 2021). This is by the statement of Thompson and his collaborators for the first time, that microplastic (MP) fragments and fibers are ubiquitous in the marine environment (Thompson et al., 2003). This is because the inherent durability of plastic materials makes them very persistent in seawater, which can be broken down but not decomposed and their buoyancy facilitates their transport by currents and winds to the most remote locations. As a result, MP, namely particles with a diameter <5 mm, continues to accumulate in large ocean areas, with concentrations increasing over time. However, global assessments show that only 1% of plastics entering the marine environment are still floating on the water surface and the stock of this plastic is mainly decreasing in sizes <1 mm. These findings have led some to hypothesize a series of size-based removal processes, such as consumption by fauna, sinking to deeper layers of the water column, and sequestration in sediments (Martin et al., 2020).

Based on the descriptions above, plastic waste pollution in mangrove areas is caused by various factors. First, the increase in mass plastic production since the 1950s, including microplastics from cosmetic and industrial products, has exacerbated pollution. Second, irresponsible human activities, dense population, and lack of awareness of waste management have worsened the situation. Third, the lack of effective waste management infrastructure causes waste to accumulate and pollute mangrove forests. Fourth, floods and tides carry plastic waste from land to mangrove forests, increasing accumulation and ecosystem damage. In addition, persistent microplastics in the marine environment are also transported to coastal areas, polluting mangrove sediments and threatening local flora and fauna.

### 3.2 Negative Impact of Plastic Waste in Mangrove Area

Plastic waste has a significant negative impact on mangrove forests, especially in causing the degradation of mangrove forests. Based on the results of the study, mangrove trees affected by plastic for a long time causing direct pneumatophore growth and potential leaf loss. However, trees treated with 50% plastic cover proved to be very resilient and were able to maintain their canopy throughout the trial period, while trees treated with 100% plastic cover experienced a significant decrease in leaf area index and survival at the end of the trial. Mangrove trees are relatively resistant to partial burial by plastic waste, but mangrove stands will eventually be damaged if plastic continues to accumulate (van Bijsterveld et al., 2021).

The negative impact of plastic waste in addition to having an impact on mangrove forests also causes water and soil pollution. If plastic waste is buried in the ground, it will pollute

the soil and groundwater (Karuniastuti, 2013). Plastic waste that decomposes into microplastics can pollute water and soil in mangrove forests, causing danger to marine life and humans who depend on the ecosystem. In addition, hazardous chemicals released from plastic waste, such as BPA and phthalates, can also pollute the environment, threaten human health, and cause ecosystem disruption. Both of these impacts cause serious damage to biodiversity and the sustainability of mangrove forests.

Plastic waste pollution in mangrove forests also has an impact on flora and fauna in the mangrove ecosystem. Fragments of plastic will degrade into microplastics. These synthetic polymers that cannot be completely decomposed will remain environmental contaminants for a long time. Microplastics contain chemical compounds added during their manufacture and absorb contaminants in their surrounding environment (Hantoro & Widianarko, 2018). The potential threat of microplastics (MP) in the environment to organisms is related to their transport into biota directly (primary ingestion) indirectly by eating contaminated prey (trophic level) (Deng et al., 2021; Markic et al., 2018). These small plastic particles are easily mistaken for food and are ingested by various marine organisms at almost every trophic level including invertebrates, turtles, fish, seabirds, and large marine mammals (Autta et al., 2017; Deng et al., 2021). If microplastics enter and are digested by marine biota, it is also possible that there are toxins from chemicals in the body of the biota. This is because MP has the potential to act as a vector in transporting persistent organic pollutants and heavy metals in the environment. After all, its high surface area coupled with a non-polar surface allows MPs to absorb these chemical contaminants (Deng et al., 2021; Naik et al., 2019). Once absorbed, the presence of MP can cause a series of adverse impacts on the health of marine species, such as reduced feeding activity, weight loss, slow somatic and reproductive growth rates, and low fecundity rates, (Deng et al., 2021; Trestrail et al., 2020) and cause pathologic changes (Hantoro & Widianarko, 2018). MPs can enter and accumulate in various organisms associated with mangroves, including mollusks (3.7–17.7 items MPs/individual) (Naji et al., 2018), crabs (25.6–91.2 items MPs/individual) (Not et al., 2020), sea snails (9.0–59.9 items/kg snails) (Li et al., 2020), hard clams (0.35 ± 0.08 items/g tissue w.w.) (Hamid et al., 2020), fish (in the range of 0.4–20 items/individual) (Deng et al., 2021; Hastuti et al., 2014; Huang et al., 2021; Naidoo et al., 2020). In addition to the MP analysis method, the high frequency of MP detection in mangrove organisms may be related to the high anthropogenic intervention in the mangrove ecosystem and the high number of MP in the mangrove ecosystem (Naidoo et al., 2020).

Waste pollution in mangrove forests not only affects flora and fauna in the mangrove ecosystem but also humans through the food they consume. Due to their microscopic size, microplastics can enter the bodies of not only marine biota, but also humans, either directly or indirectly through the food chain (Hantoro & Widianarko, 2018). The risk of contamination of seafood products is also a very real risk for restaurants that serve seafood to their customers. This should be another reason for restaurants near the coast to stop polluting, as they add to the contamination of the locally



caught seafood they serve (Danopoulos et al., 2020). Other pollution such as heavy metals and domestic waste also have an impact on the accumulation of contaminants in seafood species. When viewed from a food safety perspective, seafood contaminated with microplastics is not safe for consumption and can also have an impact on humans. These health risks are currently under the supervision of the scientific community, but concerns have already arisen. Potential human health risks include physical damage causing cell necrosis, inflammation, and tissue laceration in the gastrointestinal tract, and concerns related to bioaccumulation and biomagnification of chemicals into the human body (Oliveira et al., 2020).

Ocean plastic pollution also poses serious economic concerns. Studies assessing the adverse impacts of plastic debris are essential to building a comprehensive understanding of the magnitude of the economic impact. One study estimated that marine plastic debris costs about US\$8 billion annually, including lost revenues from the fishing, aquaculture, and marine tourism industries, in addition to beach cleanup costs. For example, an estimated US\$8 billion annually is associated with marine plastic debris, including lost revenues from the fishing, aquaculture, and marine tourism industries, in addition to beach cleanup costs; the Asia-Pacific Economic Cooperation (APEC) found that in 2008, marine debris was estimated to have directly cost its 21 member countries about US\$1.265 billion. Given its potential to damage assets with high tourism value, the costs could be much higher if other industries, such as tourism, are also affected. Marine pollution due to plastic is closely related to tourism, considering that coastal and marine activities (sea and freshwater fishing, sailing and boating, water sports, and inland sailing) are an important part of this business. Thus, the negative environmental impacts caused by plastic can weaken tourism due to pollution on beaches and the sea (Oliveira et al., 2020).

Based on the descriptions above, plastic waste pollution in mangrove forest areas has a significant impact on the ecosystem. First, plastic waste can cause mangrove trees to suffocate and reduce their survival, especially when the cover reaches 100%. Second, plastic waste that decomposes into microplastics pollutes water and soil. Third, microplastics can enter the food chain, causing accumulation in mangrove organisms such as mollusks, crabs, and fish, which are then consumed by humans. Fourth, the accumulation of microplastics and related chemicals in the bodies of marine biota can hurt their health and the humans who consume them. Fifth, annual economic losses that affect the fishing industry, aquaculture, and marine tourism, and increase the cost of cleaning beaches, which has the potential to damage valuable tourism assets and weaken the tourism industry.

### 3.3 Strategy Recommendations

The first recommendation for sustainable tourism strategies to mitigate plastic waste in mangrove forests includes providing comprehensive education and awareness. This is to the statement (Garcés-Ordóñez et al., 2020), that to reduce plastic and microplastic waste in the sea is to increase knowledge about the state of plastic and microplastic pollution in the marine and coastal environment, as well as increase education and awareness of the population to prevent pollution (Cahyadi

& Widiyanto, 2021). This can be done by organizing education and training programs for local communities regarding plastic waste management and this can increase their awareness and active participation in conservation. In addition to local communities, this can be done by providing education to tourists about the importance of preserving mangrove forests and the dangers of plastic waste through various media, such as information boards and educational materials in tourist areas (Abdullah et al., 2023). This integrated approach will help reduce plastic waste and preserve the mangrove ecosystem effectively. An example of its implementation is building public and tourist awareness of nature conservation through the Smart Mangrove application so that it becomes a container for a collection of materials, which can be studied repeatedly after arriving home. The methods used are (1) Providing training that will be provided including basic computer knowledge training, basic information technology training, internet introduction, SMART Mangrove application training, (2) Involving partners in activities to maintain the sustainability of the program to continue to conserve mangroves by involving the participatory role of the community. Education is carried out through the SMART Mangrove application package which is an educational and information media starting from the mangrove damage that has occurred, the impact of the damage, and efforts to save it (Hariadi, 2016).

To mitigate plastic waste in mangrove forests through sustainable tourism, one effective strategy is to increase tourist participation in conservation efforts. Tourists can be encouraged to bring their own refillable drinking bottles and cloth shopping bags, reducing the use of single-use plastics. "No Plastic Straw" and "No Plastic Bags" policies can be implemented throughout tourist areas to reduce the distribution of plastic that is difficult to decompose. In addition, beach or mangrove forest clean-up programs with tourists can be held regularly, not only to maintain environmental cleanliness but also to increase awareness and direct involvement of tourists in nature conservation. The implementation of this strategy can have a significant positive impact on reducing plastic waste and protecting vital mangrove ecosystems (Behuria, 2021).

To mitigate plastic waste in mangrove forests through sustainable tourism strategies, the third recommended strategy is waste management and recycling. It is important to provide adequate waste bins in tourist areas and ensure that waste is properly sorted and processed. Collaborating with local communities to develop plastic waste recycling programs is also essential, as involving local communities in waste management will increase the success of the program (Ismowati et al., 2022). To increase the low recycling rate, the industry faces several challenges. Although plastic waste has been recycled, most of the results are not used according to their original function due to the downcycling process (i.e. the decline in material quality), so the industry needs to improve the quality of the materials recovered and recycled (Shen & Worrell, 2024). In addition to recycling, it is also necessary to encourage the use of environmentally friendly products such as refillable drinking bottles and cloth shopping bags in tourist areas can significantly reduce the amount of plastic waste produced, helping to maintain the cleanliness and sustainability of mangrove forests.

To mitigate plastic waste in mangrove forests through sustainable tourism strategies, close collaboration between governments, non-governmental organizations, and local communities is needed. This partnership can result in a comprehensive strategy that prioritizes effective plastic waste management, including supporting research and development programs for innovative technologies (Zurba et al., 2020). In addition, sharing knowledge and experiences with tourism managers in other regions can expand the application of best practices and innovative solutions, strengthening collective efforts to maintain the cleanliness and sustainability of mangrove forests. For example, Portugal passed a national law banning single-use plastic cutlery in restaurants, pubs, and similar places in September 2020. The country is also experiencing multi-stakeholder initiatives, with governments, businesses, and civil society participating in efforts to reduce plastic waste (Oliveira et al., 2020).

Sustainable tourism strategies to mitigate plastic waste in mangrove forests include several comprehensive steps. First, education and awareness-raising for local communities and tourists about the dangers of plastic waste and the importance of mangrove forest conservation are carried out through training programs and educational media such as the Smart Mangrove application. Second, encouraging tourist participation in conservation with "No Plastic Straw" and "No Plastic Bags" policies, as well as regular clean-up programs. Third, waste management and recycling by providing adequate facilities and involving local communities in recycling programs, as well as promoting the use of environmentally friendly products. Finally, collaboration between governments, non-governmental organizations, and local communities to support effective plastic waste management and share best practices, as exemplified by a multi-stakeholder initiative in Portugal.

### 3.4 Implications

Providing comprehensive education and awareness to mitigate plastic waste in mangrove forests has significant implications for various parties. For local communities, training on plastic waste management and information technology will increase their capacity to protect the environment and make a real contribution to mangrove forest conservation. For tourists, through education delivered through various media and the SMART Mangrove application, they will become more aware of the impact of their behavior on the ecosystem, which is expected to reduce plastic waste in tourist areas (Hariadi, 2016). Governments and environmental organizations will benefit from increased community and tourist participation in conservation programs, which can strengthen efforts to preserve ecosystems sustainably. In addition, involving partners in conservation activities will help ensure that these programs continue to run in the long term with the support of wider resources and networks. This overall approach can create effective collaboration between parties, ensuring better sustainability of the mangrove environment (Cahyadi & Widiyanto, 2021).

Increasing tourist participation in conservation efforts will have positive implications for various parties. Tourists will feel more responsible and environmentally conscious, reducing their plastic footprint by bringing refillable water bottles and cloth shopping bags. Tourism operators and local businesses need to adapt to "No Plastic Straw" and "No Plastic Bags" policies, which will reduce long-term costs for cleaning and

managing plastic waste (Mosquera, 2019). Governments and tourism area managers will get stronger support from the community and tourists in environmental conservation, strengthening their sustainability programs. Beach or mangrove forest clean-up programs will also increase collaboration between various stakeholders, including local communities, NGOs, and tourists, creating a cleaner environment and a shared awareness of the importance of maintaining mangrove ecosystems.

Waste management and recycling in mangrove forest tourism areas will have a broad impact on various parties. Tourists will find it easier to dispose of waste properly, reducing environmental pollution. Tourism managers and local governments need to provide adequate waste management facilities and infrastructure and ensure that waste sorting and processing are carried out properly, which can improve the destination's reputation as an ecologically responsible place (Choirunnisa & Gravitiani, 2022). Collaborating with local communities in recycling programs will empower local communities, create new economic opportunities, and raise environmental awareness. The industry will face challenges in improving the quality of recycled materials to address downcycling (Shen & Worrell, 2024), but this also opens up opportunities for innovation in recycling technology. The use of environmentally friendly products by tourists will reduce the amount of plastic waste produced, support the local industry that produces these goods, and help maintain the cleanliness and sustainability of the mangrove ecosystem.

Collaboration between the government, non-governmental organizations, and local communities in managing plastic waste in mangrove forests will have various positive implications (Oliveira et al., 2020). The government will get support from comprehensive policies and regulations, strengthening national efforts to reduce plastic waste, as Portugal has done by banning single-use plastic cutlery. Non-governmental organizations can play an important role in research, development of innovative technologies, and community education, increasing the effectiveness of waste management programs. Local communities will be empowered through active involvement in these programs, which not only increases their awareness and participation but also creates new economic opportunities. This partnership also allows for the sharing of knowledge and experiences with tourism managers in other areas, expanding the application of best practices and innovative solutions, and strengthening collective efforts to maintain the cleanliness and sustainability of mangrove forests. This will result in a cleaner environment, sustainable tourism, and long-term preservation of the mangrove ecosystem (Ismowati et al., 2022).

Education and awareness about plastic waste mitigation in mangrove forests have significant implications for local communities, tourists, governments, environmental organizations, and industry. Educated local communities can better protect the environment and contribute to mangrove conservation, while more environmentally conscious tourists will reduce plastic waste in tourist areas. Governments and environmental organizations will benefit from the active participation of communities and tourists in conservation programs, strengthening ecosystem preservation. Collaboration with local communities in recycling and waste management programs also empowers communities, creates new economic opportunities, and enhances the reputation of tourism

destinations. Through collaboration between governments, NGOs, and communities, as well as the implementation of effective policies and regulations, these collective efforts can result in a cleaner environment, sustainable tourism, and long-term preservation of mangrove ecosystems.

#### **4. Conclusion**

Plastic pollution in mangrove areas is caused by increased plastic production, irresponsible human activities, lack of effective waste management infrastructure, flooding, and tidal surges that exacerbate the situation by bringing plastic waste from land into mangroves, and persistent microplastics contaminating sediments and threatening local flora and fauna. The impacts of this pollution are significant to the ecosystem, causing mangrove trees to suffocate; contaminating water and soil; accumulating microplastics in organisms that can be harmful to humans; and annual economic losses affecting the fisheries, aquaculture, and marine tourism industries, as well as increasing the cost of beach clean-ups, which damages tourism assets and weakens the tourism industry.

Based on these issues, the recommended sustainable tourism strategy to mitigate plastic waste in mangrove forests includes several key steps: first, education and awareness raising through training programs and media such as the Smart Mangrove application for local communities and tourists about the dangers of plastic waste and the importance of mangrove conservation. Second, encouraging participation with "No Plastic Straw" and "No Plastic Bags" policies, as well as regular clean-up programs to reduce waste. Third, waste management and recycling with adequate facilities and involving local communities, as well as promoting environmentally friendly products. Finally, collaboration between the government, NGOs, and communities to support effective waste management and share best practices. These efforts aim to maintain a cleaner environment, support sustainable tourism, and ensure the long-term preservation of the mangrove ecosystem.



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