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Technical report

The Costs of Environmental Degradation from Plastic Pollution in Selected Coastal Areas in the United Republic of Tanzania

February 2023

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Report No: AUS0003181

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The Costs of Environmental Degradation from Plastic Pollution in Selected Coastal Areas in the United Republic of Tanzania

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ACRONYMS & ABBREVIATIONS

Acc.	Accumulation of litter
BAU	Business as usual
bn	billion
CDS	Container deposit scheme
CO_2	Carbon dioxide gas
COED	Cost of environmental degradation
EMA	Environmental Management Act 2004, Tanzania
EPR	Extended Producer Responsibility
ESS	Ecosystem services
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Ha	Hectare (an area 100m*100m)
Kg	Kilogram
Km	Kilometer
m	million
Mt	Million metric tons
MSW	Municipal Solid Waste
NEMC	National Environment Management Council of Tanzania
NGO	Non-governmental organization
PET	Polyethylene terephthalate
$PM_{2.5}$	Particulate matter under 2.5 micro-meter diameter
PPP	Public-Private Partnership
SDGs	Sustainable Development Goals
SW	Solid Waste
SWM	Solid Waste Management
SS	Standing stock of litter
t	ton (1,000kg)
TEV	Total Economic Value
Ton	US measure of 2,000lbs (907.1 kg)
TZS	Tanzanian Shilling
UDSM	University of Dar es Salaam
UNEP	United Nations Environment Programme
US$ or $	US Dollar
VSL	Value of statistical life
ZEMA	Zanzibar Environmental Management Authority
ZUSP	Zanzibar Urban Services Project

ACKNOWLEDGMENTS

This report is one of the outputs of the World Bank's Advisory Services and Analytics (ASA) Program "Tanzania-Zanzibar Problue *Supporting Blue Economy Policy Implementation through Marine Debris Control and Coastal Zone Management*." It summarizes the findings and results of a study on the cost of environmental degradation from marine plastic pollution in selected coastal areas of Tanzania. The report aims to assist both the Government of Tanzania and the Revolutionary Government of Zanzibar in deepening the understanding of the economic costs of environmental damage caused by marine plastic pollution and areas for future actions to address these issues.

The ASA was developed under the overall guidance of Mara Warwick (Country Director for Tanzania), Iain Shuker (Practice Manager, Environment, Natural Resources and Blue Economy Global Practice), and Preeti Arora (Operations Manager for Tanzania) of the World Bank. It was implemented by a team led by Ruxandra Maria Floroiu (Lead Environmental Specialist/Task Team Leader, TTL) and comprised Jane Kibassa (Senior Environmental Specialist/co-TTL), Ruth Tiffer-Sotomayor (Senior Environmental Specialist/co-TTL), Jian Xie (Sr. Environmental Specialist), and Enos E. Esikuri (Sr. Environmental Specialist).

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The authors are also grateful to the First Vice President Office (Zanzibar), Zanzibar Environmental Management Authority (ZEMA), Ministry of Blue Economy and Fisheries, and Department of Marine Conservation of the Revolutionary Government of Zanzibar, the National Environment Management Council (NEMC) of Tanzania, the National Bureau of Statistics of Tanzania, the Tanzania Tourist Board, the Ministry of Natural Resources and Tourism, Ministry of Water, Ministry of Livestock and Fisheries, Ministry of Works and Transport, Ministry of Home Affairs (Immigration Department), the Vice President Office of Tanzania, and relevant municipalities for sharing information and holding meetings and discussions with the World Bank team.

The authors would like to thank Diji Chandrasekharan Behr, Christopher Mark Ingoe, and Giovanni Ruta of the World Bank for their valuable comments and suggestions as peer reviewers of the report.

Support for this report was provided by PROBLUE, an umbrella multi-donor trust fund administered by the World Bank that supports the sustainable and integrated development of marine and coastal resources in healthy oceans.

EXECUTIVE SUMMARY

Plastics are used worldwide due to their durability and low manufacturing costs and a significant portion of plastic becomes waste that ends up in the ocean. In 2017 there were over 438 million metric tons (Mt) of plastics produced globally. Each year, 19-23 Mt of plastic wastes is estimated to leak into the world's aquatic ecosystems and the ocean. In Tanzania, it is estimated that some 29,000 tons of plastic waste enter the ocean each year. This plastic waste leakage comes primarily from land-based sources due to the country's weak solid waste management (SWM).

Plastic waste is an environmental pollution problem which negatively impacts ecosystems, public health, and local economies. Plastic waste accumulated on land and in water bodies contaminates the natural environment, attracts pests, spreads waterborne diseases, and degrades the natural environment and ecosystems; it eventually breaks down and contributes to leaching processes and the generation of microplastics. Some plastic wastes can enter the air as fine particles or fibers through open burning or road dusts. The burning of plastic waste also produces black carbon and increases CO_2 emission levels, with implications for climate change and public health. Marine plastic pollution negatively impacts various economic sectors in coastal areas that depend on marine resources, coastal habitats and wildlife. For instance, marine tourism, fishing, and aquaculture depend on a clean aquatic environment. Plastic and microplastic waste contaminate beaches, sea grass areas and coral reef habitats, lower the quality of marine ecosystems and biodiversity, and endanger bird and marine wildlife through entanglement and the ingestion of plastics of different sizes. They also endanger human health through food chains.

Valuation of the cost of environmental degradation (COED) from marine plastic pollution helps to understand the scale of pollution's economic impacts and prioritize activities for mitigation of these impacts. Negative impacts of plastic pollution cause direct loss of the economic sectors of tourism, fisheries, aquaculture, and marine transport and reduce the value of marine natural capitals and marine ecosystem services. The damage and potential remediation costs of marine plastic pollution, however, are avoidable if actions are taken to prevent plastic waste from entering the ocean. The value of the COED will likely exceed the cost of preventing marine pollution at source before waste disperses. Estimating the COED will enable the government and policy makers to introduce and implement well-targeted strategic responses and investments to address the sources of marine plastic waste.

The objective of the study is to assess and valuate the costs of environmental degradation from marine plastic pollution, identify and prioritize critical areas and issues, and provide recommendations for effective marine plastic pollution control in select coastal areas in Tanzania and Zanzibar. The study reviewed literature and available government documents, engaged, and consulted with relevant government agencies. The study used beach surveys conducted during preparation, and also developed a methodology of economic valuation for estimating COED. Thirteen beach sites in six coastal locations—from Mafia Island, north to the Kenyan border, including the west coast of Zanzibar—were selected as plastic waste hotspots, for the filed and drone surveys. Unguja (Zanzibar Island) and the city of Dar es Salaam were selected as COED case studies due to their significance in the country's

coastal economy, the amount of waste generated, and the potential impacts of plastic pollution on their marine ecosystems and economy.

The beach and drone surveys found that beach and marine litter were high by international standards. The beach surveys revealed significant waste and plastic litter densities, with repeat surveying showing few signs of a diminished density level of beach litter. Drone surveys further confirmed that piles of plastic on the hinterland behind a beach contribute to beach litter. An analysis of waste types estimated the plastic waste component of beach litter, and a "brand audit" determined the geographical and commercial origins of plastic items from their labelling.

The concept and valuation methods available from environmental and natural resource economics have been adapted for the study to estimate the COED from marine plastic pollution in the selected coastal areas. Total economic value (TEV) used in the study refers to the sum of all economic values, including indirect use and non-use, provided by a given ecosystem. The study also employed various market and non-market or surrogate market approaches to quantify COED. Market-based valuation approaches use the changes in productivity or revenue at market values; for example, impacts on marine activities such as fisheries and aquaculture can be valued by the changes in fishing or aquacultural productivity at market values. Non-market or surrogate market approaches become useful when it is difficult to quantify environmental impacts by direct market value, such as the impact of the change of environmental quality on tourism. The willingness to pay (WTP) approach was employed to estimate the cost of marine debris on beaches to tourism. The cost of environmental health impacts was estimated by the cost of premature deaths using the value of statistical life (VSL), which is a measure of how much individuals are willing to pay for a reduction in the risk or likelihood of premature death. As valuing COED from marine plastic pollution is a new study area and data is often limited or even does not exist, valuation methods have to be developed and improved to overcome the limitation. When local data was not available, the benefits transfer approach was used by transferring and adopting available information from completed studies in other similar places or contexts. In addition, some conservative assumptions were made in COED estimation. Despite the efforts, the cost of some impacts is still missing in the analysis; for example, the cost of damage to marine wildlife is not included due to lack of available information.

The costs of environmental impacts on local economic sectors, public health, and marine ecosystems were valued and the COED results reveal that marine plastics pollution causes a net economic cost to the economy and the environment of study areas, and that in some areas costs can be quite significant. The following table for Zanzibar (Unguja Island) shows the estimated COED in 2019 was US$17.6m, equivalent to 1.31% of the island's GDP. The COED in Dar es Salaam however is much less, at US$10.3m or equivalent to only 0.1% of the city's GDP. This is because the city has a more diverse and balanced economic structure and less reliance on the coastal and marine environment. The total COED of the two study areas was US$28.0m (see Table ES-1 below).

Table ES-1. COED of Dar es Salaam and Unguja, Zanzibar Island in 2019

Unit: US$ million

	Dar es Salaam	Unguja, Zanzibar	Total	Percentage of Total COED
Economy				
- Tourism	5.31	13.75	19.06	68.2%
- Fishing	0.41	0.52	0.93	3.3%
- Aquaculture	0.01	0.02	0.03	0.1%
Public health	2.2	0.53	2.73	9.8%
Ecosystem, marine wildlife* and biodiversity*	2.4	2.8	5.2	18.6%
Total COED	**10.3**	**17.6**	**28.0**	100%
Share of GDP (%)	**0.10%**	**1.31%**	**0.24%**	

* Not quantified.

The COED of the two study areas reveals a wide range of marine plastic pollution impacts on local economies, public health, the natural environment and beyond. The greatest cost unsurprisingly occurs in tourism, which is an extremely important industry in coastal economies, especially in Unguja Island, Zanzibar, where the cost to tourism from marine plastic pollution is estimated at US$13.75m per year. Estimates for Dar es Salaam indicate an annual tourism cost of US$5.31m as there are fewer marine tourists. The economic loss of the marine tourist sector is 68% of the total COED for the two study sites. Impacts of plastic pollution on the coastal marine environment are an estimated US$5.2m, 18.6% of the total COED, but may be highly underestimated, as impacts on marine wildlife and biodiversity were unable to be quantified in the study due to the lack of data. The public health costs were 10% of the COED for the two study sites. In Dar es Salaam, the cost of health impacts was estimated at US$2.2m in 2019. Unguja has a much smaller population and had a lower estimate of US$0.53m. The annual impact to fisheries and aquaculture is US$0.52m in Unguja and $0.41m in Dar es Salaam, about 3.3% of the total COED.

The analysis of COED results, including comparisons between study areas and sectors, is useful for prioritizing marine plastic pollution management activities in the future. The COED illustrates that significant economic costs impacts from plastic waste can be reduced by improved SWM in urban settings before the pollutant disperses. The future COED can be reduced by more targeted policy interventions which require government actions and public and private sector participation.

Several policy recommendations draw on the COED results and are summarized below:

Prevention through waste management. It is critical for Tanzania to improve its waste management and prevent plastic waste from entering water bodies. Plastic waste control to improve the marine environment and reduce the COED could start by addressing the quantity and types of plastic products that are being imported, produced, and used in Tanzania. Effective implementation of the existing ban on single-use plastic products is an initial and important step for a developing country like Tanzania, in addition to more effective SWM systems to

collect and treat plastic waste. The government may consider expanding the ban to cover more plastic products. The majority of marine plastic waste creating the COED is coming from coastal cities, especially Dar es Salaam, the nation's largest city. It is therefore important for Tanzania to improve its municipal SWM systems, particularly for collection, recycling, and treatment of plastic waste aiming to significantly reduce plastic waste from urban areas entering water systems and the ocean. Given this importance, SWM programs and investment activities should be considered as part of municipal service improvement programs. There should also be feasibility studies and trials of some technical measures, such as plastic litter traps in waterways and rivers, leading to the sea. In addition, the environmental management of vessels, port facilities, fishing and aquaculture needs to be strengthened to reduce their plastic litter and contribution to the COED. The country should consider a program to incentivize fishers and marine transport operators to bring their plastic waste—such as unwanted fishing gear and nets—to shore for collection and recycling.

Addressing the impacts of plastic waste on Tanzanian marine tourism. Tourists and residents expect a pollution-free marine environment with white beaches, clear blue ocean, and the opportunity to enjoy marine wildlife. Relevant government agencies, the tourism industry, NGOs, and local community stakeholders can cooperate in the development of preventative and remediation plans to protect the economic benefits derived from tourism. Tourism industry service providers, such as hotels, should first apply the 3R (reduce, reuse, and recycle) principles to their own plastic waste, ensuring the recyclability of the plastic they use and then examine ways to reduce the number of plastic bottles in beach litter.

Beach cleaning for tourism. While prevention is preferable, expenditure on additional beach cleaning in popular tourist areas is required to decrease the perception of "environmental uncleanliness" among visitors. More regular cleaning of popular tourist beaches during the tourism season may have net benefits and reduce the COED from plastic beach waste, but risks becoming an almost permanent requirement if the original land-based sources of plastic waste remain uncontrolled due to inadequate SWM and plastic waste prevention.

Protecting marine and coastal ecosystems. The COED has demonstrated that the protection of the marine environment will address the risk from plastic pollution to the majority of the economic benefits derived from the tourism, fisheries and aquaculture industries, protecting many incomes and livelihoods. Managing marine plastic pollution and increasing the value of ecosystem services must be a national priority. Impacts of marine plastic on wildlife and marine ecosystems need to be studied further.

Reducing public health impacts. Marine plastic pollution is a threat to public health, and policy attention should be given to reducing plastic litter that traps water that then spreads insects, and the open burning of plastic waste by households and businesses, both of which have adverse health outcomes for both tourists and residents.

Protecting marine fisheries and aquaculture industries. These marine industries require a clean marine environment, but they are suffering from plastic litter. Reduced levels of marine plastic litter and microplastic pollution will maintain tourist demand for seafood and protect fish from ingesting plastic. The beach surveys indicated a correlation between pollution

hotspots, fish landing sites, fish markets and inadequate SWM in nearby towns that can be addressed.

Environmental management policy and tourism fee. Reducing the COED from marine plastic pollution requires both well-designed environmental policy and regulatory frameworks and the implementation of effective policy instruments. In-depth policy review and analysis is necessary. The existing fee system for tourism should be reviewed and a new "marine environment fee" particularly on international tourists who have a higher WTP margin could be considered to help local governments finance preventive or remedial plastic pollution control activities that protect the tourism industry and encourage further development.

Promoting public education and participation. To reduce waste generation and litter, increase collection and recycling, and protect public health, governments, in collaboration with communities, NGOs, and the private sector, should help organize and incentivize public education and participation activities and provide necessary financial and logistical support.

Strengthening data collection and information management. Environmental monitoring, data collection and management, and in-depth analyses will better inform policy makers. Government agencies can work with municipalities, stakeholders, and NGOs to collect and compile data on plastic waste pollution and build capacity to monitor and value the impacts of marine plastic pollution.

This study is the first of its kind for valuing the cost of environmental degradation from marine plastic pollution in Tanzania. It has faced some limitations, which can be further addressed in future research. One main constraint is the limited availability of environmental and economic data in the study areas. The COED is likely underestimated due to the difficulty of valuing some impacts. In addition, the lack of time-series data means the COED study is in 2019 only and did not attempt to analyze the trend over time. Despite the limitations, the report contributes to the emerging topic of valuing the cost of environmental degradation from marine plastic pollution, and it provides a useful base for policy analysis and decision-making in the future.

Chapter 1. Introduction

Plastics have been used ubiquitously in numerous products and goods due to their unique characteristics such as being lightweight and durable and their low manufacturing costs. A significant portion of plastic waste has been leaking into the environment and ending up in oceans, causing an environmental pollution problem and negative impacts on ecosystems, public health, and local economies. Marine plastic pollution, in particular, negatively impacts economic sectors in coastal areas that rely on marine resources, marine habitats, biodiversity, and wildlife. Plastic and microplastic waste contaminate beaches, sea grass areas, and coral reef habitats, lowers the quality of marine ecosystems and biodiversity, endangers bird and marine wildlife through entanglement and the ingestion of plastics of different sizes, and threatens human health through food chains.

Globally, plastics production has risen from 2 million tons (Mt) in 1950 (EEA, 2019) to over 438 Mt annually in 2017 (Geyer et al., 2017). In 2020 the global plastics market was estimated at US$580 billion (UNEP, 2021a). If recent growth rates continue, global plastics production is expected to double within the next 20 years (Lebreton & Andrady, 2019), and triple by 2050 (Geyer et al., 2017).

The rapid increase in the production and consumption of plastics, accompanied by inadequate management of plastic waste throughout the lifecycle of plastics value chains, especially its "end life" disposal, has led to widespread plastic pollution. In many developing economies a lack of infrastructure for municipal solid waste management has led to "mismanaged waste," with an estimated 60 to 99Mt of mismanaged plastic waste produced globally in 2015 (Lebreton & Andrady, 2019). Globally, only 10% of total plastic waste is being recycled and 14% is burned. The rest is disposed of by burial or remains unmanaged, contributing to plastics' subsequent entry into water courses and then the ocean (UNEP, 2021a).

It's been estimated that 19-23Mt of plastics leak into the world's aquatic ecosystems and the ocean annually (Borelle et al., 2020). The stock of plastic waste in the ocean is estimated at between 75Mt and 150Mt (Jang et al., 2015; Ocean Conservancy & McKinsey, 2015). These diverse polymers persist in a range of shapes and sizes, from visible plastics to the invisible fibers and microplastics that have been increasingly identified as remaining in the biosphere, but not fully degrading, creating potential health issues for all biological life, including humans, and having impacts on the environment. Ryberg et al., (2019) found that approximately 3Mt of microplastics remained in the environment in 2015. There is a need to control the plastic life cycle from production to end of life (UNEP, 2021a). Some recent East African regional studies have identified the extent of mismanaged plastic waste leakage into the ocean, with annual averages of 37,000 tons (or t thereafter) from Kenya, 29,000t from Tanzania, 17,000t from Mozambique, and 79,000t from South Africa (Pucino et al., 2020).

Located on Africa's east coast, Tanzania including Zanzibar and other islands has a coastline of 1,424 km. Mainland Tanzania and the Zanzibar Archipelago, which sits 25-40 km off the Tanzanian mainland in the Western Indian Ocean, have a range of attractive beaches and small islands and are well-known tourist destinations.

Tanzania is an important importer and user of plastic products on the African coast. The plastic waste primarily originates from land-based sources due to the country's inadequate solid waste management (SWM). Due to population growth, urbanization, and improving living standards, Tanzania and many other Africa countries are experiencing increasing demand for plastic goods and plastic packaging materials (Jambeck et al., 2018). The countries are facing challenges in recognizing the environmental issues around plastic waste and the importance of reduction, reuse, and recycling of plastic waste and solid waste management (SWM) (CARDNO, 2020).

Tanzania generated 315,000t of plastic waste in 2018 (IUCN-EA-Quantis, 2020). As discussed above, the country has about 29,000t of plastic waste entering the ocean each year, representing about 9% of the country's annual total of plastic waste. The figure reflects the country's limited capacity for plastic waste collection and management.

The use and inadequate disposal of plastic products causes high levels of plastic leakage leading to pollution of coastal and marine environment. The problem has been growing gradually and the current SWM system is not catching up with the increase in solid and plastic waste generation or effectively stopping plastic waste reaching the ocean. This has led to a range of economic, environmental, and social costs being borne across Tanzania, with a weak institutional response. The country needs to strengthen its policy, financial and institutional arrangements for improving its solid waste and plastic pollution management.

Plastic waste leakage contaminates beaches and marine ecosystems and incurs economic losses in local economies. Studies on the impacts of plastic pollution on ocean ecology indicate that plastics and micro plastics cause significant environmental damage (UNEP, 2021b). According to a review of 59 studies of plastic and the environment in Africa, plastics are most frequently found in estuarine and marine environments across the continent (Akindele & Alimba, 2021).

In Tanzania and Zanzibar in particular, plastic pollution causes direct damage to ocean activities such as fisheries, aquaculture, shipping, marine transport, and tourism (UDSM, 2022). There are also indirect impacts on the environment as seen in a reduction of the ecosystem services provided by the ocean, as well as a reduction in the quality of marine ecosystems and habitat, reducing the value of the ocean's environmental natural capital. The cost of environmental degradation (COED) from marine plastic pollution has not previously been estimated in Tanzania. The cost of marine plastic pollution is noted as an "avoidable cost," because both the damage and potential remediation costs would not occur if plastic litter could be prevented (McIlgorm et al., 2020). There is a clear need for the country to address the high levels of marine pollution that come from plastic consumption and urban solid wastes.

Efforts to reduce plastic pollution impacts on the country's environment have included a national campaign started in 2016 to ban plastic carrier bags. In 2019, the campaign led to the Environment Management (Prohibition of plastic carrier bags) Regulations of 2019. The Regulation emphasizes a ban on the import, export, manufacturing, sale, and use of plastic carrier bags regardless of their thickness. The campaign and the Regulation catalyzed the involvement of almost all sectors in reducing plastic carrier bags. Alternative non-woven bags of more than 70 GSM were introduced as alternatives with less environmental impact.

In recent years the governments of Tanzania and Zanzibar have prioritized the "Blue Economy" and the management of their marine areas for greater sustainable economic and social benefits. This includes the marine environment which has not been the subject of much research (WIOMSA, 2021; Shilla, 2019). However, it has been noted that both Tanzania's mainland coast and Zanzibar have significant levels of waste and plastic in the ocean and on beaches (WIOMSA, 2021; Nipe Fagio, 2020a). The growing marine plastic problem was observed by regional studies more than a decade ago, but data and information was limited (UNEP & WIOMSA, 2008; Lane et al., 2007). The information gap on marine waste in Tanzania has only recently started to be addressed and needs further research (IUCN-EA-Quantis, 2020; Shilla 2019). Much of what is currently known about plastics in the ocean comes from global research.

To support the United Republic of Tanzania's endeavor to control marine plastic pollution and advance the blue economy agenda, the World Bank has engaged with government agencies in mainland Tanzania and Zanzibar through an Advisory Supports and Analytics program with the financial support of ProBlue a multi-donor trust fund. A study on the costs of environmental degradation (COED) from marine plastic pollution is one of the activities under the ProBlue Program.

This report summarizes the findings of the COED study. Its objective is to identify and assess the impacts of plastic pollution, evaluate the costs of environmental degradation, and propose and prioritize actions for plastic pollution control in the coastal areas in Tanzania and Zanzibar. This study estimates the economic and environmental costs arising from plastic pollution considering two case study areas, Dar es Salaam and Unguja Island in Zanzibar Archipelago. The information from these case studies defines a range of policy actions needed to address marine plastic pollution in other coastal population centers in Tanzania.

The study reviewed literature and available government documents, engaged, and consulted with relevant government agencies, and conducted beach surveys. A methodology of economic valuation for estimating COED was developed. Several different sources of economic data were used for a range of market and non-market economic valuation approaches. The overall method seeks to estimate the COED using assessment approaches applied in previous World Bank studies (Croitoru et al., 2022; Croitoru et al., 2019; Croitoru & Sarraf, 2010). Unguja (Zanzibar Island) and the city of Dar es Salaam were selected as COED case studies due to their significance in the country's coastal economy, the amount of waste generated, and their marine environments. The wider ProBlue program commissioned 13 beach sites in six coastal locations, from Mafia Island north to the Kenyan border including the west coast of Zanzibar, selected as plastic waste hotspots, with manual beach litter and drone surveys conducted (UDSM, 2022).

The COED study was however limited by the availability of environmental and economic information and data in study areas. The COED is also likely underestimated due to the difficulty in estimating some impacts, for example, the impact on marine species. Some assumptions, as conservative as possible, have to be made for valuing some economic costs of marine plastic pollution. Despite the limitations, the report makes an original contribution on the emerging topic of valuing COED from marine plastic pollution. It is useful to decision

makers and professionals in prioritizing plastic pollution management activities. The report also provides a useful baseline for future studies.

Following this introduction, Chapter 2 discusses drivers and sources of marine plastic pollution, plastic use, and environmental degradation from plastic pollution in Tanzania. This chapter also introduces the selection of plastic pollution hotspots and the results of the survey of marine plastic litter at these sites. Chapter 3 assesses the impacts of plastic pollution on Tanzania's marine economy, public health, and marine environment. Chapter 4 presents the economic valuation of environmental degradation from marine plastic pollution through the case studies in Zanzibar and the city of Dar es Salaam. Chapter 5 provides the summary of the COED results, discusses their policy implications, and then points out the limitations of the study and the way forward.

Chapter 2. Overview of Marine Plastic Pollution

This chapter first discusses the drivers and sources of marine plastic pollution and provides an overview of plastics use and plastic pollution as well as environmental degradation from marine plastic pollution in Tanzania. Then, the selection of hotspots with marine plastic pollution and the results of surveys at the hotspots are presented in the second half of the chapter.

2.1 Drivers and sources of marine plastic pollution

Since the invention of polypropylene with high mechanical resistance in the 1950s, plastic has eclipsed other materials in its uses and it is now indispensable for creating safe, effective products globally and in every industry (UNEP, 2021a; Lebreton & Andrady, 2019; Geyer et al., 2017). The increasing use of plastic products in Tanzania and many other developing countries has been driven by population, economic growth, urbanization, and increasing living standards (Barnes, 2019; Jambeck, 2015). Rising living standards have led to the adoption by consumers in Africa's developing countries of disposable plastic products or packaging for convenience and also beverage containers (UNEP 2021a and 2021b; Adebiyi-Abiola et al., 2019; Jambeck et al., 2018). The rapid growth of plastics use is also aided by the high availability of plastic products that are cheap to produce and buy (Pew & SYSTEMIQ, 2020; Ocean Conservancy and McKinsey, 2015).

Much of the plastics produced and consumed are single-use plastics, discarded after their one-time use. Surveys in Kenya found over half of the marine plastic waste was made from single-use plastics such as plastic bags and bottles (CARDNO, 2020). Mainland Tanzania and Zanzibar have followed this trend with a variety of plastic packaged products noted in beach waste survey results (UDSM, 2022; Nipe Fagio 2020a). As observed in the rapid growth of Dar es Salaam (UDSM & UNEP, 2018), the growth in plastic waste in Tanzania reflects rising plastic consumption along with increased economic prosperity (i.e., increasing per-capita GDP) and a weak solid and plastic waste management system (UDSM & UNEP, 2018).

Sources of marine plastic in Tanzanian waters

Plastic waste generated on land is estimated to contribute 80% of the plastic in the ocean (UNEP 2021b, 2005). The plastic is sourced from mismanaged waste, and its occurrence in the ocean correlates with a proximity to adjacent urban centers, rivers, estuaries, beaches, and islands (Geyer et al., 2017; Schmidt et al., 2017; Lebreton et al., 2017; Jambeck et al., 2015). For example, in Tanzania in 2018, at least 70% of the 29,000t annual leakage of plastic into the ocean from land sources was estimated to come from Dar es Salaam and its associated rivers (IUCN-EA-Quantis, 2021).

Marine plastic pollution is largely symptomatic of the failure of the SWM system to manage plastic waste and to prevent it entering the water courses and the ocean. Most developing countries have inadequate solid waste management (SWM) systems. Inadequate SWM systems further make it hard to separate plastic waste stream and inhibit plastic recycling to take place (Pew and SYSTEMIQ, 2020). There is a low level of public awareness about plastic as a pollutant and low willingness to pay for plastic pollution management, especially in poorer

communities. This results in limited public participation, though high plastic waste levels have led to waste segmentation and recycling initiatives in the community, for example in Dar es Salaam (Fassin et al., 2017).

Several reports have indicated that inadequate urban SWM systems in mainland Tanzania and Zanzibar are the main source of plastic entering the ocean (IUCN-EA-Quantis, 2021; Shilla, 2019; Jambeck et al., 2018). The plastic waste sources in Tanzania are discussed as follows.

Household waste. It comes from the residue of goods consumed of which plastic is one type of the generated waste. In Dar es Salaam it is estimated that each person produces 1kg of general waste per day, which includes plastic (UDSM & UNEP, 2018). Limited collection, and a lack of proper disposal of household waste at appropriate dumping sites, leads to informal dumping and burning of plastic waste in local communities. According to the interviews with government officials in charge of SWM, the consumption of plastic carrier bags has been reduced since the implementation of the Regulation banning plastic carrier ban in 2019 (UDSM, 2022).

Industrial and commercial sectors. There are considerable amounts of plastics produced by the manufacturing, packaging, and transport of goods. Businesses may informally dispose of plastic waste by discarding, burning or burying when not having access to adequate SWM system or simply to avoid the costs of proper disposal. Microplastics come from industries such as the abrasion of rubber tires, road markings and plastics contributing to city dust generation, and have been found in marine sediments in Tanzania (Mayoma et al., 2020; Ryberg et al., 2019). Coastal recreational and leisure activities by tourists are also a recognized source of plastic litter on beaches (Grelaud & Ziveri, 2020; Asensio-Montesinos et al., 2019).

Waste collection and disposal sites. Landfill sites are often overwhelmed by the amount of waste generated due to population growth like in the case of Dar es Salaam (MFP-NSO, 2022; UDSM & UNEP, 2018; Huisman et al., 2016; Palfreman, 2014). At sites the mismanaged waste is often related to the lack of capacity to separate and recycle waste, causing the plastic escaping from the sites and being blown by wind and rain into the adjacent landscape and communities. Where organized waste collection has not taken place, households often openly burn their trash and throw them into open spaces, drains or water courses (Nipe Fagio, 2020b). The land-based sources of plastic waste greatly exceed the marine sources.

Fisheries, aquaculture, and other human activities at sea. Plastic waste is also generated by fishing, aquaculture, and other marine sectors. An estimated 20% of total plastic pollution comes from marine activities such as shipping, marine transport (e.g., ferries), fishing, aquaculture, and marine tourism (McIlgorm et al., 2022, 2020, 2011; UNEP, 2017). Abandoned Lost and Discarded Fishing Gear (ALDFG) from commercial fishing is an estimated 10% of total marine plastic waste, and degrades to become microplastics (Gilman et al., 2021; GESAMP, 2016; Macfadyen et al., 2009). Lost fishing gear and overboard littering at sea in Tanzania was estimated at 69 tons in 2019 (IUCN-EA-Quantis, 2021). Aquaculture is a source of different forms of plastic that come from floats, nets, and lost equipment (GESAMP, 2020; Huntington, 2019). Marine sources of plastic waste in Tanzania and Zanzibar require more study as project interviews indicated that discarded fishing gear is dumped on shore, re-used

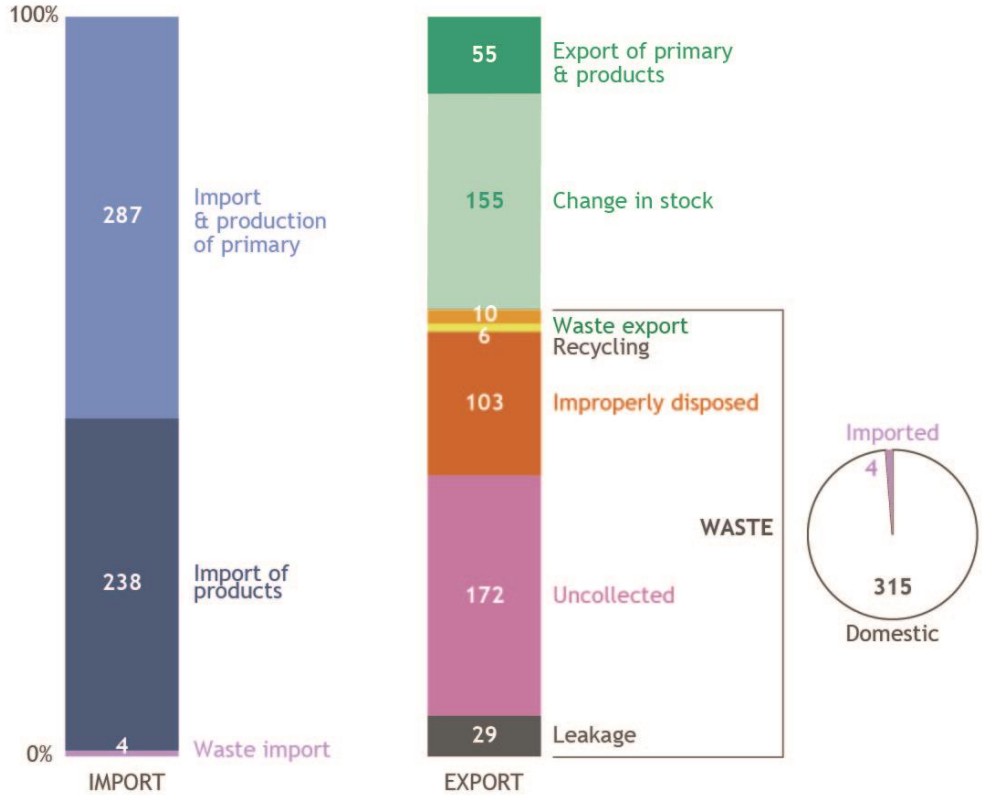
by other fishers or seaweed farmers, or ends up on land as cheap fencing to prevent pests in small-scale agriculture (UDSM, 2022; IUCN, 2020).

Other sources. Plastic pollution in Tanzanian waters also includes transboundary pollution from neighboring countries, with Mozambique contributing most due to prevailing water currents (Chassignet et al., 2021). There are also oceanic sources from island states such as the Comoros (Kelleher, 2021). Due to the East African Coastal Current, marine litter further moves north from Tanzania to Kenya year-round (Okuku et al., 2020; Ryan, 2020).

2.2 Plastic use and pollution in Tanzania

Tanzania's plastics industry has grown, especially since 2020, in part due to increasing trade engagement with China (CTI, 2020; Xia, 2019). A considerable amount of plastic used in Tanzania comes through the import of products and production of primary goods. Figure 1 shows that Tanzania's import of both plastic products and primary plastic materials in 2018 was 525,000t, from which 311,000t of domestic plastic waste were generated. Only 3.6% of the plastic waste was recycled and less than 0.5% recycled domestically. Tanzania does not have any leakage from primary pellets since the country does not produce any primary plastic.

Figure 1. Country plastic material flow of Tanzania in 2018



Unit: '000 metric tons Source: IUCN-EA-Quantis, 2020.

Tanzania's plastic imports grew at an annual average rate of 1.5% in 2011-2020. The country's national GDP grew at an annual average rate of 5.0%, which was above the nation's population growth rate of 3.2%, over the period of 2012-2022 (MFP-NSO, 2022). Tanzania's plastic consumption is projected to increase with its population and economic growth in the future, as

is the plastic waste generation. As the country has been taking some plastics reduction actions, such as the ban on use of single use plastic bags, its growth rate of plastic use was lower and will likely continue to be lower than the predicted growth rate of global plastic production which was predicted at 4% on average from 2015 to 2050 (UNEP, 2021a &b; Geyer et al, 2017).

Figure 1 further indicates that most of the plastic waste is mismanaged, with it being either improperly disposed of (32.6%, or 103,000t), uncollected (54.6%, or 172,000t), recycled (3.6%, or 10,000t) or leakage (9.2%, or 29,000t) and estimated to enter Tanzania's rivers and ocean. This equates to a leakage of 0.5kg per capita per annum for Tanzania (Pucino et al., 2020). Of the 29,000t of plastic leakage in Tanzania, 2,018t (7%) are microplastics mainly in the form of tire dust (1,383t), textile fibres (359t) and cosmetics (276t). IUCN-EA-Quantis (2020) further estimated that 42% of mismanaged waste (or about 130,000t) in Tanzania could become a source of air pollution through the uncontrolled burning of plastic waste.

Tanzania's per-capita plastic waste generation is only 5.6kg per year, much lower than a world average of 29kg/capita/year. However, since Tanzania's per-capita GDP is only about 1/10 of the world average, the country should have a much lower per capita value than the current 5.6kg per year. The higher than expected per-capita plastic waste generation indicates a weak management of plastic waste in Tanzania which, together with the country's inadequate SWM, is leading to higher plastic pollution and environmental costs per unit of GDP.

2.3 Overview of environmental degradation from marine plastic pollution in Tanzania

In the last decade there has been an increasing recognition that plastic pollution is causing a range of environmental impacts on land, air, and water/marine environments (see in Box 1).

Box 1. The environmental impacts of plastics

"*Plastics are the largest, most harmful and most persistent fraction of marine litter, accounting for at least 85 per cent of total marine waste. They cause lethal and sub-lethal effects in whales, seals, turtles, birds and fish as well as invertebrates such as bivalves, plankton, worms and corals. Their effects include entanglement, starvation, drowning, laceration of internal tissues, smothering and deprivation of oxygen and light, physiological stress, and toxicological harm.*

"*Plastics can also alter global carbon cycling through their effect on plankton and primary production in marine, freshwater and terrestrial systems. Marine ecosystems, especially mangroves, seagrasses, corals and salt marshes, play a major role in sequestering carbon. The more damage we do to oceans and coastal areas, the harder it is for these ecosystems to both offset and remain resilient to climate change.*

"*When plastics break down in the marine environment, they transfer microplastics, synthetic and cellulosic microfibres, toxic chemicals, metals and micropollutants into waters and sediments and eventually into marine food chains.*

"*Microplastics act as vectors for pathogenic organisms harmful to humans, fish and aquaculture stocks. When microplastics are ingested, they can cause changes in gene and*

protein expression, inflammation, disruption of feeding behavior, decreases in growth, changes in brain development, and reduced filtration."

Source: UNEP, 2021b.

The following is a general description of some of the key environmental impacts.

Air pollution. Plastics can enter the air as small particles or fibers and degrade air quality. The burning of plastic, both indoors and outdoors, affects the air quality and public health due to its emissions of the black carbon, particulate matter (PM2.5), and Persistent Organic Pollutants (e.g., Dioxin and Furan) and increasing CO_2 levels, with implications for the climate (Xie et al., 2021, Reyna-Bensusan et al., 2019).

Public health. Plastics in urban waste are often buried and degrade slowly. When breaking down into smaller microplastics it may be absorbed or ingested by plants and animals. Mismanaged plastic waste stays in the environment and leads to litter accumulation which creates breeding grounds for pests and for spread of waterborne diseases such as malaria, where mosquitoes take advantage of water accumulation (Krystosik et al., 2020). Waste plastic can also carry unsanitary microfilms with translocation risk to the environment and public health implications (UNEP, 2021b).

Marine economy. Plastic pollution in the marine environment has implications for marine industries such as fishing and aquaculture that require a clean and sanitary environment for their operation (McIlgorm et al., 2020). Tourism requires a clean environment, especially beaches and coral reef habitats free from plastic litter.

The marine environment, biodiversity, and wildlife. Plastic pollution degrades the marine environment in a range of ways as summarized in Box 1 above.

Tanzania's marine environment and marine plastic pollution

The Tanzanian marine environment is a significant natural asset and needs to be protected from degradation. Box 2 below describes the geographical context, ecological characteristics, and natural assets of the Tanzanian marine environment.

Box 2. Overview of the Tanzanian Marine Environment

"*Tanzania's coastline is 1,424 km long. Although it has extensive territorial waters, its generally narrow continental shelf means that its total shelf area is only a quarter the size of the Mozambican shelf. Its two major river systems are the Rufiji and the Ruvuma. The delta of the Rufiji River extends to Songo near Mafia Island. It has one of the largest mangrove forests in eastern Africa. The Ruvuma River straddles the Tanzania–Mozambique border and also has extensive mangrove forests. The Tanzanian side is a national marine park. Tanzania has the third largest stands of mangrove forest in the Western Indian Ocean (WIO) after Madagascar and Mozambique. Tanzania also has several large islands such as Pemba and Unguja (informally known as Zanzibar) in the north and Mafia to the south. They are all rich in coral reefs. Tanzania's mainland coastline is fringed by coral reefs except where there are major rivers. They are frequently associated with shallow seagrass beds. The northern coastline around Tanga has several offshore submerged coral reefs.*"

Tanzania's coast consists of two ecoregions. First the Southern Somalia, Kenya, and northern Tanzania "monsoon coast" driven largely by the north-flowing East African coastal current; and second, Southern Tanzania, which is influenced by the Mozambique Channel, where the South Equatorial Current meets the African coast. Tanzania's key marine habitats harbor numerous plant species such as: mangroves (9), seagrasses (12) and hard corals (265).

The marine animal groups in Tanzania's marine environment show high biodiversity and numerous species that include coral reef fishes (286), coastal bony fishes (<2,200 in WIO), sharks (>50), rays (15), echinoderms (400+), mollusks (3,270), marine mammals (35), turtles (5) and seabirds (~150).

Source: Samoilys et al., 2015.

Tanzania's marine environment is at risk of being degraded by plastic pollution. The geography, prevailing currents and weather patterns, all influence plastic pollution impacts in Tanzania's coastal waters.

There is limited information on the impact of plastic litter on marine environments such as beaches and coral reefs (Ryan et al., 2021; Nipe Fagio, 2020b; Shilla, 2019; UNEP & WIOMSA, 2008). A few specific studies are available on plastics' degradation of mangroves, seagrasses, rivers and estuaries and the seafloor in Tanzania (Ryan et al., 2021). Likewise, there is little information on the impacts of plastics on the following categories of marine life: bony fishes, marine invertebrates, sharks and rays, marine mammals, turtles, and seabirds (Ryan et al., 2021). The need for more current information and research on marine plastic and its environmental impacts is agreed upon by regional marine science researchers (WIOMSA, 2021; Ryan et al., 2021; Shilla, 2019). Under the World Bank Problue program, beach surveys on marine plastic litter were carried out at selected hotspots. The survey results provide some useful information to assess the efforts of beach clean-ups (See Section 2.4 and Annex 1).

High levels of microplastic accumulations have recently been noted in marine sediments in Dar es Salaam (NAO, 2021; Mayoma et al., 2020). Microplastics occurred inside half of cockles that were sampled in Dar es Salaam and was four times the level found in cockles in other coastal areas in Tanzania (Mayoma et al., 2020). Local communities that depend on collecting seafood have low awareness of the environmental pollution from microplastics (NAO, 2021).

In Tanzania, voluntary beach clean-up information collected by a group of Non-Government Organizations (NGOs) indicate there are considerable amounts of plastic pollution on beaches (Nipe Fagio, 2020a & b). This confirms that the plastic pollution loads are undoubtedly impacting the marine environment in Tanzania with a range of socio-economic costs (WIOMSA, 2021; Ryan et al., 2021; UNEP, 2021b; IUCN-EA-Quantis, 2020).

2.4 Selection of plastic pollution hotspots

To improve knowledge of plastic pollution in coastal areas, this study undertook a survey of plastic waste in a set of hotspots in selected locations in coastal Tanzania. A plastic pollution hotspot is generally defined as a place where a large quantity of plastic litter occurs due to a number of factors, such as tides and wind making it aggregate.

The following criteria were considered in the choice of marine sites in conjunction with suggestions from local authorities:

- *The geographic location of the site*: for example, its proximity to a city or to river mouths, estuaries, ports, an island or a marine protected area.
- *The impact of the plastic pollution*: What activities take place and what impact may the plastic pollution have on current and future users and the environment? For example, discouraging leisure, bathers and tourists and impacting animal life or the environment.
- *The source of the plastic pollution in the hotspot*: Being able to identify and confirm the origin of plastic waste facilitates potential preventative and remedial action.
- *Representativeness and contribution to the objectives of the study*: A site may have a combination of the features above that can contribute to the study.

The site selection excluded privately operated beach sites and areas that have regular clean-up exercises.

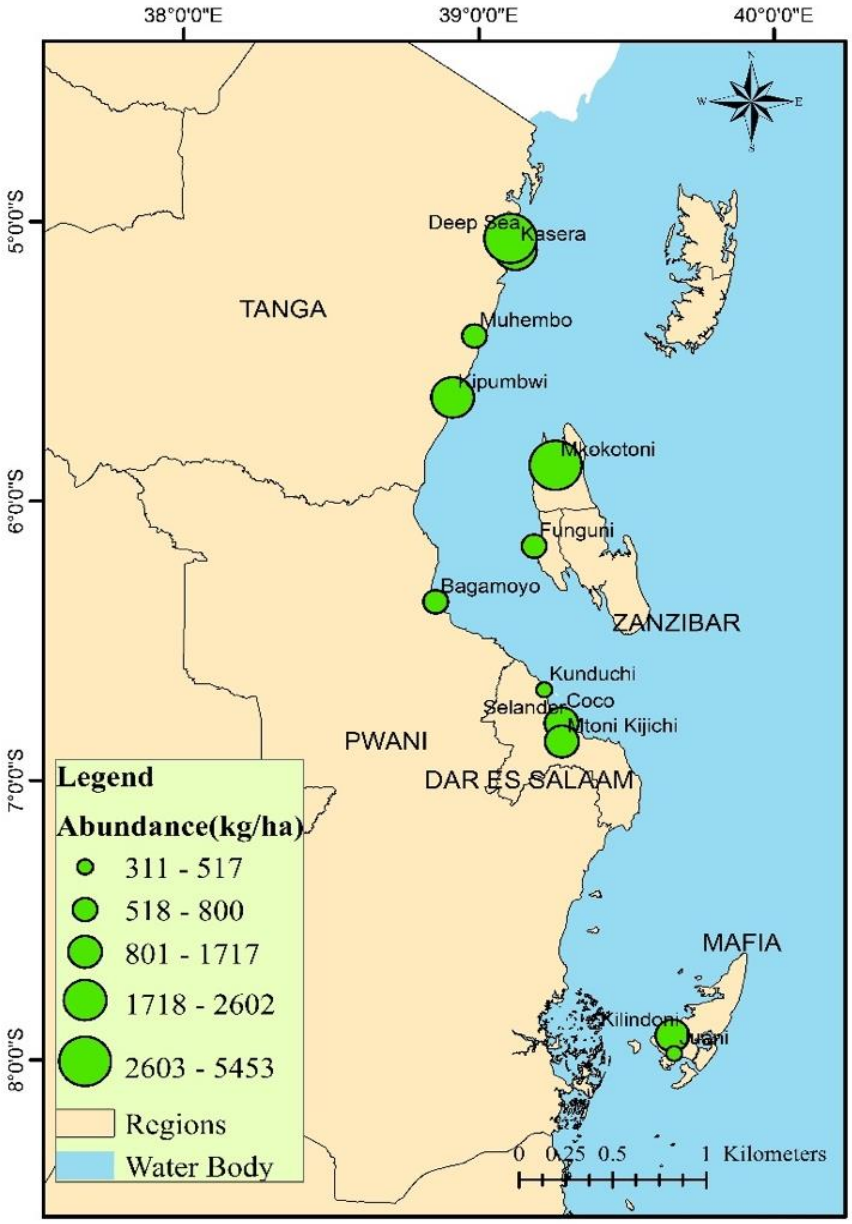
The following hotspots in Table 1 were chosen by the project in consultation with the key national agencies namely, National Environment Management Council (NEMC) of Tanzania and Zanzibar Environmental Management Authority (ZEMA). They are selected sections in 13 beaches in six coastal areas from Mafia Island in the south, to Tanga in the north of Mainland Tanzania and included the west coast of the island of Zanzibar (See Figure 2).

Table 1. Hotspots for the marine plastic survey

Location and Site	**Characteristics**
1.Tanga	
a) Chumvini to Deep Sea Fish Market up to the Tanga Port b) Kasera Fish Market to Mnyanjani Beach	Fish market with limited infrastructure adjacent to beach. Popular with local people, business, and tourism. Low infrastructure fish market area adjacent to mangroves. Estimated 1,500 fishers, 170 boats (2017) loading fish and small goods trade.
2. **Pangani**	
a) Mwembo Beach b) Kipumbwi Village	Occasional community beach visit used for celebrations. Pangani river brings plastic, as does the ocean. Trading and fish processing with boat repairs. Boats ferry charcoal, crops, to Zanzibar and Pemba and return with coconut and cloves.
3. **Bagamoyo (Pwani)**	
Badeco Beach	Historic town with fish buying, processing, and market. Trade with Zanzibar and Pemba.
4. **Dar es Salaam**	
a) Kunduchi fish market to Fish frying area b) Coco Beach c) Selander Beach d) Mtoni Kijichi	Fishing, processing, boat repair and food vending. Several tourist hotels, though beach has erosion and is adjacent to mangroves. Popular 2km-long beach with tourists, walking and snacks. Hotels near beach. At Tanzanite bridge over Msimbazi river, with mangroves, estuarine & sand area. Mangrove and beach used for celebrations, but no formal tourism.
5. **Mafia Island**	
a) Kilindoni Beach b) Eastern side of Juani Island	West side port, fish market with processing -some tourist hotels. East side on Indian Ocean with limited tourism. Turtle nesting area.

6. **Unguja, Zanzibar**	
a) Mkokotoni Town beach b) Funguni-Msikiti Mabluu – Kinazini beach	Town services the community on Tumbatu island. Boats trade goods with mainland. Stone Town has fish landing & a fish market, boat repairs, food stalls and shops. Tourist attraction with some recreational beach use.

Figure 2. Map of Tanzanian coastal regions showing the location of survey sites and spatial distribution and abundance of marine litter

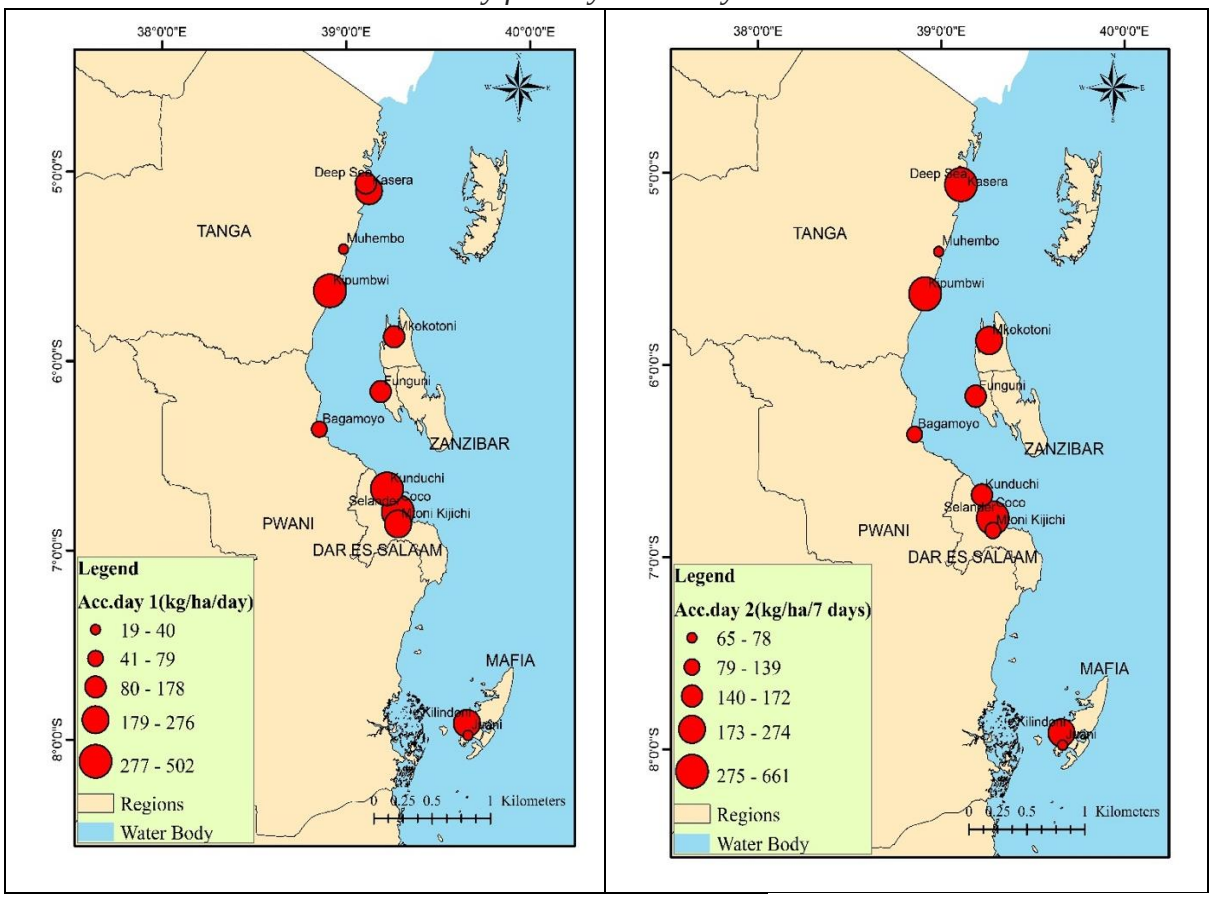


Source: UDSM, 2022.

2.5 Summary of the hotspot survey results

Surveys of marine litter in selected hotspots follow an established approach to determine the extent of waste and the origin of plastic on beaches. In January to March 2022, the project completed plastic pollution surveys at each of the project's six coastal locations. Each location had 2-3 hotspot sites selected to conduct a survey of plastic pollution on the shoreline. The details of the survey results are reported in Annex 1 and UDSM (2022). The geographical locations of the hotspots and the standing stock survey results are reported in Figure 2 and Figure 3.

Figure 3. Map of the Tanzanian coastal regions showing accumulation of marine litter per day for Day1 and Day 7



Source: UDSM, 2022.

The standing stock of waste is measured on Day 0 and has litter from the pre-survey period. The survey is repeated on Day 1 and then on Day 7 to obtain estimates of the accumulation of litter after the initial Day 0 litter removal. The summary results are presented as weight of waste per area (kg/hectare) obtained from each survey site and are also presented as pieces or items per hectare (UDSM, 2022).

Each of the 13 sites along the coastlines shown in Figure 3, had waste levels in excess of 300kg/ha which are considered to be moderately high densities of litter (UDSM, 2022). However, of the 13 hotspot sites, 7 sites (Mkototoni, Deep Sea, Kasera, Kipumbwi, Coco Beach, Juani and Mtoni Kijichi-ranked in decreasing order) had beach waste densities in excess

of 1,200kg/ha which are high levels of beach litter (UDSM, 2022). The highest standing stock result was 6.54 tonnes per hectare (t/ha) at Mkokotoni in Zanzibar and the second highest was 3.91 t/ha at the Deep-Sea site in Tanga. Both sites have fishing, fish markets and small boat trading activities. They also are adjacent to towns where inadequate waste mismanagement leads to the high-density litter hotspots. These beach litter densities are considered to be extremely polluted (UDSM, 2022), comparable to beaches in Mombasa, Kenya (CARDNO, 2020) and in North Africa (Nachite et al., 2019).

The 6 less polluted sites (Funguni, Kilindoni, Selander, Kunduchi, Bagamoyo and Muhembo- ranked in decreasing order) are considered to be moderately polluted (UDSM, 2022), comparable to beaches in Spain (Asensio-Montesinos et al., 2021), but higher than results in Port Elizabeth, South Africa (Barnardo et al., 2021). The accumulation results are reported in Figure 3. See Annex 1 for more information on the results of the beach surveys.

The accumulation results indicate that the replacement of litter the day after the standing stock removal differs slightly to the standing stock results, with some sites such as Kipumbwi, Dar es Salaam and Kilindoni on Mafia Island having higher rates of accumulation after lower standing stock results. The Day 7 results indicate significant new accumulation at sites that had previously had high standing stock and Day 1 accumulation results. However, the replacement of litter after removal is influenced by the amount of waste in the adjacent ocean, neap and spring tides, winds, and local geography and occasionally the Day 7 accumulation results can be less than the Day 1 result. The details of the survey results are provided in Annex 1.

The survey also examined the types of waste in detail (see Annex 1). By number of pieces, plastic beverage bottles were the highest (14.5%), followed by plastic bottle caps (9.0%) and clothing items (7.0%). An analysis of the brands on plastic items showed that beverage drink bottles were the most frequent form of plastic waste and were produced by three large companies (UDSM, 2022). The number of plastic bottles being recycled has increased significantly in recent years, but there remains a need to reduce the number of plastic bottles found on beaches (UDSM, 2022).

Chapter 3. Impacts of Marine Plastic Pollution on Selected Areas

This chapter first provides an overview of the marine economic sectors in Tanzania and Zanzibar. It then presents the selection of the areas for the COED case studies and assesses the impacts of marine plastic waste on the selected areas. The economic costs of the impacts will be valued in Chapter 4.

3.1 Overview of the marine economy

The Marine Economy in Tanzania

Assessing the impacts of plastic on the marine environment requires information on the value of activities within the marine economy. The marine, or ocean economy is "*that portion of the economy which relies on the ocean as an input to the production process or which, by virtue of geographic location, takes place on or under the ocean*" (Colgan, 2004). For the purpose of the study, the profiles of the marine economies of Tanzania and Zanzibar were developed to provide the context for COED analysis and are presented in Tables 2 and 3.

Table 2. Estimates of the marine economy of Tanzania's mainland coastal areas in 2019 (based on authors' research)

Sector	Sector output	Value (TZS Bn)	Value (US$m)	% of national GDP (%)	Employ-ment (# of jobs)	Data sources and notes
Living Resources						
- Marine Fishing	60,977 tonnes	286.6	125.26	0.20%	53,035	Gross value of small-scale marine catch (URT-MLF, 2019)
- Marine Aquaculture	1,785 tonnes	8.25	3.6	0.006%	1,934	Seaweed, oysters & prawns (URT MFP, 2020).
Marine Transportation						
- Water transport		252	110.1	0.18%	N/A	Interview with National Bureau of Statistics, May 2022
Tourism & Recreation	*1,527,230 visitors*	*15,465*	*6,741*	*10.7%*	*1,538,000*	Total tourist numbers (WTTC, 2021)

- Marine tourism	213,812 visitors	2,159	944	1.54%	215,320	14% of tourists (12.2% beaches, 1.8% diving & fishing (NBS-NBOT, 2020)
- Marine park and reserve unit fees	N/A	1.73	0.75	0.0012%	N/A	Interview with Marine Park & Reserve Unit, Ministry of Livestock and Fisheries, May 2022
Total Tanzanian marine economy		**2,706**	**1,183**	**1.93%**	**270,289**	

Source: National Statistics 2019
Note: N/A - not available.

According to national statistics as indicated in Table 2 above, Tanzania's mainland marine economy was estimated to be US$1,183bn in 2019, representing 1.93% of mainland Tanzania's GDP in the same year. The main economic contributions of marine industries are from marine tourism (1.54% of GDP), and small-scale fishing (0.2% of GDP). Table 2 also shows that marine tourism and fishing are 80% and 10.4% of the marine economy, respectively.

Mainland Tanzania had received 1,527,000 international tourists in 2019. Tourism employed 1.538m people comprising 6.2% of the national employment. The travel and tourism sector's contribution to GDP in 2019 was US$6,741.2 m, an equivalent of 10.7% of the GDP (WTTC, 2021). Tourists visiting Tanzania subsequently reduced to 620,900 in 2020 due to the COVID-19 pandemic. International visitors spent TZS6,331bn (US$2,755m) and domestic visitors spent TZS 2,839bn (US$1,237m).

Estimates of the GDP associated with marine tourism were inferred from international visitors who stated the beach (12.2%), and diving and fishing (1.8%), were the main reason for visiting (NBS-NBOT, 2020). This translates to an estimated 213,812 international tourists were attracted by beaches and diving and fishing, and they contributed US$944m to the national economy in 2019 as shown in Table 2.

In 2019, the commercial and artisanal fishing sector employed 53,035 marine fishers and the catch of small-scale fishers was 60,977t, valued at TZS286.6bn (US$125.3m) (URT-MLF, 2019). Water transport contributed 9.4% to the marine economy.

As shown in Table 2 above, 270,289 people were employed in the marine economy, though the available information was limited. For example, limited information precluded an estimation of the percentage of women participating in the marine economy, other than in seaweed culture, where estimates were assumed to be comparable to Zanzibar (80%).

The Marine Economy in Zanzibar

Zanzibar has a long history of marine industries and dependence on the ocean. In 2020 a blue economy report (RGoZ, 2020) profiled the marine industries in Zanzibar as reported in Table 3.

Table 3. Estimates of the marine economy in Zanzibar in 2019.

Sectors	Sector output	Value (TZS Bn)	Value (US$ m)	% of GDP (%)	Employment (# of job)	Data sources and notes
Living Resources						
- Marine Fishing	36,728 tonnes	196.7	83.7	4.77%	63,240*	OCGS (2020), RGoZ (2020)
- Marine Aquaculture	9,663 tonnes	10.4	4.42	0.11%	12,903	OCGS (2020), RGoZ (2020)
Marine Transportation						
- Shipping and marine transport		1.9	0.8	0.05%		ZMA (2016) projected revenue less costs (p43) 2018/19
- Ship, Boat Building & Repair		N/A	N/A	N/A	13,925	Artisanal RGoZ (2020
Tourism & Recreation						
- Marine tourism	538,264 visitors	1,157	499	28%	22,000	OCGS (2020), RGoZ (2020)
- Indirect employment					*50,000*	
Total Zanzibar marine economy		**1,366**	**588**	**33%**	**113,068**	

Note: N/A - not available; * includes 14,333 artisanal shoreline foot fishers.

Source: RGoZ, 2020 and other government reports as indicated in the table.

The marine economy in Zanzibar is an estimated US$588m or 33% of its GDP. Tourism is the largest marine industry at 28% of GDP, and it is significantly higher than fishing and aquaculture (4.88% of GDP) (RGoZ, 2020). Marine transport is important to the island community as goods are imported and exported, and passenger ferries to the mainland are popular and frequent. This information as shown in Table 3 on marine transport is limited.

International tourism arrivals in Zanzibar create a positive and significant contribution to Zanzibar's GDP (Hafidh & Rashid, 2021). In 2019, 538,264 tourists travelled to Zanzibar,

contributing US$499m (28% of GDP) and employing 22,000 persons directly and approximately another 50,000 indirectly (OCGS, 2020; RGoZ, 2020).

Fishing produced 36,728t of catch in 2019, involving 64,240 fishers, showing the dependence on this food source for trade and local consumption (OGCS, 2020). The contribution of the marine economy of Zanzibar could be reduced significantly by the impacts of marine plastic pollution.

3.2 Selection of study areas for COED study

Needs and criteria for selecting COED study areas

Because this study aims to identify and assess the impacts of plastic pollution and evaluate the cost of environmental degradation on coastal areas of Tanzania and Zanzibar, it needs sizeable study areas beyond the small hotspots on beaches. However due to limited financial resources and time, the study could not cover all coastal areas in Tanzania and Zanzibar. It was therefore necessary to select a couple of areas on which to value the cost of environmental degradation (COED) from marine plastic pollution for this study.

Zanzibar Island (Unguja) and Dar es Salaam city were selected as suitable case study areas for the COED study due to their economic importance to the national economy, data availability and the potential scale of environmental impacts from marine plastic pollution. Both areas also are environmentally significant and are also known to contribute plastic pollution to the ocean. The methodology and results of the COED study of the two selected areas should be instructive and demonstrative for other coastal cities in Tanzania. The data the study used in was mostly from 2019, providing a pre-COVID-19 pandemic estimate for future reference.

Dar es Salaam

Dar es Salaam is the largest coastal city in Tanzania and one of the fastest growing cities in Africa. The city's population has increased rapidly, from 4.36m in the 2012 census to 5.38m in 2022 (MFP-NSO, 2022) and is projected to reach 10.7m million by 2030 (UNDP, 2021).

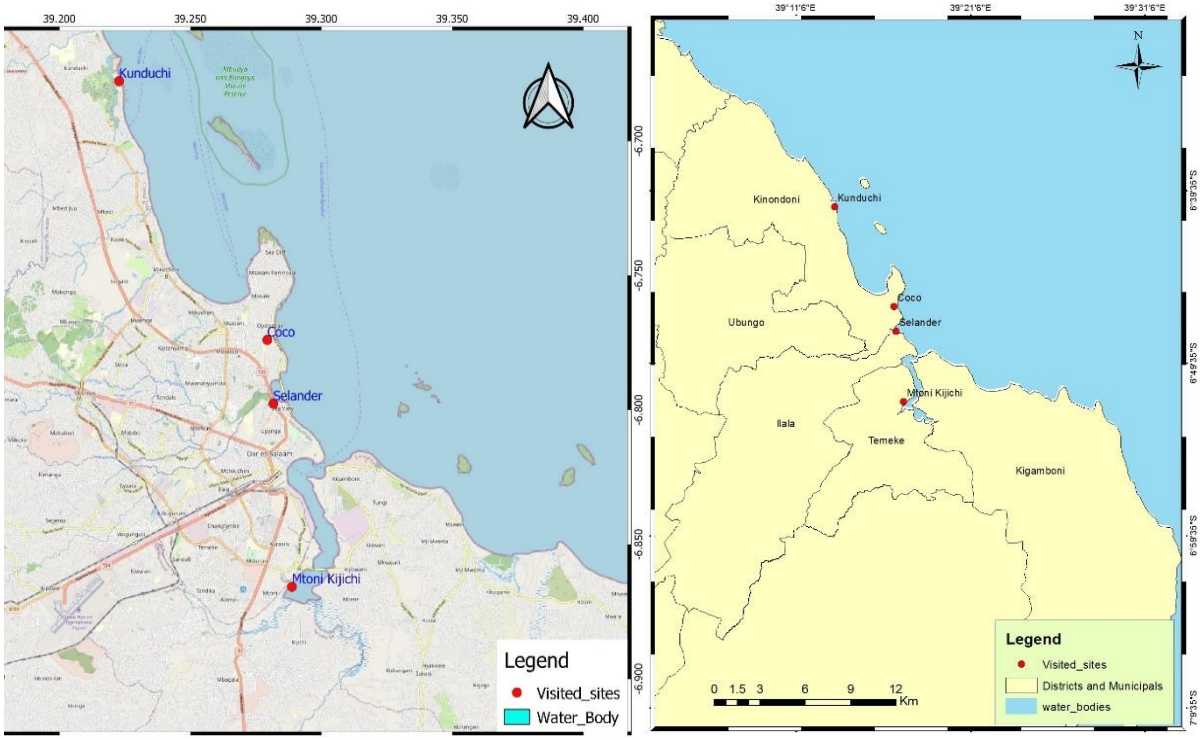
Dar es Salaam's land area is 1,393km^2 and in 2019 it had a population density of 5,222 people/km^2. The city has five districts and municipalities: Ilala, Kigambomi, Kinondoni, Temeke, and Ubungo as shown in Figure 4 below. Ilala is a city municipality.

Dar es Salaam is also Tanzania's most important economic center. In 2019 it had a regional GDP of TZS23,896bn (US$10.4bn), representing 17.1% of mainland Tanzania's economic activity (NBS, 2020). Its per capita GDP was TZS4,529,876 (US$1,980) per person in 2019 (NBS, 2020).

Due to Dar es Salaam's population growth and increasing per-capita SW generation and use of plastic, waste management has been a continuing challenge, overwhelming the city's SWM systems over the past two decades (Huisman et al., 2016). Solid waste generation has increased from 4,100t per day in 2013 to an estimated 5,000t per day in 2019 at the assumption of per capita waste of 1kg per day (UDSM & UNEP, 2018). It is projected that waste will continue to

grow more than proportionately to the population, estimated to reach 12,000t of waste per day by 2025 (World Bank, 2022; Huisman et al., 2016). Unfortunately, as the volume of waste has increased, there has been a gradual decline in the effectiveness of solid waste collection, transportation, and disposal systems (Shilla, 2019).

Figure 4. Maps of the Dar es Salaam study area, showing survey sites and the five municipality areas



Source: UDSM, 2022.

Dar es Salaam's total waste has been characterized as 57.2% organic waste, 13.1% plastic waste, 6.1% paper-related waste, 2.3% glass, 1.0% ferrous metal (steel and aluminium), and 20.3% other (Kazuva & Zhang, 2019; Huisman et al., 2016). It is estimated that less than 40 percent of the total waste generated in Dar es Salaam city is appropriately collected and disposed of in designated sanitary landfills (UDSM & UNEP, 2018; Fassin et al., 2017; Palfreman, 2014). The remaining 60 percent of waste is mismanaged, such as being littered in streets, open fields, streams, and drainage canals, or openly burnt or buried by households (UDSM & UNEP, 2018). These practices contribute to water and air pollution, annual flooding, and the spread of diseases (Fassin et al., 2017). It is estimated that only 4% of plastic is recycled or reused (IUCN-EA-Quantis, 2020). Dar es Salaam alone is responsible for approximately 70% of Tanzania's plastic leakage into the ocean (IUCN-EA-Quantis, 2020).

Zanzibar

Zanzibar is an autonomous region of Tanzania composed of two large and many small islands in the Zanzibar Archipelago located 25–50 km (16–31 miles) off the Tanzanian mainland. Unguja and Pemba are the main islands, with Unguja referred to informally as Zanzibar, or Zanzibar Island. The capital, Zanzibar City, is located on Unguja and includes historic Stone Town, a World Heritage Site.

The COED study focuses on the main island Unjuga (see Figure 5) with an area of 1,666km^2. Unguja has the following municipal areas: Kaskazini (A and B), Mjini Magharibi (A and B) and Kusini (Figure 5).

Figure 5. Unguja (Zanzibar Island) showing municipal areas.

Source: OCGS, 2020.

Zanzibar had a population of 1.3 million people in 2012, increasing to 1,889,773 in 2022, including a population on Unguja Island of 1,346,332 and 543,441 on Pemba Island (MFP-NSO, 2022; OCGS, 2020).

In 2019, Zanzibar's GDP was TZS4,132bn (US$1.783bn) (NBS, 2020; OCGS, 2020). Being a small island community, the regional per capita GDP is TZS2,549,000 per person per annum (US$1,114), which is less than in Dar es Salaam. The GDP of Unguja is not stated in government statistics so it was estimated for the study requirements. An estimate of US$1.344bn is deduced by assuming 95% of total tourism GDP is on Unguja, based on government tourism data on the number of hotel rooms. The balance of GDP less tourism is prorated by Pemba's and Unguja's populations, and re-combined to give the value of US$1.344bn value for Unguja and US$0.439bn for Pemba.

In 2018, Unguja generated an estimated 181,584 tons of solid waste, with 76% being urban in origin (ZUSP, 2019). Waste generated by the tourism sector was estimated at 15.8 tons per day, totaling 5,754 tons annually (ZUSP 2019). An estimated 86% of total solid waste is bio-degradable, coming from households and several markets (Abdulrasoul et al., 2016). An estimated 14% of total waste is metals, textiles, cardboard, glass, and plastic. The small amount of plastic, about 4% of total waste, is noticeable in the waste litter in Stone Town's streets and on beaches (Ally et al., 2014).

There are seasonal patterns to waste production as the increase in tourism brings 0.5-0.6 million international visitors per year during the high season (June-October) and low season (March to May) (Maione, 2021). The presence of significant accumulations of plastic and microplastic on beaches adjacent to Stone Town was confirmed by different research (Maione, 2021; O'Brien, 2018).

Like many small and populous islands, Unguja has limited waste facilities. It is estimated that less than 25% of municipal waste in Unguja is collected and transported to an official disposal site (ZUSP, 2019; Abdulrasoul et al., 2016). Unguja has an estimated 69 official and 92 unofficial dumping sites and plans to improve its waste disposal systems (ZUSP, 2019; Syberg et al., 2018). Open burning of trash is common in Zanzibar (ZUSP, 2019). The amount of waste plastic entering the ocean is unknown.

There are waste pickers who collect recyclable materials on streets and beaches in Unguja and sell them, for example, at a market price of 100-200TZS per kg for plastic, to two local recycling companies that further sell recyclable materials in Dar es Salaam (ZUSP, 2019; UDSM, 2022).

The Zanzibar government have developed a comprehensive SWM strategy for the Zanzibar Archipelago (ZUSP, 2019). This includes adopting good SWM practices for separation, collection, transportation, and disposal of different types of waste (ZUSP, 2019). Improved waste handling will benefit the communities and their livelihoods, local entrepreneurs, and informal women's groups who are highly involved in waste collection (Bhushan et al., 2018).

3.3 Impacts of marine plastic pollution

The impacts of plastic pollution on both land and marine environments have been well recognized (UNEP, 2021a & b). These impacts are broad, affecting everything from local economy to human health, wildlife and biodiversity and marine ecosystems. This section examines the available information to infer the impacts on the two case study areas.

Local and marine economies

Marine plastic pollution has impacts on the economies of Dar es Salaam and Unguja, with a range of economic costs incurred by industries and communities. Plastic waste will affect the value of the national marine economy, which includes fisheries and aquaculture relying on living resources, marine transportation (shipping, ferries, and marine transport), ship and boat building and repair; and marine tourism and recreation (McIlgorm et al., 2020; 2009; Krelling et al., 2017; Jang et al., 2014).

In both Dar es Salaam and Unguja marine plastic pollution interferes with fish and fishing activities and can increase the time taken to sort the catch and reduce the quality of fish catch (IUCN, 2020). Interviews with municipal authorities indicate that ferries and small boats have been impacted by plastic, with ropes and lines entangling outboard engines (UDSM, 2022). Plastic can also be ingested into the cooling systems of larger vessels (UNEP 2021a & b; McIlgorm et al., 2009). Plastic pollution is known to have interfered with seaweed aquaculture in Unguja (IUCN 2020). Marine plastic pollution on beaches also impacts tourism by an

unknown amount in both Dar es Salaam and Unguja. It reduces recreational and aesthetic values and adds beach clean-up and remedial costs to hotel and tourism operators (IUCN, 2020; McIlgorm et al., 2020).

Public health

In Dar es Salaam and Unguja the household burning of plastics for disposal could cause significant "black carbon" air pollution which is harmful to human health. It affects the atmosphere, by releasing greenhouse gases with a global warming potential up to 5,000 times greater than carbon dioxide (CO_2) (Reyna-Bensusan et al., 2019). Burning plastic releases particle matter ($PM_{2.5}$), toxic chemicals such as dioxins, and impacts human health causing respiratory difficulties (UNEP, 2021b). The open burning of plastics outside and inside of homes, is a major cause of premature mortality in Africa (Roy, 2016).

Air pollution from plastic fibers and particles has mortality or morbidity impacts on the populations of Dar es Salaam and Unguja and may eventually enter the marine environment as microplastic. "*In low-income regions, domestic waste - including plastics - is often burnt for heating and/or cooking purposes, exposing largely women and children to prolonged toxic emissions. Illegal disposal of plastics often takes the form of open burning, accentuating the release of toxic gases that include furans and dioxins*" (UNEP, 2018).

Mismanaged municipal solid waste in cities such as Dar es Salaam and Unguja provides a range of breeding sites and vectors for diseases with deleterious health impacts (Rasool et al., 2021; Krystosik et al., 2020). Mosquitoes can breed in water pockets creating a habitat for disease (malaria, dengue fever and chikungunya virus). This pathway has been observed in both Dar es Salaam and Unguja (World Bank, 2021; Syberg et al., 2018).

Dumped plastic may also come in contact with sewage and is thus a disease vector via pathogens such as viruses leading to diarrhea and cholera (Rasool et al., 2021; UNEP, 2021b; Palfreman, 2014). For example, in Unguja cholera mortality in 2016 was 51 persons plus unreported cases, estimated at less than ten per week, at each clinic (Syberg et al., 2018). While many of these are likely attributable to poor hygiene, sewerage and waste disposal, an unknown proportion relate to contact with plastic. A direct link between plastic pollution and human health is noted in the re-use of dumped plastic bottles, which have not been properly cleaned, by juice sellers (Syberg et al., 2018).

Plastic waste can also block drains and cause floods resulting in the loss of economic productivity through business disruption, as has been noted in parts of Dar es Salaam (Lugakingira et al., 2020; UDSM & UNEP, 2018). Plastic blockages have been responsible for mortalities, as recorded in Ghana (Croitoru et al., 2019).

With its breakdown to microplastics, humans may consume plastic particles via air or ingestion from food such as fish. The pathways of microplastics and its implications on human health need further research and 'are not fully understood in Dar es Salaam and Unguja' (UNEP, 2021b; Sequeira et al., 2020).

Environment, wildlife, and biodiversity

In Dar es Salaam the lack of sanitary landfill means that fluid leachates may enter water bodies, contaminate surface, and even ground water, and affect the health of those who use the water (UDSM & UNEP, 2018; Palfreman, 2014). The disposal of municipal solid waste can be critical on small islands such as Unguja, where the open burning of trash and incineration can occur due to limited recycling and areas suitable for dump sites (Ally et al., 2014).

Internationally, Tanzania is known for its wildlife and rich terrestrial and marine biodiversity. When plastic waste enters water courses such as creeks, rivers, estuaries, and marine areas, it impacts aquatic life through entanglement and being eaten by fish, marine animals, and invertebrates. For example, plastic dumped in rivers by inland communities makes its way to Dar es Salaam where it enters the sea, impacting marine animals and bird life.

The wildlife in the coastal waters adjacent to both Dar es Salaam and Zanzibar are negatively impacted by plastic pollution (WIOMSA, 2021). This includes the marine protected areas (MPAs) set aside for marine habitat and biodiversity conservation both in Zanzibar and adjacent to Dar es Salaam. Marine wildlife and biodiversity are higher in MPAs with those adjacent to high population centers being most impacted by plastic pollution (IUCN-EA-Quantis, 2021; IUCN, 2020). Turtles and marine mammals frequently visit coastal waters, sea grass beds and protected areas, and they are impacted by plastic pollution through possible ingestion, entanglement, and exposure to contaminants (Sea Sense 2022; IUCN, 2020). For example, plastic impedes young turtles on the east coast of Juani Island, Tanzania, as they make their way from nesting sites to the ocean over beach sand covered in plastic pollution (Sea Sense, 2021). Birds are also impacted by plastics which are ingested or by becoming entangled in plastic line (Ryan et al., 2021).

Researchers are also becoming more aware of the potential damage to the environment from microplastics and their impacts on marine fish and invertebrate life in Tanzania's estuaries, shorelines, and the seabed (Mayoma et al., 2021; WIOMSA, 2021).

Marine habitats, such as coral reefs and seagrasses, which are covered by plastic pollution, have less healthy wildlife and biodiversity and may suffer from diseases (Lamb et al., 2018). The loss of environmental conditions and impacts of plastic pollution on ecosystem services and the natural capital values the marine environment provides are a developing area of research (UNEP, 2021b; Sequeira et al., 2020; Beaumont et al., 2019).

Summary of plastic pollution impacts for the study areas

Table 4 below presents a summary of the categories of impacts from plastic pollution that occur, to varying extents, in both Dar es Salaam and Zanzibar.

Table 4. Summary of impact categories for the Dar es Salaam and Zanzibar study areas.

Category of Impact	Description
Economy (fisheries, tourism, and other relevant sectors)	• Impacts on marine industry - fishing, seaweed aquaculture, shipping and transport, tourism, and recreation. • Need for protection of ocean and beaches from waste and maintaining cleanliness of beaches and marine environment.
Public health (main vector-borne diseases, any info and data of mortality and morbidity trends)	• Open and household burning of plastic waste; Air pollution due to high $PM_{2.5}$. • Waste is breeding site for mosquitoes, pests and diseases (malaria, cholera, and diarrhea). • Flooding due to blocked drains. • Human ingestion of plastic via seafood
Natural environment (water quality, land contamination)	• Untreated leachate from waste dumps impacts water quality. • Mismanaged municipal solid waste. • Informal dumping into rivers and waterways.
Wildlife and biodiversity	• Impacts on biodiversity and habitat condition, even promoting disease (corals). • Impacts on river and marine life. • Impacts Marine Protected Areas (MPAs). • Marine mammals, turtles, birds and fish face ingestion and entanglement.

Valuing the impacts identified above requires different levels of information and data at each study area. The available data is a limitation for the economic valuation of impacts and the estimation of COED in the study.

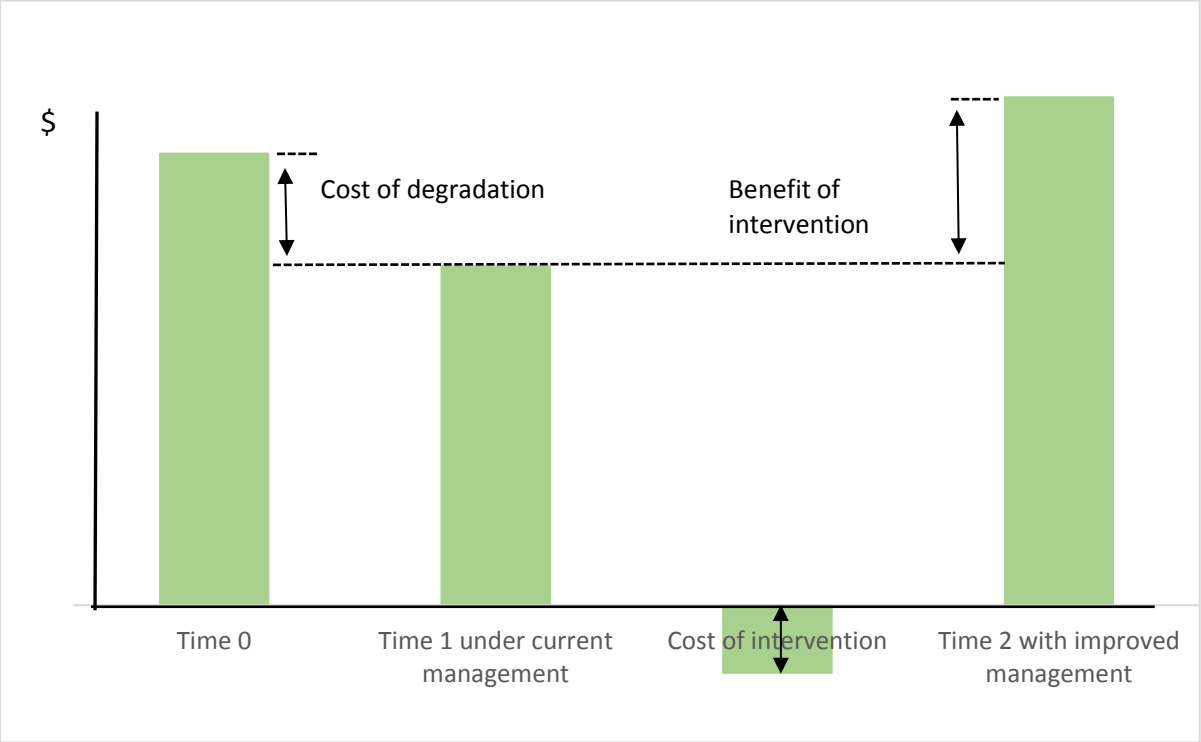
Chapter 4. Valuation of Environmental Degradation from Marine Plastic Pollution

This Chapter first introduces the environmental economics concepts and methods used to evaluate the costs of environmental degradation and then presents their application to, and the results from, the case studies of Zanzibar and Dar es Salaam, respectively.

4.1 Concepts and valuation methods

Pollution reduces environmental benefits, imposes economic costs, and creates health threats to humans. The COED measures reductions in the economic values of the natural environment due to environmental pollution and degradation over a given timeframe. With investment in an intervention, such as prevention or remediation, environmental benefits can be restored—thereby reducing the COED. It's possible to assess the benefits and costs of different interventions to prevent or remediate environmental pollution and degradation. The conceptualization of the COED, and the benefits from remedial interventions, are illustrated in Figure 6.

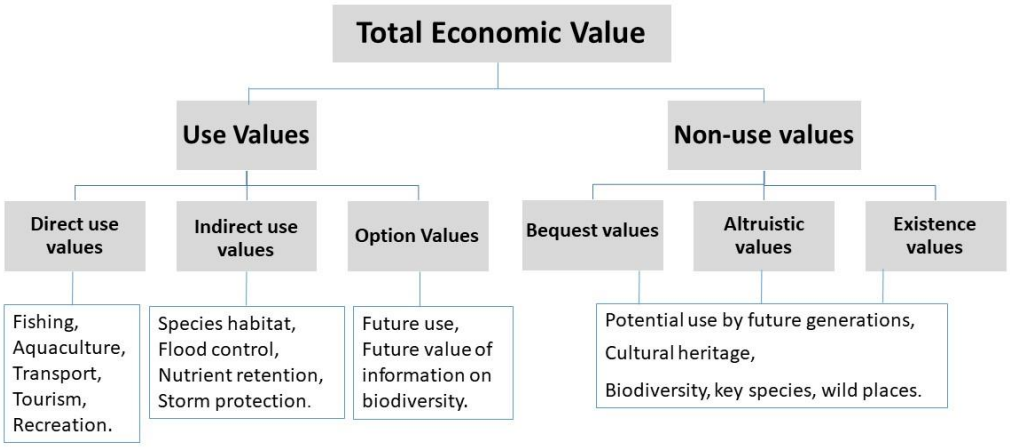
Figure 6. The Cost of Environmental Degradation (COED)



Source: Adapted from Croitoru et al., 2019.

Well-established concepts and valuation methods in environmental economics can be used to valuate COED, such as total economic value (TEV), market value approaches, and surrogate market approaches. TEV is the sum of use and non-use values of an environmental resource as illustrated in Figure 7.

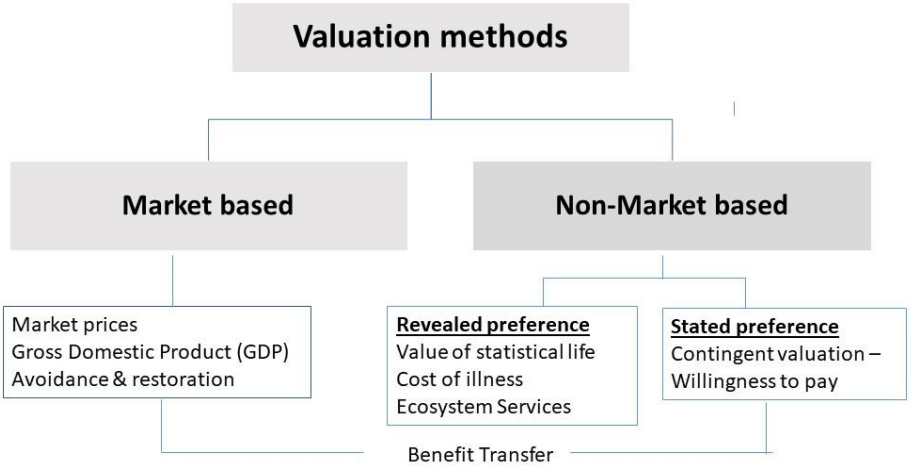
Figure 7. Total Economic Value of the marine environment.



Source: Adapted from Barbier, 2012, and World Bank, 2016.

Figure 8 outlines various valuation methods, both market and non-market or surrogate market approaches, which can be employed to quantify the values of environmental goods and services and their changes.

Figure 8. Methods for economic valuation



Source: Adapted from World Bank, 2016.

The COED has been expressed as a percentage of gross domestic product (GDP) in past studies to make it comparable to other national economic indicators familiar to both policy makers and the general population (Croitoru & Sarraf, 2018; 2010).

There have not been any studies of the COED from marine plastic pollution in Tanzania. This study adopted a set of valuation methods; they are summarized in Table 5 and briefly discussed below. Their applications are presented in two case studies on Zanzibar and Dar es Salaam, explored in the next two sections, respectively.

Table 5. Valuation methods applied in this study

Affected sector	Environmental degradation	Valuation methods used
Economy		
Fisheries, Aquaculture	Damage to economic productivity.	A percentage of sectoral outputs or GDP for marine industry sector as the COED.
Tourism	Damage to tourism demand.	Stated preference: WTP for additional cleanliness. Benefits transfer approach.
Public health		
Air and water	Air pollution, including open and household burning. Mosquitoes and pests gathered by plastics, sanitation issues in water.	A percentage of national health data and VSL for mortality.
Environment, wildlife, and biodiversity		
Environment	Reduction of marine ecosystem services (ESS).	Non-market values, benefits transfer.
*Wildlife and biodiversity**	Damage to wildlife.	Not quantified.

Key: VSL -Value of statistical life; WTP- Willingness to Pay; * No information available

Source: Adapted from Croitoru et al., 2019

Fisheries and aquaculture

Market valuation methods were applied in the fisheries and aquaculture sectors, where the sectoral output change can be directly measured by the change in productivity and market value due to environmental impacts. Marine plastic pollution can result in a loss in revenues or the outputs of marine fisheries and aquaculture (Krelling et al., 2017; Jang et al., 2014). A 2020 study for the Asia Pacific Economic Cooperation (APEC) estimated that lost production due to marine litter and plastic impacts on catches, catch sorting, engines, and fishing gear and concluded was equivalent to 1.0% of the total production value of fishing and aquaculture industries (McIlgorm et al., 2020). Other studies have assumed similar percentages of economic losses from marine litter, though not all are expressed as a percentage of GDP (Linh and Brouwer, 2022; Viool et al., 2019; Newman et al., 2015; Mouat, 2010). Following this APEC study example, this COED study used the assumption of 1% loss due to plastic pollution in sectoral output value of fisheries and aquaculture.

Tourism

The Willingness-to-pay (WTP) approach, an established contingent valuation or non-market method, was used in the study to estimate the environmental damage marine plastic poses to tourism. A WTP survey was recently done in a World Bank study on Unguja Island, the main Zanzibar Island (World Bank, 2020; Soppelsa et al., 2020). A total of 1,063 international tourists were asked if they would be willing to pay an additional amount per night to improve

"environmental protection and cleanliness" in Zanzibar. Fifty-four percent of tourists expressed a willingness to pay and specified a dollar amount (Soppelsa et al., 2020). The relevant results of the WTP survey are provided in Table 6 below.

Table 6. Results of WTP survey in Unguja 2019

Type of tourist attraction	Percentage of willing-to-pay respondents (%)	Average WTP value by attraction (US$ /person/night)
Beaches	63.4%	4.89
Ocean and marine sports	9.1%	5.10
General coastal nature and environment	8.4%	4.03
Total of marine attractions	**80.9%**	**4.74**

Source: Adapted from Soppelsa et al., 2020.

Based on the results of the WTP survey of 2019, beaches, ocean sightseeing and marine sports, and climate-nature-environment were the primary attraction for the majority (81%) of tourists. The 63.4% of all tourists attracted by beaches expressed a WTP at an average value of US$4.89 per person per night for additional beach cleanliness. Tourists attracted by ocean and water sports in Unguja Island, or 9.1% of total visitors, had a WTP of US$5.10 per person per night, and 8.4% of all tourists attracted by the coastal environment and marine ecosystems had a WTP of US$4.03 per person per night. The tourists' willingness to pay for beach cleanliness indicates they were not fully satisfied with the beach condition and were expecting it to be cleaner. Furthermore, a visitor's WTP for beach cleanliness reflects a basic level of economic loss in their enjoyment of beach activities. The survey also confirmed that service providers, such as hotel operators, believed that "environmental cleanliness" in Unguja had not improved over the last ten years, and was impacting tourism (Soppelsa et al., 2020).

The results of the WTP survey were directly used in this study to estimate COED to beach and marine-related tourist activities in the Unguja (Zanzibar Island) case study, then applied to the Dar es Salaam case study following the benefit transfer approach.

Public health

As discussed in Section 3.2, plastic pollution is a source of air, water and land pollution and a cause of mortality and morbidity. The public health impact of plastic pollution can be seen in premature deaths due to ambient and indoor air pollution from the open burning of plastic waste, an unsafe water supply and sanitation related to plastic pollution. However, the health impact of plastic waste in the marine context is supported by limited scientific data.

Based on the Tanzania-specific mortality data available from the Global Burden of Disease (GBD) study (IHME, 2020) and the World Bank/IHME (2016) guidelines, the study developed a method of health impact assessment and economic valuation. The numbers of premature deaths due to ambient and indoor air pollution (measured by $PM_{2.5}$), unsafe water supply, and

poor sanitation, respectively, were reported in the GBD study. Their sum is the total number of premature deaths caused by environmental pollution. About 25% of the national population lives along the coast of Tanzania (World Bank et al., 2014). To get the premature deaths in coastal population only, the national total of premature deaths due to environmental pollution was further prorated according to the population distribution between coastal area and inland.

The estimated contribution to $PM_{2.5}$ from plastic burning has been reported in studies that has been used as a reference. For example, the median estimated contribution of plastic burning ranges from 5–15% of $PM_{2.5}$ in Bangladesh, 0.3–3% in the U.S.A., 13.4% of $PM_{2.5}$ in Delhi, India, and 6.8% of $PM_{2.5}$ in Nanjing, China (Islam et al., 2022). To estimate premature deaths attributable to plastic pollution in coastal areas, this study assumes 2% of premature deaths from plastic pollution. While the 2% figure is arbitrary, it likely represents a conservative estimate.

The economic costs of premature deaths were monetized using the Value of Statistical Life (VSL) method. For the study, Tanzania's VSL was estimated at US$55,323 in 2019. Since no VSL study has ever been done in Tanzania, the study took the available U.S.VSL (EPA, 2022) and adjusted to the Tanzanian figure according to the difference in per-capita GDP between the two countries. It should be noted that the VSL result is a conservative estimate that does not capture the full value of life and is not related to personal remuneration. Nevertheless, the low-end estimate of health impacts is useful to illustrate the need for addressing marine plastic pollution from the public health viewpoint.

The premature deaths and economic costs of coastal Tanzania are presented in Table 7. Among the Tanzanian coastal population, there were an estimated 17,219 premature deaths annually attributable to air and water pollution and sanitary problems. Plastic pollution accounts for 344 premature deaths in the coastal Tanzanian population in 2019 and incurred an economic cost of US$19.1 million that year. The national numbers can be further prorated for two case studies according to their coastal population.

Table 7. Estimates of premature deaths and economic costs from marine plastic pollution in Tanzania's coastal areas in 2019

Premature deaths, costs and % due to plastic	**By ambient air pollution ($PM_{2.5}$ only)**	**By indoor air pollution ($PM_{2.5}$ only)**	**Unsafe water**	**Unsafe sanitation**	**Total**
Premature deaths nationwide (number)	3,845	22,729	23,919	18,384	**68,877**
Premature deaths among coastal population (number)	961	5,682	5,980	4,596	**17,219**
Premature deaths due to marine plastic pollution (number)					**344**

Economic costs due to marine plastic pollution (million US$)	1.1	6.3	6.6	5.1	**19.1**

Source: Adapted from Roy, 2016; World Bank & IHME, 2016; and NBS, 2020.

Environment, wildlife, and biodiversity

A recent study (Ghermandi et al., 2019) on the value of marine ecosystem services (ESS) in the Mozambique Channel, which included the coastal regions of Tanzania and Zanzibar, estimated a total marine ESS value of US$2.2 billion across a range of different types of marine ecosystems (Ghermandi et al., 2019). Marine ESS values were estimated for the case studies of Dar es Salaam and Zanzibar. Please see the following sections and Annex 2 for the details of the data and relevant adjustments).

Regarding the economic impact of plastic pollution, a study by Beaumont et al. (2019) suggested it was between 1% and 5% of ESS values globally. The 5% estimate was applied to Zanzibar and Dar es Salaam in this study, due to the evidence from the beach surveys of high levels of plastic litter by international standards. There was no available information on wildlife impacts or biodiversity values.

4.2 The COED of marine plastic pollution in Zanzibar

This case study estimates the COED of Unguja island, the main island of Zanzibar, from the impacts of plastic pollution on the economic sectors (tourism, fisheries, and aquaculture), public health, and marine environment in 2019.

Tourism

Zanzibar, an internationally renowned tourist destination with a long history and tropical climate, competes with the Seychelles and Mauritius for international tourists in the West Indian Ocean (World Bank, 2019; Lange, 2015). The main city is Stone Town in Unguja island, a UNESCO World Heritage Site, and a popular destination for historical and marine tourism. There are many tourist resorts on the island, mainly along the beaches on the north and east coasts, and additional smaller, less formal tourist venues all along the island's coastline. In 2019, 538,264 international tourists from many parts of the world visited Zanzibar (see Table 8). Their average stay in Zanzibar was four nights per person. Zanzibar's tourism employs 22,000 people directly and another 50,000 indirectly and contributed US$499m in direct economic expenditure and 28% of GDP in 2019 (RGoZ, 2020).

Table 8. International tourists in Zanzibar by home region in 2019

Origin	**2019**	**%**
Europe	341,756	63%
Asia	42,536	8%
Africa	61,312	11%
America	74,247	14%

Oceania	8,633	2%
Not stated	9,780	2%
Total	**538,264**	**100%**

Source: OCGS, 2021.

To estimate the economic cost to tourism from plastic pollution in Unguja, the WTP value of the tourist survey introduced in Table 6 of the previous section was applied to the number of tourist nights in Table 8. As a result, international tourists expressed a total WTP value of US$10.5m per year for the cleanliness and protection of Unguja's beaches and marine environment, of which US$8.34m represents improved beach cleanliness on Unguja, US$1.2m for environmental improvement for marine sports, and US$0.91 for general coastal nature and the environment (see Table 9 below). The total WTP value estimated in this study indicates the low-end estimate of the economic cost to tourism.

Table 9. Estimates of WTP values for environmental cleanliness by marine attractions in Unguja, 2019

Attraction	Average WTP by attraction (US$ /person/night) *	No. of overnight stays by tourists (person nights) *	Total WTP for cleanliness per year (US$m)
Beaches	4.89	1,706,491	8.34
Ocean and marine sports	5.10	265,605	1.25
General coastal nature and environment	4.03	244,262	0.91
Total of marine attractions	**4.74**	**2,216,358**	**10.5**

Source: *adapted from Soppelsa et al., 2020.

Evidence from other studies indicates that impacts of environmental uncleanliness due to beach litter can make tourists significantly curtail their holidays (Qiang et al., 2020). In Tanzania, the sizeable airfares make shortening the duration of international tourists' visits less likely, but dissatisfaction with environmental cleanliness may lead to fewer repeat visits and recommendations of the destination to others (Soppelsa et al., 2020). This may represent a potential additional loss of US$3.25m per year in the tourism sector in the coming years.

In summary, the study estimated the economic cost from plastic pollution as US$10.5m in Unguja's tourism sector in 2019. And an additional loss of US$3.25 in annual tourism revenue from non-returning tourists in the coming year. If the same tourist no-return rate is assumed over years, this revenue loss can be an approximate add-on cost every year, making the total estimated economic cost to tourism up to US$13.75m in Unguja, Zanzibar in 2019.

Fishing and aquaculture

Marine fishing in Zanzibar involves 63,240 fishers and in 2019 produced a total catch of 36,728t, demonstrating the importance this food source has for trade and local consumption

(OGCS, 2020). Seaweed aquaculture production in Zanzibar was 9,663t in 2019, 33% of which is from Unguja (OCGS, 2021). Based on the assumption that the damage from plastic pollution could be 1% of the total value of marine fisheries production (discussed in section 4.1), the estimated damage to fisheries in all of Zanzibar is US$840,000 and to aquaculture US$40,000. Excluding the loss of fishing and seaweed aquaculture on other islands of Zanzibar, such as Pemba, an adjusted cost estimate for Unguja Island is US$520,000 to fisheries and US$10,000 to aquaculture (see Table 10). These values represent direct costs to the industries from plastic impacts on catches, catch sorting, engines, fishing gear, and seaweed farms.

Table 10. Estimated damage from plastic pollution for fishing and aquaculture in Zanzibar and Unguja in 2019

Economic sector	Production or catch (tonnes)*	Value (TZS Bn)	Value (US$m)	Estimated cost (1% of total value) (TZS Bn)	Damage estimate (US$m)
Marine Fishing in Zanzibar	36,728	196.7	83.7	1.97	0.84
Aquaculture - seaweed in Zanzibar	9,663	10.4	4.42	0.10	0.04
Total	**46,391**	**207**	**88**	**2.07**	**0.88**
Marine Fishing in Unguja	22,856	122.4	52.08	1.22	0.52
Aquaculture - seaweed in Unguja	3,221	3.5	1.5	0.03	0.01
Sub-total	**26,077**	**126**	**54**	**1.25**	**0.53**

Source: *adapted from OCGS, 2021.

Public health

Plastic pollution causes public health impacts in Unguja as the island has a very limited capacity for wastewater treatment, and solid waste disposal and there is often open burning of plastic waste (Ally et al., 2014). An estimate of the health impacts from air, water and waste pollution, as well as their estimated contribution to premature mortality, can be made from the national data in Table 7 and the VSL approach introduced in the previous section. The premature deaths and economic costs in coastal Tanzania are pro-rated by population to provide the 2019 estimate for Unguja (see Table 11 below). The study estimated that in 2019, 10 premature deaths in Unguja can be attributable to plastic pollution through ambient and indoor air pollution and unsafe water supply and sanitation. The economic cost of the plastic pollution-related premature deaths was estimated at US$0.53m per year.

Table 11. Estimate of premature deaths and economic costs related to plastic pollution in Unguja in 2019

	Ambient Air Pollution ($PM_{2.5}$)	Indoor Air Pollution ($PM_{2.5}$)	Unsafe Water Supply	Unsafe Sanitation	Total
Premature deaths (persons)*	27	159	167	129	**482**

Economic cost of premature deaths (US$m)*	1.5	8.8	9.3	7.1	**26.7**
Premature deaths due to plastic pollution (assuming 2% of the total) (persons))					**10**
Economic cost due to plastic pollution (assuming 2% of the total) (US$m)	0.03	0.18	0.19	0.14	**0.53**

Source: * adapted from NBS, 2020; Roy, 2016; World Bank & IHME, 2016.

Environment, wildlife, and biodiversity

According to Ghermandi et al., (2019), the value to marine ESS in Unguja, namely the ecosystems of Kaskazini, Zanzibar South and Central and Zanzibar West, was estimated at US$74.0m (see Annex 2 for details). To prevent double counting, Unguja's net ESS values were US$56.0m after the removal of the cost to tourism (US$13.4m) and fisheries (US$4.6m). The annual economic cost of plastic pollution on ESS is estimated to be 5% of this value, i.e., US$2.8m. The COED study had no studies or information on the existence value of marine wildlife or biodiversity for economic valuation.

Summary of COED for Unguja

The study has valued the impacts of plastic pollution on Unguja's economy, public health, and environment. The total COED in Unguja is US$17.6m. This cost is equivalent to 1.31% of Zanzibar's total GDP in 2019, or US$1.344bn. In the COED estimate, tourism accounts for 78% of losses, the loss of marine ecosystem services 16%, and fisheries and public health at 3% each. See Table 12 below. Unsurprisingly, the greatest impact is the cost to tourism, indicating the sector's importance to Unguja and the urgent need to protect it from marine plastic pollution. Valuing COED from marine plastic pollution is a new field, and some impacts, such as those on wildlife and biodiversity, are hard to quantify. The analysis made conservative assumptions, and the COED represents a low-end estimate.

Table 12. Summary of the estimated COED from plastic pollution in Unguja in 2019

Unit: million US$

Category of impacts	**COED of Plastic Pollution (US$m)**	**Percentage of total COED**
Economic sectors		
Tourism (WTP for cleanliness improvement)	10.5	60%
Tourism (Loss of not returning)	3.25	18%
Marine Fisheries*	0.52	3%
Marine Aquaculture*	0.02	0%
Public health	0.53	3%

Environment, wildlife, ** and biodiversity**	2.8	16%
Total	**17.6**	100%
Share of GDP (%)	**1.31%**	

* Direct estimates; ** Not quantified.

4.3 The COED of marine plastic pollution in Dar es Salaam

Situated on the coast of the Indian Ocean, with a river and estuary entering the sea, Dar es Salaam is a port and Tanzania's previous capital city. The city has five districts: Ilala, Kigambomi, Kinondoni, Temeke and Ubungo. Applying the same methodology introduced in Section 4.1, this section estimates the economic impacts of plastic pollution on the city's tourism, fishing, aquaculture, public health, and marine ecosystem services.

Tourism

In 2019, 1,527,230 international tourists visited Tanzania, with 719,481 being from other African nations (MNRT, 2021). Leisure and holiday were the main purpose for 1,066,370 tourists (69% of total) (MNRT, 2021). Total tourism earnings in 2019 were US$2.6 billion (MNRT, 2021). Approximately 88.6% of the international tourists stay in hotels and their total daily average spending was US$266 (US$379/day for package bookings and US$216/day for non-package).

In 2019, there were 936,031 international tourists (61.2% of total) arrived by air, with 322,275 (34.4%) landing at Julius Nyerere International Airport in Dar es Salaam, and 55.4% flying directly into Arusha and Kilimanjaro international airports to access safari tourist experiences. International tourists visit Tanzania for an average of 13 days (MNRT, 2021). Many international tourists visit Dar es Salaam as a part of their holiday, visiting historic attractions, beaches, and marine parks. However, the average number of visitor overnights in Dar es Salaam is not available, as national tourism statistics only check entries and exits, and data on domestic tourism remains under development (MNRT, 2021).

Tourist exit surveys indicate that 213,813 (14%) of all international visitors prioritize beaches, ocean and water sports attractions. Given that 846,000 (55.4%) of tourists arrive at inland airports for wildlife tours, some of the remainders presumably visit for coastal tourism. This study assumed that 50% of the 322,275 tourists arriving via Dar es Salaam airport were intent on marine and coastal tourism. If each international visitor to Dar es Salaam spends five nights this would total 1,607,633 overnights. The number of overnights for marine and coastal tourism is 803,817 visitor-nights.

There have been no studies of WTP among tourists visiting Dar es Salaam for additional beach cleanliness. Using the benefits transfer approach, the available WTP results from Unguja were adopted in the analysis of Dar es Salaam, with a WTP value for beach cleanliness at US$4.87 per tourist per night. The total value of the WTP for cleaning beaches and other marine tourist sites is estimated at US$3.91m (see Table 13). The value represents the tourists' unfulfilled

satisfaction level due to their experience with marine plastic pollution—in other words, it is the economic loss of the tourism sector.

Table 13. Estimated total value of the WTP of tourists for improving cleanliness of beaches and other marine activities in Dar es Salaam in 2019

Nights stayed, expenditure, and damage estimate	Amount	Note
Total number of visitor nights*	1,607,633	5 night per visitor
Number of visitor nights for marine & coastal tourism	803,817	50% of total visitor nights
Total Willingness-to-pay (US$m)	**3.91**	at unit cost of US$4.87/visitor/night

Source: * adapted from MNRT, 2021.

In Unguja, the WTP survey found that 1.03% of tourists were dissatisfied with beach cleanliness and indicated no intention of returning. Assuming the same percentage in Dar es Salaam, there would be a potential loss of US$1.4m in annual tourism revenue, making the total cost to tourism US$5.31m per year.

Fishing and aquaculture

The fish catch for Dar es Salaam in 2019 was 20,188.3t, with a value of TZS 94.9bn (or US$41.47m) (URT-MLF, 2019). Assuming 1% of the total market value of the catch as the cost of plastic pollution to marine fisheries (McIlgorm et al. 2020), the cost is estimated at US$410,000.

Data on the specific production value of marine aquaculture in Dar es Salaam was not available. It was therefore inferred from available national data to be US$1.0m. Again, with the 1% assumption, estimated plastic pollution cost to marine aquaculture is US$10,000 (URT-MFP, 2020).

Public health

Similar to the Zanzibar study, the number of premature deaths in Tanzania's coastal area was prorated by populations to obtain the estimate for the coastal area of Dar es Salaam. The study further assumed 2% of the premature deaths in coastal areas is due to plastic waste-related pollution such as open burning of plastic waste and water-borne diseases. It is estimated that 41 premature deaths occurred in the coastal area of Dar es Salaam in 2019 because of plastic pollution. Applying the VSL to the premature deaths, the estimated cost of health impacts is US$2.2m in 2019 (see Table 14 below).

Table 14. Estimate of premature deaths and economic cost of plastic pollution in Dar es Salaam in 2019

	Ambient air pollution ($PM_{2.5}$)	Indoor air pollution ($PM_{2.5}$)	Unsafe water supply	Unsafe sanitation	Total
Premature deaths in coastal population (persons)*	113	671	706	542	**2,032**
Economic cost of premature deaths in coastal areas (US$m) *	6.3	37.1	39.0	30.0	**112**
Premature deaths due to plastic pollution (assuming 2% of the total) (persons)					**41**
Economic cost due to plastic pollution (US$m)	0.13	0.74	0.78	0.60	**2.2**

Source: * adapted from Roy (2016), World Bank & IHME (2016), and NBS (2020);

Environment, wildlife, and biodiversity

According to the study of Ghermandi et al. (2019), the total ESS value of marine ecosystems in Dar es Salaam amounts to US$59.2m. Deducting the cost to tourism and fisheries for avoiding double counting and then applying the 5% assumption for plastic pollution costs, the resulting estimate is US$2.4m in 2019. There was no available information and estimates on the impact of plastic pollution on wildlife and biodiversity.

Summary of COED for Dar es Salaam

The results of COED from marine plastic pollution in Dar es Salaam are summarized in Table 15 below. The total COED was US$10.33m in 2019. Similar to Unguja, Zanzibar, the highest was the cost to tourism, making up 52% of the COED. Coastal tourism activities are less popular than inland safaris and the absolute cost to tourism from marine plastic pollution in Dar es Salaam is smaller than that in Unguja. In contrast, the health impact of plastic pollution is larger than in Unguja, comprising 21% of the COED, primarily due to inadequate waste management. The impacts on marine ecosystems are significant at 23% of the COED and the loss of marine fisheries is 4%. As Dar es Salaam has a more diverse and much bigger economy than Zanzibar, the total COED from marine plastic pollution was equivalent to only 0.1% of the city's US$10.4bn GDP in 2019, much smaller than the percentage loss in Zanzibar.

Table 15. Summary of the estimated COED from plastic pollution in Dar es Salaam in 2019

Unit: million US$

Category of impact	COED of Plastic Pollution (US$m)	Percentage of total COED (%)
Economy		
Tourism	3.91	39%
Tourism not returning	1.4	13%

Marine fishing*	0.41	4%
Marine aquaculture*	0.01	0%
Public health	2.2	21%
Environment, Wildlife & biodiversity****	2.4	23%
Total	**10.33**	100%
Share of GDP (%)	**0.10%**	

* Direct estimates; ** Not included.

4.4 Costs and benefits from cleanup

As seen in Figure 6, beach cleaning or other remediation activities will not only incur a cost but also yield environmental benefits that reduce the overall COED. This section further analyzes the costs and benefits from remedial actions, using beach cleanup as an example. This analysis aims to guide interventions that reduce environmental impacts and therefore the COED.

The inclusion of cleanup costs in the study is limited by issues of representation in the extrapolation of results from small marine litter hotspots to the whole of the Zanzibar and Dar es Salaam coastlines. For example, a hotspot on a beach will generally have litter densities that exceed those of the coastline as a whole. Similarly, the benefit values from hotspot cleanups were not able to be established for the entirety of case study areas. However, the study tries to demonstrate some findings on remedial costs of cleaning up marine plastic litter and project the possible benefits.

The average cost of beach cleaning was based on the daily costs of beach cleaning equipment and labor (US$378) being applied to a 2.5-hectare sample site (see Annex 3). The waste survey results in Annex 1 were used to produce a daily average cost per ton of beach litter for each survey area. The results ranged from US$46-$588/ton with a mean of US$220/ton and a median of US$138.8/ton for beach cleaning. These costs reflect high variation in the quantum of debris between hotspot sites. Caution is required if extrapolating these estimates to larger areas. The accumulated Day 1 and Day 7 results have a higher average cost per ton than the standing stocks results as there is less litter density. The median results of US$908/ton (Day 1) and US$1,095/ton (Day 7) indicate that lower litter densities have higher per-unit cleaning costs.

The median value of US$138/ton is a typical overall daily cost estimate for the beach cleaning of a standing stock of litter. It is similar to a recent beach cleaning study in Kenya, which found a cost of U$125/ton (CARDNO, 2020). The survey results were costed out at US$378/day. In practice, a beach cleaning exercise may cover more area than in our restricted survey exercise, especially when litter densities are low.

Remedial costs of clean-up in Zanzibar

The estimated costs of beach cleaning at two sites on Unguja, Funguni and Mkokotoni were developed from the project's standing stock and accumulation survey results (see Annex 3). The Funguni site had moderate waste density levels, with a remedial cost of US$228/ton.

Remediation in Mkokotoni costs US$46/ton, as it had the study's highest density standing stock result. The high beach waste density gave a deceptively low cleaning cost per ton, not reflecting the challenge the cleanup team had in removing 6.5 tons/ha of litter in a day from this 2.5-hectare site. The Funguni site had moderate waste density levels but was still above those expected at tourism sites internationally (Barnardo et al., 2021).

The costs of remediation exercises can be estimated from either the daily cost of beach cleaning from the beach surveys or the average cost per ton as explained in Annex 3. It is assumed that there are 25 beach cleanups per annum, i.e., one cleanup in each of 25 weeks during the high season for tourists and at festival times when local communities relax and celebrate on the beach (UDSM, 2022). The range of the estimated total costs of the beach cleanups per annum at the two survey beaches in Unguja is presented in Table 16. The costs vary between sites due to beach length and a significant difference in waste density.

Table 16. An estimated range of daily and annual cost estimates for 25 beach cleans per annum at sites in Unguja

Beach sites in Unguja	Length of beach (km)	Range of daily beach cleaning cost (US$'000)	Range of total beach cleaning costs for 25 days (US$'000)
Mkokotoni	5.35	4.0-12.1	101-301
Funguni	1.39	0.3-1.1	7.5-27.5

Source: UDSM, 2022.

As introduced in a previous section, a survey of tourists in Unguja on their willingness-to-pay indicated a total value of $10.4m per annum from tourists to improve beach cleanliness. Of this US$2.5m was for the Stone Town area, where Funguni beach is located. Beach cleanup could be applied at Funguni to maintain beach cleanliness and quality for keeping tourist visits in Stone Town.

Table 17 further shows the results of a preliminary cost-benefit analysis for Funguni beach. As the annual cleanups will bring amenities to the visitors, the benefits can be assumed as a portion of their willingness-to-pay value for beach cleanliness. The WTP value is assumed as percentages –1%, 2.5%, 5%, and 10%– and their total economic benefits per annum are shown in the second column of Table 17 below. The benefits are then compared against the total annual costs of beach cleanup in the range from the low end of US$7,500 to the high end of US$27,500 presented in Table 16. The benefit-cost ratios (B-C ratio) of each scenario are presented in Table 17.

Table 17. The projected annual costs and benefits of beach cleaning of Funguni beach, Unguja in 2019

Percentage of WTP assumed (%)	Economic benefit per annum (US$)	B-C ratio (at low cost)	B-C ratio (at high cost)
1.0%	25,000	*3.3*	*0.9*
2.5%	62,500	*8.3*	*2.3*
5.0%	125,000	*16.7*	*4.5*
10.0%	250,000	*33.3*	*9.1*

Benefit-cost ratios show beach cleanups are economically viable with B-C ratio higher than 1 and B-C ratios from 2.3 to 9.1 are possible. A recent study in Kenya (CARDNO, 2020) found a benefit-cost scenario of 9 for marine litter on beaches in similar circumstances.

In summary, the available information suggests that the considerable annual COED of US$17.7m estimated for Unguja could be reduced by cleanup of key sites that tourists consider to be unclean. However, the remediation measure is only a temporary solution, and it should be complemented by a range of long-term preventative actions, for example, reduction of land-based plastic waste from entering the ocean.

Remedial costs of clean-up in Dar es Salaam

The average costs of beach cleaning for the four study sites in Dar es Salaam are reported in Annex 3. The estimated average daily costs of cleaning the standing stock of beach litter were: US$89/ton at Coco beach; US$123/ton at Mtoni Kijichi; US$468/ ton at Kunduchi; and US$588/ton at Selander. The average was US$317/tonne across the four sites. The results for Coco beach and Mtoni Kijichi were below the national average of US$138/tonne, due to their high waste levels. Kunduchi and Selander had moderate pollution and higher average beach cleaning costs than the other two sites. The waste levels at all of these sites were above international expectations of a tourism destination (Barnardo et al., 2021).

Following the same approach used for Unguja above, the potential costs of remediation exercises can also be estimated for Dar es Salaam. A summary of the daily and annual remedial costs of 25 beach cleanups during the 25 weeks during the tourist season at each of the four sites are presented in Table 18. Also see Annex 3 for details.

Table 18. An estimated range of daily and annual costs of cleanups at beach sites in Dar es Salaam

Beach sites	Length of beach (km)	Range of daily costs of beach cleaning s (US$'000)	Range of total beach cleaning costs for 25 days (US$'000)
Kunduchi	10	1.1-9.7	28-241
Selander	4	0.7-3.8	17-96
Coco Beach	3.5	0.1-3.3	51-67
Mtoni Kijichi	3.5	1.4-3.3	37-84

Source: UDSM, 2022.

The total daily and annual remediation costs for cleaning all plastic waste on the beach differ by site as the conditions on the ground may vary; for example, Kinduchi beach is 10km long and the topography varies, so not all of it may require cleaning.

Dar es Salaam has extensive beach cleaning by a range of NGOs (Nipe Fagio, 2020a). However, as a long-term remedial action, there is concern that expenditures on beach cleaning may be "never ending." There is 20,300t of plastic waste entering the sea from Dar es Salaam annually. The beach refills from the adjacent stock of plastic in the ocean are discussed in Annex 1. Only a small portion ends up on Dar es Salaam's beaches and the majority remains in the ocean and is distributed along the Tanzanian coastline (IUCN-EA-Quantis, 2020; Nipe Fagio, 2020b). So, while beach cleaning is a remedy for local situations in the short term, there is also an immediate need for preventive SWM actions to reduce the amount waste and plastic entering the sea from Dar es Salaam in a long term (World Bank, 2021).

Chapter 5. Summary and Policy Implications of the COED Study for Marine Plastic Pollution Management

This chapter summarizes the results of the COED study in Zanzibar and Dar es Salaam and discusses its policy implication to marine plastic pollution management and the way forward.

5.1 Summary of the COED study

The COED of the two study areas reveals a wide range of marine plastic pollution impacts on local economies, public health, the natural environment and beyond. The greatest cost unsurprisingly occurs in tourism, which is an extremely important industry in coastal economies, especially in Zanzibar. In Unguja Island, Zanzibar, the cost to tourism from marine plastic pollution is estimated at US$13.75m per year. Estimates for Dar es Salaam indicate an annual tourism loss of US$5.36m. This relatively small of tourism loss in Dar es Salaam is due to a smaller number of tourists for marine and coastal recreational activities.

The second and third ranked costs are the impacts on public health and fisheries, respectively. Costs to public health come from three sources: sanitation-related impacts, air pollution from the burning of plastic waste, and abandoned plastics that become insect breeding grounds and sources of pathogen spread. In Dar es Salaam, health impacts cost an estimated US$2.2m per year. Unguja has a much smaller population and a lower estimate of US$0.53m.

The annual impact on fisheries and aquaculture is US$0.52m in Unguja and $0.41m in Dar es Salaam. These costs derive from the need to: clean fishing nets, gear, and engines; conduct additional catch sorting; and remove plastics from seaweed farming areas. The survey revealed plastic litter is correlated with towns with fish landing sites, fish markets, and inadequate SWM.

The COED also includes impacts of plastic pollution in the coastal marine environment, including the reduction of the value of ecosystem services. But this cost may be highly underestimated, as impacts on marine wildlife were omitted due to the lack of data. Therefore, the cost of the plastic pollution impacts on coastal and marine eco-systems are conservatively estimated at US$2.8m per year in Unguja and US$2.4m per year in Dar es Salaam. The estimates do not include environmental costs of some marine ecosystems and marine wildlife from plastic pollution in Tanzania's national ocean area due to the difficulty to identify and quantify them.

In summary, the COED of plastic pollution in Unguja is estimated at US$17.6m, equivalent to 1.31% of Zanzibar's total GDP of US$1.344bn in 2019. The COED in Dar es Salaam is US$10.5m, equivalent to 0.1% of Dar es Salaam's GDP of US$10.4bn in 2019. The total COED for the two coastal sites is US$28.0m for 2019.

5.2 Policy Implications of the COED results on marine plastic pollution management

The COED first helps the government, communities, and local residents start to recognize two plastic waste impacts: first, the vulnerability of the marine environment and local industries (such as tourism and fisheries) to marine plastic pollution and second, the potential health risks of plastic waste. The COED results, including comparisons between study areas and sectors, are useful for prioritizing marine plastic pollution management activities in the future. The future COED can be reduced by more targeted policy interventions. The COED illustrates that significant economic cost impacts from plastic waste can be reduced by improved waste control at sources, such as SWM in urban settings, before the pollutant disperses. Specific policy implications of the COED results can be summarized as follows.

Improve waste management to reduce pollution and control plastic waste entering water bodies. Plastic waste control to improve the marine environment and reduce the COED needs to start by addressing the quantity and types of plastic products that are being imported, produced, and used by Tanzania. Effective implementation of the existing 2019 Regulation on banning plastic carrier bags is an initial and important step for a developing country like Tanzania, since it lacks adequate SWM systems to collect and treat plastic waste. The government may consider expanding the ban to cover more plastic products. The majority of marine plastic waste creating the COED is coming from coastal cities, especially Dar es Salaam, the nation's largest city. It is therefore important for Tanzania to improve its municipal SWM systems, particularly for collection, recycling, and treatment of plastic waste. In 2018, the Government of Tanzania developed the National Solid Waste Management Strategy to reduce waste generation, improve waste collection and disposal, and promote waste re-use and recycling (UDSM & UNEP, 2018). Through implementing the Strategy starting in major urban areas such as Dar es Salaam, the country may significantly reduce plastic waste from land-based sources entering water systems and the ocean.

Incentivize tourism sector to address plastic pollution on beaches. International visitors bring much needed economic benefits to Unguja and coastal Tanzania. Tourists and residents expect a pollution-free marine environment with white beaches, clear blue ocean, and the opportunity to enjoy marine wildlife. To protect these tourism benefits, the government, tourism industry, NGOs, and local communities should be encouraged to cooperate to address plastic waste on beaches. Tourism industry providers, such as hotels and tourist service providers, should first apply the 3R (reduce, reuse, and recycle) principles to their own plastic waste. For example, they should ensure the recyclability of the plastic they use and examine ways to reduce the number of plastic bottles in beach litter. National environment and tourism agencies need to work with the tourism industry, NGOs and stakeholders to develop preventative and remediation plans to protect tourism and reduce the COED from marine plastic pollution.

Prioritize beach cleaning. While prevention is preferable, expenditure on additional beach cleaning in popular tourist areas is required to decrease the perception of "environmental uncleanliness" among visitors. Preliminary benefit-cost analysis of beach cleaning in Stone Town, Unguja indicated that more regular cleaning of popular tourist beaches during the tourism season may have net benefits and reduce the COED from plastic beach waste. The benefits and costs of beach cleaning and other policy interventions need to be assessed through monitored trials to evaluate the effectiveness of additional expenditure. However short-term

expenditures on beach cleaning may become an almost permanent requirement if the original land-based sources of plastic waste remain uncontrolled due to inadequate SWM and plastic waste prevention. A combination of beach cleaning and waste preventing actions in the short- and medium-term is necessary.

Protect marine and coastal ecosystems. Marine and coastal ecosystems are critical assets for local economies. These ecological assets attract tourism, protect marine life, support fisheries and sustain local economies. The study quantified the impacts of marine plastic pollution on marine and coastal ecosystems. The COED study has demonstrated that the protection of the marine environment from plastic pollution will benefit the tourism, fisheries and aquaculture industries and protect the livelihoods and incomes of many local residents. Thus, managing marine plastic pollution and increasing the value of ecosystem services must be a national priority.

Protect public health. Marine plastic pollution is a threat to public health, and policy attention should be given to reducing plastic litter that traps water that then spreads insects, and the open burning of plastic waste by households and businesses, both of which have adverse health outcomes for both tourists and residents.

Improve environmental management practices in fisheries and aquaculture. Marine fisheries and aquaculture industries require a clean marine environment but experience the COED from plastic litter. Tourists expect to consume high quality local fish while on vacation in Tanzania's coastal areas. Reduced levels of beach litter and microplastic pollution will prevent plastic ingestion by fish and maintain tourist demand for seafood. The beach surveys indicated a correlation between pollution hotspots and fish landing sites, fish markets and inadequate SWM in nearby towns. In addition, fisheries and aquaculture are also a direct source of marine plastic waste, although they generate much less than cities. The environmental management of vessels and port facilities needs to be strengthened to reduce their plastic litter and contribution to the COED. The country should consider a program to incentivize fishers and marine transport operators to bring their plastic waste—such as unwanted fishing gear and nets—to shore for collection and recycling.

Introduce environmental management policy and marine environmental protection fee. Reducing the COED from marine plastic pollution requires both well-designed environmental policy and regulatory frameworks and the implementation of effective policy instruments. In-depth policy review and analysis is necessary. The COED analysis in Zanzibar further indicates international tourists are willing-to-pay for improved environmental cleanliness, especially on recreational beaches and marine sites. The existing fee system for tourism should be reviewed and a new "marine environment fee" particularly on international tourists who have a higher WTP margin could be considered. A well-targeted and justified environmental fee will help local governments finance preventive or remedial plastic pollution control activities. Such programs can help protect the tourism industry and encourage further development.

Targeted public education and participation for behavioral change. Public education programs are necessary to raise public participation in activities to reduce waste generation and litter, increase collection, and protect public health. Governments, in collaboration with

communities, NGOs, and the private sector, should organize such programs and provide necessary financial and logistical support.

Improve data collection and information management. Finally, strategy development and policy making rely on good economic and environmental information. Plastic waste monitoring, data analysis, and waste accounting can help to collect, process, and improve information. Government agencies can work with municipalities, stakeholders, and NGOs to collect and compile data on plastic waste pollution and build capacity to monitor and value the impacts of marine plastic pollution.

5.3 The way forward

This study is the first of its kind for valuing the cost of environmental degradation from marine plastic pollution. It aimed to gather and review existing data and information available from regional, national, and municipal studies, literature, and government documents and conduct economic valuation of environmental degradation from marine plastic pollution. There is a need for more current information and research on marine plastic and its environmental impacts. Beach surveys were conducted on a set of selected hotspots to fill some information gaps on the distribution and accumulation of marine plastic waste in coastal areas.

However, as introduced previously, the study faced some limitations which need to be addressed in future research. One main constraint is the limited availability of environmental and economic data in the study areas. The benefits transfer approach was employed when local data were missing, since there is useful information in similar areas to fill analytical gaps. For example, information from international health research was used to estimate and valuate health impacts in selected coastal areas of Tanzania. The results of a recent survey of tourists' willingness-to-pay for cleaner beaches in Zanzibar were used, and subsequently transferred to the Dar es Salaam analysis. In addition, the lack of time-series data means the COED study is in 2019 only and did not attempt to analyze the trend over time.

Environmental monitoring, data collection and management, and in-depth analyses will help deepen this study and better inform policy makers. For instance, the hotspot surveys and analysis can be extended and diversified based on the sources of plastic waste and impacts, e.g., SWM sites. Impacts of marine plastic on wildlife and marine ecosystems need to be further studied. The COED is likely underestimated due to the difficulty of valuing some impacts. SWM is critically important in plastic waste control. Given this importance, SWM programs and investment activities should be considered as part of municipal service improvement, especially investments in collection and recycling facilities to control waste at source before it disperses. There should also be feasibility studies and trials of some technical options for plastic waste control. For example, the use of plastic litter traps in waterways and rivers leading to the sea.

Despite its limitations, the report contributes to the emerging topic of valuation of the cost of environmental degradation from marine plastic pollution and provides a useful base for policy analysis and decision-making in the future.

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Annex 1: Results from the survey of plastic pollution hotspots

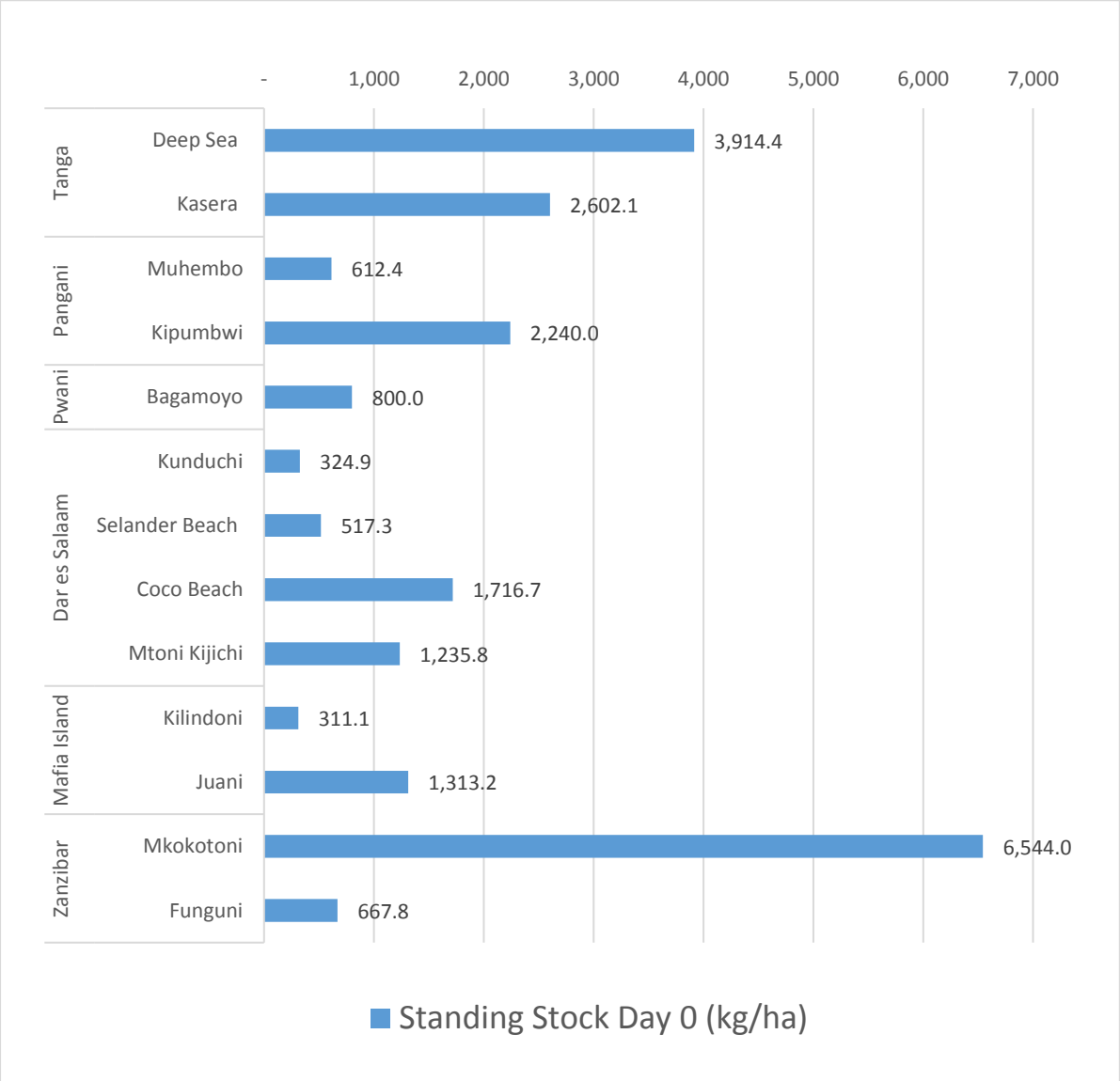
Surveys of marine litter in selected hotspots have been popular in determining the origin and extent of beach waste and monitoring the effectiveness of beach cleaning. Supported by the multi-donor trust fund PROBLUE, beach surveys on marine plastic waste were carried out from January to March 2022 at its six coastal locations, each of which had 2-3 hotspot sites (UDSM 2022). Internationally accepted survey methodologies (Barnardo & Ribbink, 2020) were used in the surveys.

The following surveys at hotspots were undertaken:

- An initial Day 0 standing stock survey for a designated sample area on the beach site (usually 50m wide and 500m long, an area of 25,000m^2). The standing stock (SS) refers to evaluating plastic litter densities that are found in areas which have not been cleaned recently. The number of pieces and weight of waste and plastic pollution were estimated for the area sampled; and
- The next day, Day 1, an accumulation survey (Acc.) repeated collection over the same area to establish daily rates of waste accumulation. The Acc. survey was then repeated 6days later, referred to as Day 7, to examine patterns of plastic accumulation. The project method was a proxy of the much longer and more resource intensive approach of accumulation surveys on ten sequential days (Barnardo & Ribbink, 2020).

The sampled site area was measured enabling the estimation of the density of the standing stock of plastic waste, measured in pieces/hectare or weight kg/hectare. The accumulation results are time-related, and rates are expressed as pieces/ha/day, or kg/ha/day. The results from the survey locations and specific sites are reported in Figure A-1.

Figure A-1. The Standing stock Day 0 survey results for the sites north to south in mainland Tanzania and Zanzibar

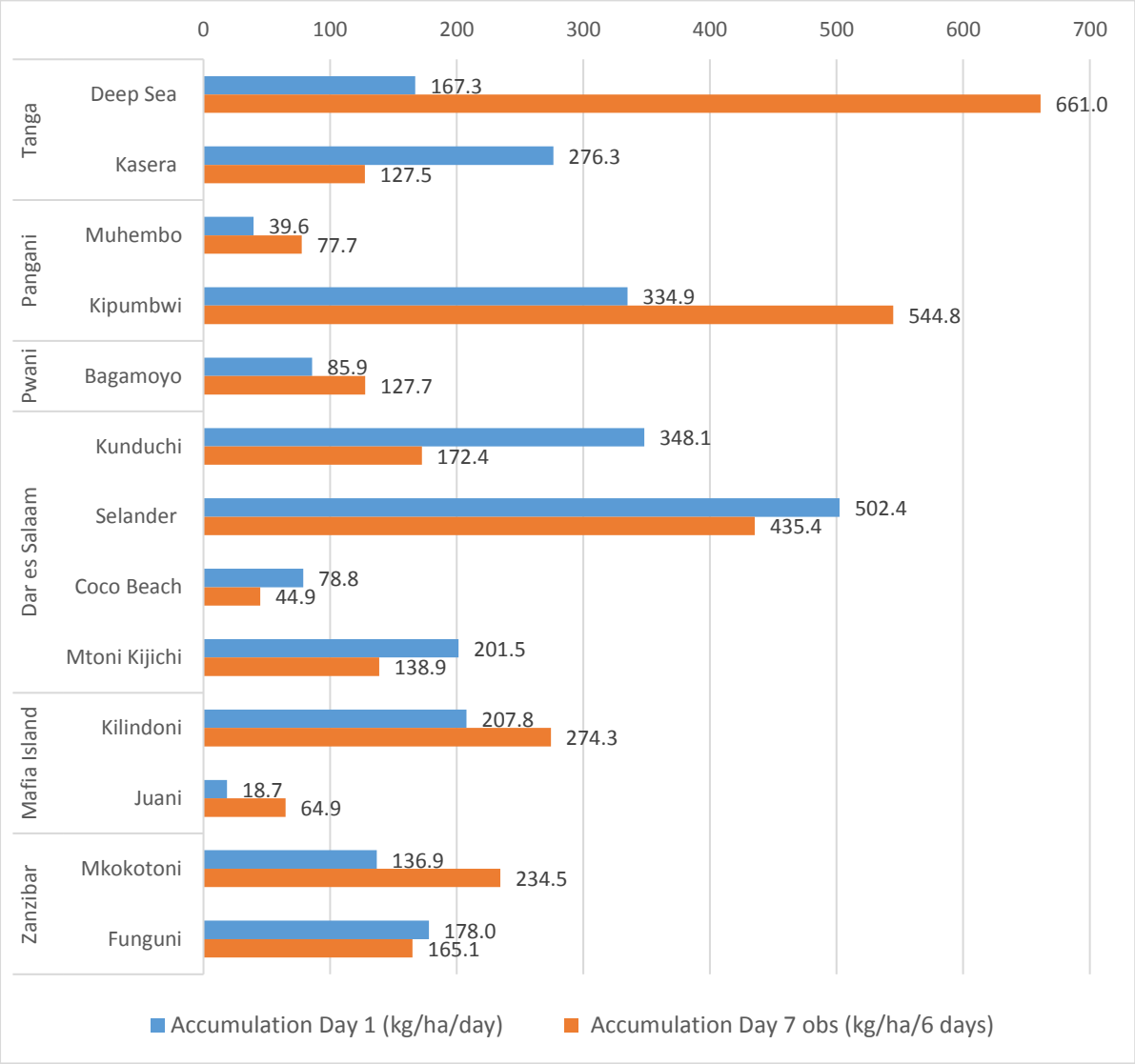


Source: UDSM, 2022.

As shown in Figure A-1, the standing stock density of plastic pollution collected on Day 0 varied between sites, ranging from 311.1kg/ha in Kilindoni to 6,544kg/ha in the town of Mkokotoni in northwestern Zanzibar. The variation reflects pollution load at different locations or sites, as some of them are fish market sites (e.g. Tanga-Chumvini, Kipwumbi and Mkokotoni) and some are influenced by rivers and estuaries.

Figure A-2 shows the survey results for the accumulation rate of plastic pollution which varied between Day 1 and Day 7, six days after Day 1, due to waste accumulation after the initial standing stock sample was removed on Day 0. The results showed that each site was subject to highly variable amounts of waste accumulation. On occasions the Day 1 total was higher than the Day 7 total as waste in the adjacent ocean is lifted and re-laid by neap and spring tides, driven by winds and currents, in an unpredictable fashion. Accumulation rates are also influenced by local geography and shoreline features.

Figure A-2. The Accumulation survey results for the sites in mainland Tanzania north to south and Zanzibar on Day 1 and Day 7



Source: UDSM, 2022.

Seasonal variations in waste accumulation have been noted from monitoring the river Mbezi, where more litter was collected in October 2019 (dry season) than in April 2020 (wet season) and the additional water in the wet season washes plastic accumulated in rivers during dryer periods into the sea and then onto beaches (Nipe Fagio, 2020b).

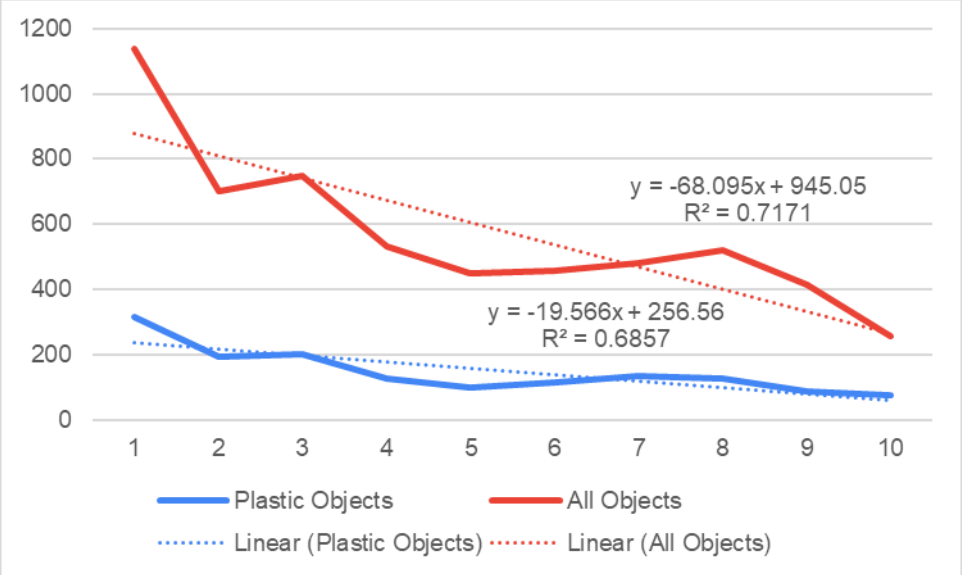
The accumulation results confirmed a correlation between high waste densities and fish market sites (e.g., Tanga-Chumvini, Kipwumbi & Mkokotoni). Of the non-fish marketing sites, Selander had significant plastic densities and a high accumulation rate due to its estuarine and beach location at the end of one of Dar es Salaam's main rivers.

Discussion of waste survey results and the effectiveness of beach cleaning

The accumulation results from this project's beach surveys indicated that beach plastic waste levels were generally reduced after cleaning, but beaches were not likely to remain clean. We sought other research evidence on how repetitive beach cleaning affected waste accumulation rates in Dar es Salaam.

The project was able to access data to investigate beach waste accumulation and cleaning further from a recent waste cleanup survey by a local Tanzanian NGO, Nipe Fagio (2020b), That study had cleaning taking place over ten consecutive days on beaches in Dar es Salaam (Nipe Fagio, 2020b). Results are reported in Figure A-3.

Figure A-3. The weight of all objects and plastic on each of 10 days of beach cleaning at three sites in Dar es Salaam combined (Selander, Mbezi & Kigamboni beaches)



Units: kg/ sample area Source: Adapted from Nipe Fagio, 2020b.

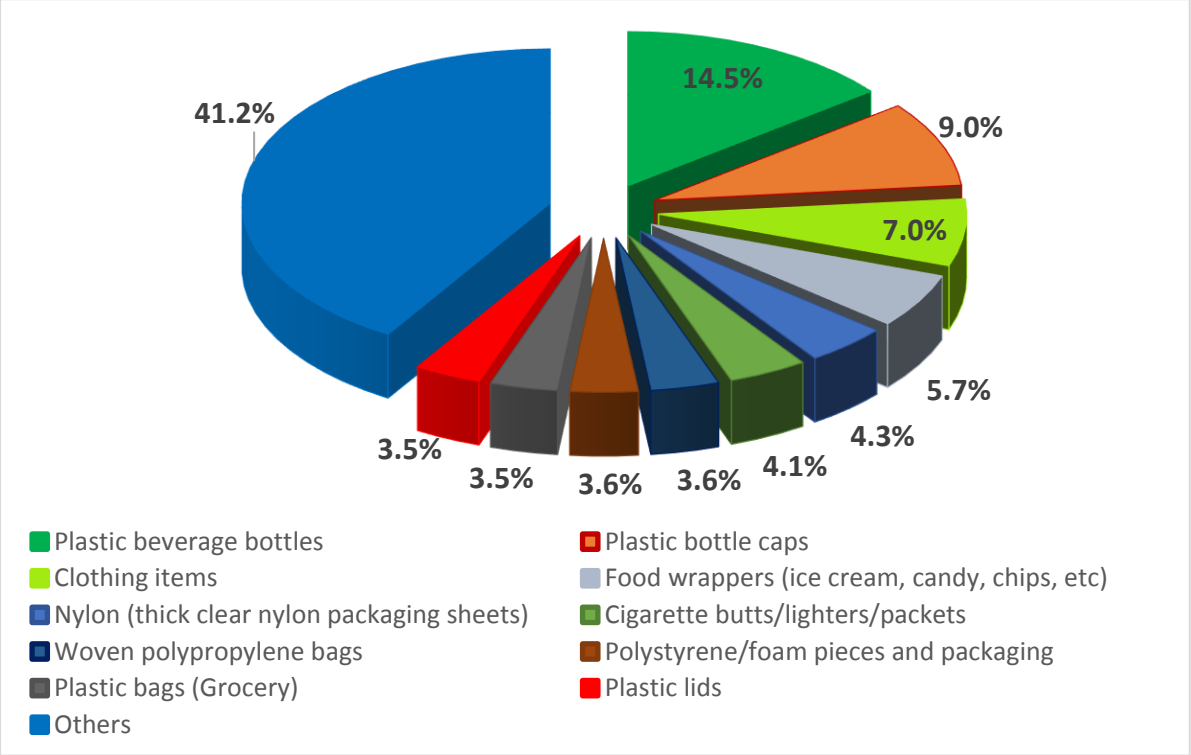
As shown in Figure A-3, the weight of all objects, such as glass and cardboard, had a trend commencing at 945kg (intercept) with a predicted reduction of 68kg/day with reasonable statistical fit in the 10-day sample. Plastic objects had an intercept of 256kg which reduced by 19.5kg/day. For all objects the daily cleaning over 10 sequential days showed signs of reducing waste object densities, though the plastic waste component reduced at a slower rate. The results show that despite 10 days of beach cleaning there remains plastic waste accumulation. The results are consistent with the ocean adjacent to shore holding large amounts of marine plastic waste refilling the beach after waste removal.

Beach cleaning is a remedial action and does not address the sources of the waste, with cleaning becoming a continuing cost with localized short-term benefit at best. The local NGO community, which has the most experience in beach cleaning, considers continually cleaning beaches as impractical and an uneconomic remedy to solely address the high levels of waste and plastic coming from Dar es Salaam into the ocean (Nipe Fagio, 2020b).

Types of waste on beach cleans

Results of the proportions of different types of waste by pieces from the 13 site surveys in 2022 are presented in Figure A-4.

Figure A-4. The proportions of the top ten waste types by number of pieces collected from the 13 survey sites along the coast of Mainland Tanzania and Unguja



Source: UDSM, 2022.

The waste results show that the prevalence of plastic beverage bottles, bottle caps, clothing and snack food wrappers are a major issue for the control of plastic pollution. Other plastic wastes include nylon sheets and polystyrene and foam with likely origins in municipal waste or from coastal communities. Packets for ice cream, chips, stirrers, cigarettes, and other discretionary consumables may be from household waste or from the sites adjacent to the beach where people relax, consume snacks and beverages, and smoke. The "others" category includes a wide range of less frequently occurring waste, with household and community waste items such as footwear, flip flops, sponge pieces and generic food packaging trays, medicinal, sanitary and cosmetic items.

Brand analysis

The project survey also completed an analysis of the plastics identifying their commercial brands (UDSM, 2022). Almost all (99%) were manufactured locally within Tanzania, with only 1% coming from foreign sources. Beverage and water bottles were the main type of plastic identified (86.6%) with plastic PET bottles dominating (84.7%). They were produced by several large companies: Bakhresa Food Products Ltd (33%), MeTL Group Ltd (19%) and The Coca-Cola Company (11%). The most frequently occurring brands of plastic beverage bottles were Mo Xtra (12.1%), Drop of Zanzibar (6.5%), Uhai (6.2%) and Azam Energy. Locations that have tourists, such as Mafia Island and Mkokotoni in Zanzibar, had the most diverse litter with the highest frequencies of water bottles (UDSM, 2022). The brand analysis shows that two-thirds of PET bottles were produced by just three companies. This should enable some potential policy solution negotiations with the producers of these products.

Drone survey

The project had a survey at each site by drones, with results reported in UDSM (2022). The drone was able to detect accumulated piles of plastic, but not individual pieces like the manual beach survey. The drones covered an area greater than those of the beach surveys, which comprised just 13-40% of the areas covered by the drones (UDSM, 2022). These enabled densities of waste to be identified on the parts of the beach that were not manually sampled giving an indication of the representativeness of the sites surveyed (UDSM, 2022).

The drone survey results were also able to examine the back beach areas on the landward side of the beach. This identified piles of plastic bottles and waste discarded by the public, which are a source of plastic waste on beaches (UDSM, 2022).

Annex 2: Ecosystem System Services Valuations for Tanzania and Zanzibar with Estimations of Plastic Pollution Damage

The economic damage from plastic pollution can impact marine economic sectors, reduce ecosystem services (ESS) values and also detract from natural capital values. There has been limited investigation of marine ESS values and the cost impacts of plastic pollution empirically (McIlgorm et al., 2020; Arabi & Nahman, 2020; Beaumont et al., 2019).

Tanzania and Zanzibar

There was an ESS study for Zanzibar by Lange & Jiddawi (2009). The ESS data was limited to fisheries, seaweed aquaculture, and mangrove harvesting as provisioning service values, and tourism and recreation as cultural service values in GDP terms. The paper did not consider the costs of the environmental or pollution impacts.

In a study of ESS values in the Northern Mozambique Channel, there are more recent ESS estimates for coastal regions of both Tanzania and Zanzibar (Ghermandi et al., 2019). The study includes provisioning services (fishery, mariculture-data not available); regulating services (carbon sequestration of mangroves, seagrass and wetlands); shoreline protection (coral reef mangrove and other wetlands); and cultural services (tourism and recreation) (Ghermandi et al., 2019) reported in Table A-1.

Table A-1. Marine ecosystem service values in Tanzania and Zanzibar in 2016

Unit: US$ millions per year

Service Ecosystem		**Carbon Sequestration***		**Coastal protection***				
Tanzania	**Fishery#**	**Mangrove**	**Seagrass**	**Coral reef**	**Mangrove**	**Tourism**	**Recrea-tion**	**Total (US$m)**
Tanga	3.2	58.6	0	0.13	0.07	230.7	33.4	326.1
Pwani	7.8	320.3	0	0.24	0.38	273.1	114.7	716.52
Dar-Es-Salaam	2	12.7	0	0.24	0.06	8.8	35.4	59.2
Lindi	7.6	199.4	0	0.2	0.23	556.8	5.4	769.63
Mtwara	1.4	56.2	0	0.07	0.06	145.7	7.3	210.73
Total Tanzania	**22.0**	**647.2**	**0.0**	**0.9**	**0.8**	**1,215.1**	**196.2**	**2,082.2**
Zanzibar								
Kaskazini-Pemba	1.3	0	0	0.42	0	3.8	21.9	27.4
Kaskazini-Unguja	1.3	0	0	0.1	0	3.7	10.1	15.2
Kusini-Pemba	0.9	0	0	0.33	0	4.2	21.6	27.0
Zanzibar South & Central	1.4	0	7.2	0.21	0	7.8	29.9	46.5

Zanzibar West	1.9	0	0	0.07	0	1.9	9.4	13.3
Total Zanzibar	**6.8**	**0**	**7.2**	**1.13**	**0**	**21.4**	**92.9**	**129.4**
Total Tanzania & Zanzibar	**28.8**	**647.2**	**7.2**	**2.0**	**0.8**	**1,236.5**	**289.1**	**2,211.6**

Note: * Wetlands removed; # Mariculture results were not available.

Source: Adapted from Ghermandi et al., 2019

The Ghermandi et al. (2019) study found that marine ESS values for Tanzania in 2016 were US$2.08bn and US$129m for Zanzibar.

For Unguja, the ecosystem values for Kaskazini–Zanzibar, Zanzibar South and Central and Zanzibar West were US$75.0m as shown in Table A-1. Removing the economic costs to tourism (US$13.4m) and to fisheries (US$4.6m) to avoid possible double counting, the net ESS values for Zanzibar were US$56.0m. Recreation is for the local population, differs from tourism, and is retained in the data.

The economic impact of plastic pollution has recently been proposed as being between 1% and 5% of ESS value globally (Beaumont et al., 2019). The project applied the higher 5% estimate to the case studies due to the evidence from the beach cleaning of high levels of plastic litter by international standards. For Unguja the impact of plastic pollution was estimated as 5% of US$56.0m, that is US$2.8m per annum.

The estimate of the ecosystem values for Dar es Salaam in Table A-1, were US$59.2m (Ghermandi et al., 2019). Tourism and fishing values were deducted to avoid double counting leaving an estimate of US$48.4m. The COED was 5% of US$48.4m, that is US$2.4m per annum. There was no available information on wildlife impacts or values.

Annex 3: Remedial Costs of Marine Plastic Waste Control

Plastic pollution remediation and clean-up costs

The cost of a cleanup intervention is not included in the estimates of the COED, as it is a remedial expenditure to restore the environment (see Figure 6). In Tanzania municipalities and private beach resorts are regularly involved in beach cleanup. Non-government organizations (NGOs) also have volunteer and sponsor cleanup days (Nipe Fagio, 2020a). Remedial costs include costs of the labor, equipment, and transport as well as waste disposal (UDSM, 2022). Table A-2 summarizes the range of remedial costs for cleaning up marine plastic litter from different international studies.

Table A-2. Range of remedial costs for plastic pollution cleanup

Litter remediation method or prevention strategy	Collection cost (US$ per ton)*	Collection cost (US$ per ton)**
Garbage cans	50-150	
On street*, sweeping**	100-920	101
Entry to drainage system*; cleaning storm drain grates**	220-1,270	754
Exit of drainage system*- nets and litter traps**	1,450-5,580	261-783
Other litter traps		2,611-6,526
River shoreline*, by-hand volunteer**	2,650-4,550	2,611-3,916
Beach shoreline, using labour costs (US) and mechanical	1,950-45,050	
In river or bays (skimmer or trash collector)	150-29,700	
In open ocean	4,925-74,695	
Waste collection and transportation		26
Landfill disposal		27
Plastics to fuel		127-152
Recycling		594
Education and public outreach per person per year		0.10-0.18

Source: Compiled from *World Bank, 2021; *Kaza et al., 2018; **GPO, 2013.

The Table A-2 results indicate that the cost of addressing waste at source is less than after it disperses into water and drainage systems requiring nets and litter traps.

The fieldwork with Nipe Fagio (2020b) enabled the following estimated costs per tonne to be made for Tanzania and Zanzibar. The average daily costs of the Nipe Fagio survey team in 2022 were: equipment (bags, etc.) US$74/day, waste transport and disposal US$130, and labor US$174 /day shared by 5 persons and, thus, a total of US$378 per day. Assuming these costs, the project's survey results for beach waste were used to estimate the cost per tonne of clean up for the initial standing stock and the Day 1 and Day 7 accumulated waste data presented in Figures A-5 and Figure A-6.

The costs per tonne of plastic waste for cleaning the standing stock, shown in Figure A-6, range from US$46-$588/tonne, with a mean of US$220/tonne and a median of US$138.8/tonne for beach cleaning. The range in daily average cost of beach cleaning reflects a high degree of variation in the amount of debris between sites. The daily expenditure was a fixed amount of US$378/day for equipment and labor applied to the 2.5-hectare sample site. Caution is required when extrapolating these estimates to larger areas.

Figure A-5. Estimated average cost per tonne for remedial beach waste collection for standing stock results

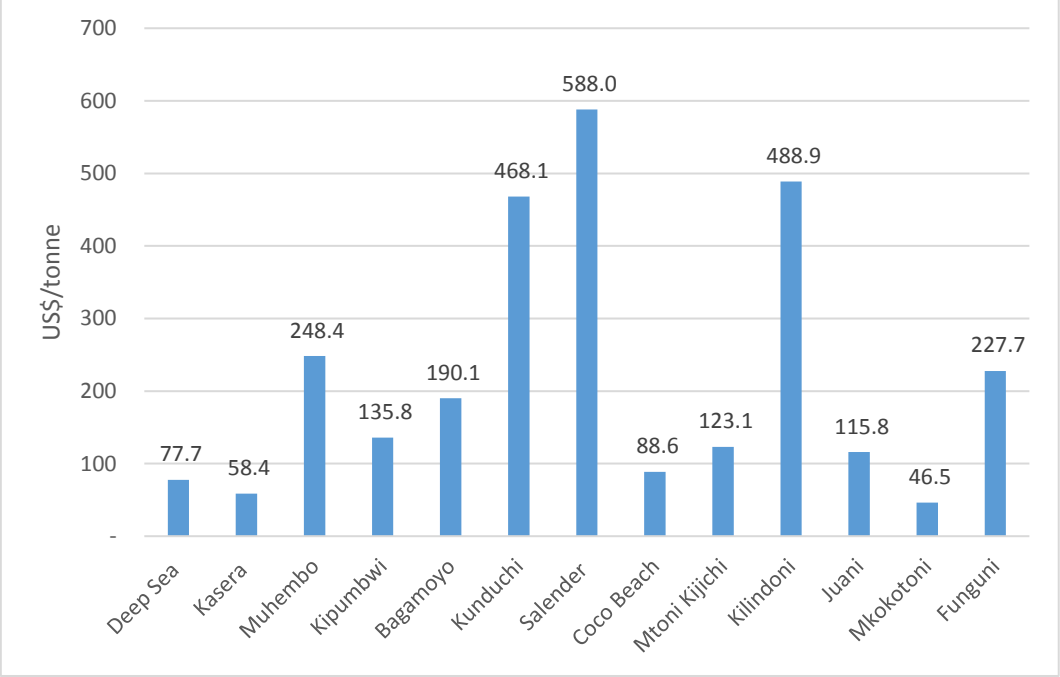
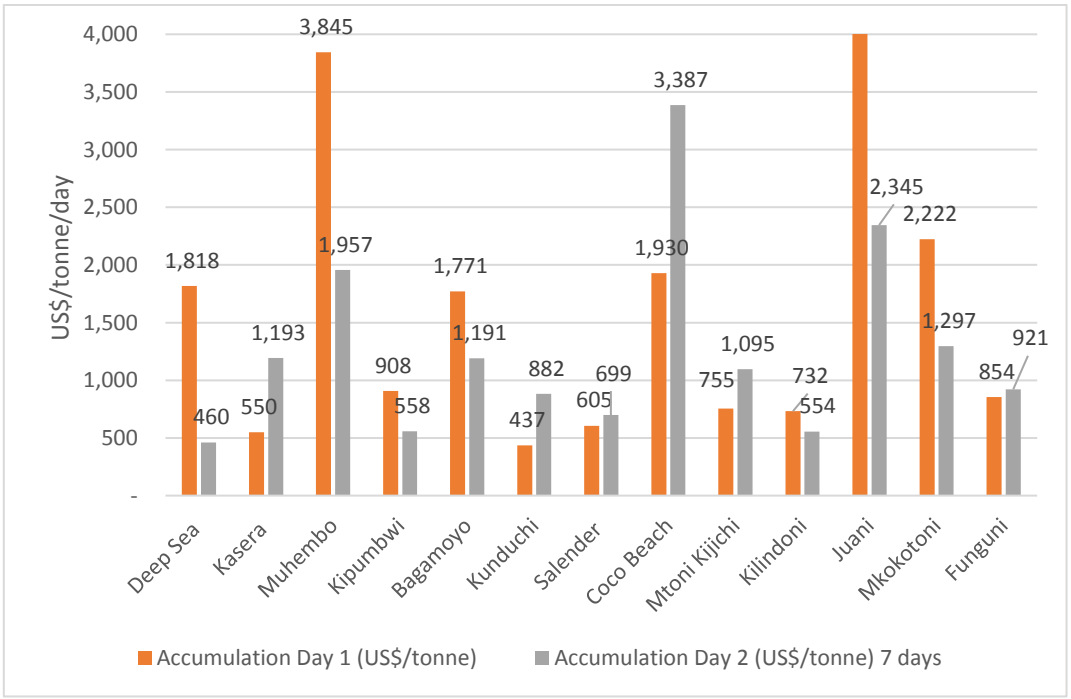


Figure A-6. Estimated average remedial cost per tonne for collection of standing stocks by beach



The accumulation Day 1 results range from US$437-$8,148/tonne (off graph), with a mean of US$1,890 and median of US$908/tonne. Day 7 results range from US$360-$3,387/tonne, with a mean of US$1,272 and median of US$1,095/tonne. The accumulated Day 1 and Day 7 results have a higher average cost than the standing stocks results as there is less litter density.

The median standing stock value of US$138/tonne in this study is proposed as the most reliable daily cleaning cost estimate. It is similar to a recent beach study in Kenya, which found a cost of US$125/tonne, due to cheap labor rates in Kenya costing just 10% of those in in Europe (CARDNO, 2020). More empirical testing would be required to determine whether daily, weekly or other gaps between cleaning events would meet beach cleanliness levels acceptable to tourists at the most efficient average cost per tonne.

Remedial costs in Zanzibar

The estimated costs of beach cleaning on Unguja developed from the project's standing stock (SS) and accumulation (Acc.) survey results are reported in Figure A-6 and A-7. They were: Funguni, US$228/tonne (SS) and US$854/tonne (Acc.); and Mkokotoni US$46/tonne (SS) and US$2,222/tonne (Acc.).

Remedial costs in Dar es Salaam

From the information on beach cleaning reported in Figure A-7 and A8, the estimated costs of cleaning are: Kunduchi US$468/tonne (SS) and US$437/tonne (Acc.); Selander, US$588/tonne (SS) and US$605/tonne (Acc.); Coco beach, US$89/tonne (SS) and US$1,930/tonne (Acc.); and Mtoni Kijichi US$123/tonne (SS) and US$775/tonne (Acc.).

The remedial cost analysis reveals the considerable public contribution made by NGOs and volunteers involved in national beach waste clean ups in Tanzania and Zanzibar, as shown by the opportunity costs of their time and cost savings to municipal authorities from not having to clean beaches more frequently (Nipe Fagio, 2020a).

These costs are indicative as they are derived from the project's cleaning exercise and are less than data in other international studies presented in Table A-2. They are not the relevant commercial or municipal costs that may apply for policy making and should be treated with caution.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