# The economic impact of plastic pollution

## in Antigua and Barbuda

### Impacts on the fisheries and tourism sectors, and the benefits of reducing mismanaged waste

Damien MITTEMPERGHER, Leander RAES and Aanchal JAIN

IUCN Economics Team and Ocean Team

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# Acronym List

| Acronym | Description |
|---|---|
| ALDFG | Abandoned, Lost, or Otherwise Discarded Fishing Gear |
| ABWREC | Antigua and Barbuda Waste Recycling Corporation |
| APEC | The Asia-Pacific Economic Cooperation |
| APWC | Asia Pacific Waste Consultants |
| BaU | Business-as-Usual |
| BPA | Bisphenol A |
| CBA | Cost-Benefit Analysis |
| CBD | Convention on Biodiversity |
| EEZ | Exclusive Economic Zone |
| EU | European Union |
| GDP | Gross Domestic Product |
| HDPE | High-Density Polyethylene |
| ICC | International Coastal Clean-Up |
| MEA | Multilateral Environmental Agreements |
| MPA | Marine Protected Areas |
| MPW | Mismanaged Plastic Waste |
| NGO | Non-Profit Organisation |
| NOAA | The National Oceanic and Atmospheric Administration |
| Norad | Norwegian Agency for Development Cooperation |
| NPV | Net Present Values |
| OECD | Organisation for Economic Co-Operation and Development |
| PET | Polyethylene Terephthalate |
| PWFI | Plastic Waste-Free Islands |
| SIDS | Small Island Developing States |
| TIDES | Trash Information and Data for Education and Solutions |
| UNWTO | United Nations World Tourism Organization |
| VTM | Value Transfer Method |
| WMB | Waste Management Budget |
| WTV | Willingness to Visit |

# 1. INTRODUCTION

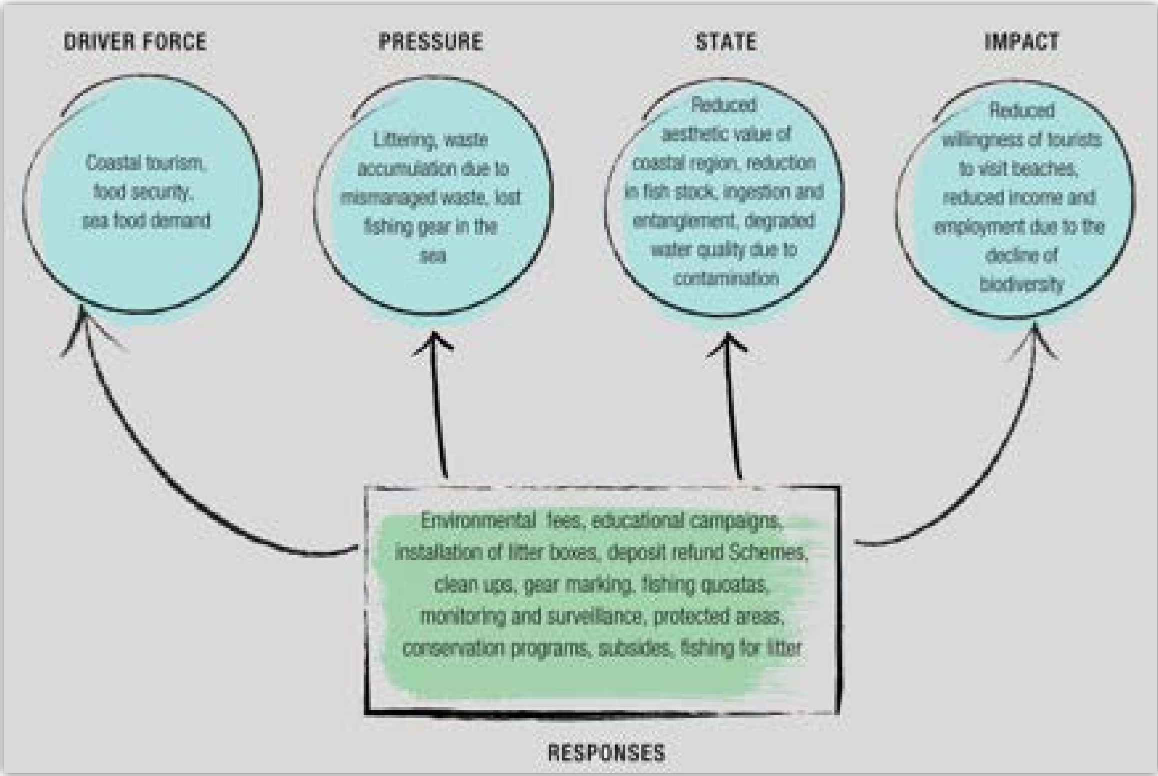
In 2019, with support from the Norwegian Agency for Development Cooperation (Norad), IUCN launched the Plastic Waste-Free Islands (PWFI) project. The initiative's overarching goal is to drive the circular economy agenda forward and to reduce plastic waste generation and leakage from island states. The project consists in assisting several island nations in the Pacific and Caribbean region to reduce plastic waste generation and eliminate leakage to the ocean on which they depend. The PWFI was implemented in Fiji, Samoa, and Vanuatu in the Pacific, and in Antigua & Barbuda, Grenada, and Saint Lucia in the Caribbean Region.

As part of the PWFI project, economic assessments were conducted. This report presents the findings of a study that aimed at estimating the impacts of marine plastics on the fisheries and tourism sectors in Antigua and Barbuda, and the costs and benefits of implementing a solution (a national recycling system, with and without regional cooperation) to reduce mismanaged plastic waste and its leakage into the marine environment.

## 1.1. MARINE PLASTICS

Since the early 1950s, the use of plastics in everyday life has increased due to its durability, lightness, and low production cost (Filho et al., 2021). The amount of plastics produced between 2002 and 2015 was the same as the amount produced in the previous 52 years, between 1950 and 2002 (Geyer et al., 2017). At a global level, only 9% of plastics produced are recycled, and 22% of the plastic waste generated is mismanaged (Watkins et al., 2015; OECD, 2022a). According to a study by Thompson (2009), 10% of all mismanaged plastics leak into the oceans. Most of the mismanaged plastics are single-use plastics, mainly coming from food packaging, bottles, straws, and grocery bags. The main source of plastic waste flow in the oceans is land-based, contributing to approximately 80% of all marine plastics (Jambeck, 2015). Land-based litter load can come directly from the shoreline caused for example by tourism or it is transported from distant areas such as inland towns and industrial sites via watersheds and wastewater pipelines, mainly due to inefficient waste management practices (Veiga et al., 2016). The remaining 20% comes from sea-based activities (Hao wu, 2020), mainly from the fisheries sector (Andrady et al, 2012). Fisheries can add to marine plastic debris through discarded, lost, and abandoned fishing gear in the oceans and waterways (Oko-Institut, 2012). In addition to this, it is also responsible for throwing litter overboard from vessels (Hinojosa, 2011; Lusher, 2017).

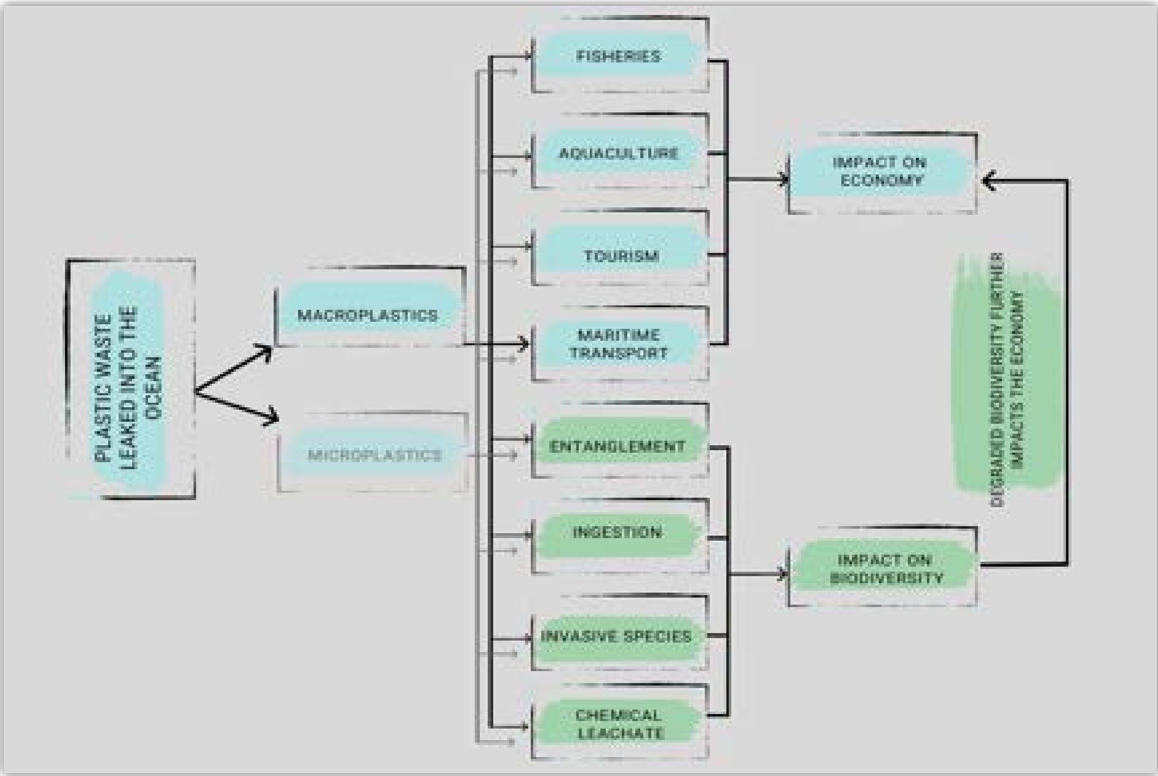
The marine plastic problem can be explained using the 'Driver, Pressures, States, Impacts and Responses' framework (Löhr et al., 2017; Miranda et al., 2019) (**Figure 1**). The drivers of plastic production originate from human needs such as food security, movement of goods and services, and shelter (Thevenon et al., 2014). These needs are fulfilled by the economic sectors where plastics are widely used (e.g., packaging of products, fishing nets for fisheries, construction, transportation, healthcare equipment, agriculture, and electronics, among others) (Abalansa et al., 2020). The use of plastics generates waste.




*Sources: Romagosa et al., 2014; Chassignet et al., 2021; Jahanishakib et al., 2021Gebremedhin et al., 2018.*

***Figure 1 – Driver-Pressure-State-Impact-Responses framework for plastic pollution with examples***

Once plastics become waste, a part of this waste is mismanaged and leaks into the oceans. This generates negative impacts to the economy and biodiversity (**Figure 2**). The plastic pollution leaked generates four types of consequences. First, it impacts the physical ocean system through contamination (e.g., reduced health of marine habitats and water quality due to the presence of plastics), and sunlight blockage (Gallo et al., 2018). Second, the reduced environmental quality impacts marine biodiversity and ecosystems (e.g., increased fish mortality rates due to ingestion and entanglement, and reduced aesthetic value of beaches due to plastic litter) (Werner et al., 2016). Third, the degraded marine biodiversity and ecosystems has an impact on the provision of marine ecosystem services (e.g., supply of seafood and raw materials, transportation, storm protection) (Beaumont et al., 2019; Barbier, 2017). Finally, the economy is directly impacted (e.g., through lower fisheries and tourism revenues) (Bailly et al., 2017).




*Source: UNEP 2014a.*

***Figure 2 – Impact of plastics ending up in the oceans[1]***

Marine plastic pollution can generate significant economic costs in the form of gross domestic product (GDP) reductions, estimated at up to US$7 billion for 2018 alone (WWF, 2021). This is driven by the loss in revenue from tourism, fishing, aquaculture, transport, and other ocean-based activities (**Figure 2**) (McIlgorm et al., 2020). The costs associated with marine litter are divided between direct and indirect costs (Newman et al., 2015). Direct costs include the expenses for repair and replacement. For instance, fisheries revenues can be impacted due to damaged gear (Macfadyen, 2009) and expenses to the government to clean beaches where recreational activities are conducted (Mouat, et al., 2010). Additionally, the shipping industry can suffer losses due to marine debris entangling with propellers, potentially obstructing the engine (IMO, 2018). The indirect costs are related with impacts to biodiversity and habitats, including costs resulting from decreased ecosystem service provision (Rodríguez et al., 2020). For instance, the fisheries sector's revenue is further reduced due to the reduction in catches in the presence of marine plastics and lost or abandoned gear (Richardson et al., 2021). Tourism industry's revenue could be impacted due to reduction in tourists' visits and spending in the presence of marine debris (McIlgorm et al., 2020).

Moreover, plastics at every stage of its life cycle (from production to consumption to waste treatment) emits a significant amount of greenhouse gases, which together with other sources, threaten the ability of the global community to keep global temperature rise below 1.5°C (Ford et al., 2022; Hamilton and Feit, 2019). It is estimated that by

[1] The study focuses on macroplastics.

2050, the plastic life cycle could contribute up to 15% of the entire carbon budget (Zheng and Suh, 2019).

These impacts will continue to increase if no action is taken to stop plastic production, consumption, and leakage. A report by the Organisation for Economic Co-operation and Development (OECD) states that the global plastic use and waste will triple by 2060 in the absence of plastic management policies. By 2060, plastic leakage to the environment is projected to double to 44 million tonnes a year, increasing the negative impacts on marine biodiversity and ecosystems, and further contributing to climate change (OECD, 2022b). To reduce the amount of plastics, efficient political responses and legal tools are required at the local, national, and international level (Nielsen et al, 2019; da Costa, 2020). The responses can be ex-ante (i.e., before plastic production and waste generation) or ex-post (i.e., once the plastic waste is dumped) (Lachmann et al., 2017; Schmaltz et al., 2020; Van Rensburg et al., 2020). Ex-ante measures include retention and reduction of waste at source (Wang, 2018). This can be achieved through changing producers' behaviour, e.g., extended producer responsibility (Raubenheimer et al., 2020; OECD, 2022a), or changing consumers' behaviour, (e.g., through bans and taxes) (Oosterhuis et al., 2014; BFFP, 2021). Consumer choices can also be altered through positive reinforcements such as educational campaigns (Willis et al., 2017) and incentives, such as deposit refund schemes for Polyethylene terephthalate (PET) bottles and plastic bags (Schuyler et al., 2018). In the case of ex-post responses, waste treatment and management techniques need to be addressed (Willis, 2018; Rajmohan et al., 2019). A report by PEW (2020) estimated that the amount of mismanaged plastics will more than double in the next 20 years if nothing is done. Jambeck et al. (2015) mention that to achieve a 75% reduction in the mass of mismanaged plastic waste, the 35 top-ranked countries with poor waste management practices would need to improve their waste management system by at least 85% by 2025. However, improving waste management infrastructure requires substantial investments (and time), especially in low and middle-income countries. The focus of these countries should first be on improving solid waste collection (UNEP, 2018) and then implementing local/coastal clean-ups (Rochman, 2016).

Some policies also aim at reducing plastics that have already escaped into the sea. For example, incentivising the fishing industry and rewarding fishers to bring back litter has proven to be successful in some cases (OSPAR, 2017; KIMO, 2010). This said, it might be more efficient to work on economic instruments that target land-based waste to reduce a significant amount of plastics, as most of the marine litter comes from land-based activities (Sheavly & Register, 2007; Jang et al., 2014; APEC, 2019). Nonetheless, there is no one straight solution to curb the plastic problem. The choice of a set of interventions for a country depends on the source of pollution being addressed, the country's institutional characteristics and infrastructure, consumer preferences and habitual behaviour, and the economy's overall sectoral composition (Oosterhuis et al., 2014).

## 1.2. THE CARIBBEAN

The Caribbean Sea, part of the Atlantic Ocean region, is one of the largest seas in the world and has an area of about 2,753,000 $km^2$ (Menzies et al., 2022). It has rich biodiversity and marine ecosystems that are crucial for the economic growth of tourism and fisheries, and as well for the health of the inhabitants (UNEP, 2019a). Within the Caribbean Sea there is a group of states and territories, including around 7,000 islands, islets, reefs, and cays, altogether called the Caribbean Region (Otieno, 2018).

Caribbean economies depend highly on a healthy marine ecosystem, which is particularly valued for tourism (O'Brien et al., 2022). The climate and beaches help make the region one of the top tourist destinations in the world (Wong, 2015; Diez et al., 2019). The tourism sector accounts for 15% of the Caribbean Region's GDP (WTTC, 2018). Aside from this, the Caribbean Sea is also a primary source of fish, providing different socio-economic opportunities for the inhabitants of the region (FAO, 2022; CANARI, 2020). The fisheries industry represents around 4.3% of the workforce in the region (CRFM, 2021).

However, the lucrative marine and coastal ecosystems are in danger, given that the Caribbean Sea is the second most plastic-contaminated sea in the world (UNEP, 2019b). According to a 2019 report by Forbes, 10 of the top 30 global polluters per capita are from the Caribbean region (Ewing-Chow, 2019). The plastic waste leakage in these territories is driven by illegal plastic waste disposal due to poor waste management systems along with limited recycling, and weak law enforcement (UNEP, 2018). Plastic pollution could cause damaging impacts on Caribbean islands' growing economies (Diez et al., 2019). According to APWC (2021a), around half of plastic waste generated in the Caribbean region is made up of by single-use plastics, mainly composed of PET bottles and plastic bags[2]. This plastic waste mainly comes from the household and commercial sectors within each territory (AWPC, 2021a).

Small island developing states (SIDS) in the Caribbean region are particularly exposed and vulnerable to increased damage from plastic leakage, which poses a serious threat to ecosystems (Barrowclough et al., 2021; Lachmann et al., 2017). The thriving economies drive the demand for more consumer products, which exerts pressures on waste management facilities (UNEP, 2014b). Most of these islands have limited and small sized infrastructure, making the waste difficult to manage in terms of volume, composition, and recyclable potential (UNEP, 2019b).

Governments of these islands have started to recognise the impacts of this pollution on their social and economic well-being and have started to work on measures to curb plastic pollution (UNEP, 2018). Most measures focus on bans of single-use plastics and polystyrene, which comprise around 80% of Caribbean marine litter (Clayton et al., 2020). Considering the significant amount of PET and High-density polyethylene (HDPE) plastic leakage across the Caribbean islands, container deposit and transport schemes could prove effective (Schuyler, et al. 2018) to incentivise region-wide reverse logistics and to create recycling markets for countries without such availability (APWC, 2021a). However, there is little comparative analysis of policy responses to

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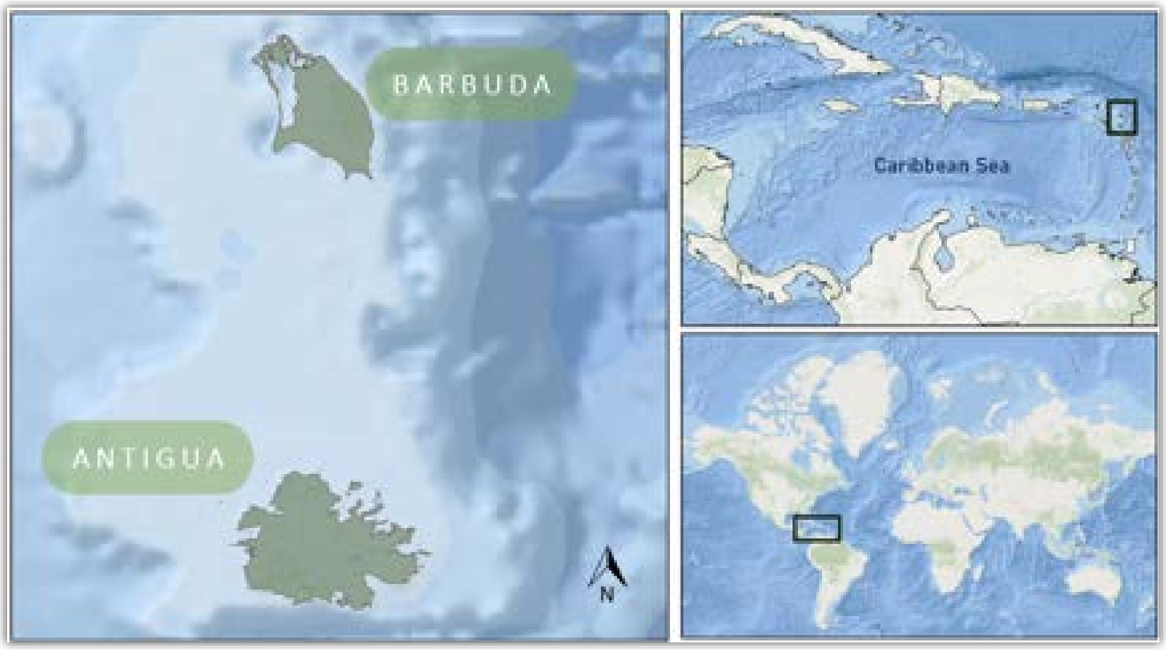
[2] This estimate is based on the estimation of single-used plastics in Antigua and Barbuda, Grenada, and Saint Lucia.

determine their efficacy (Chen, 2015; Rochman, 2016). To ensure sustainability of the Caribbean Sea's ecosystems, an integrated management approach with local stakeholders and government as well as with other nations is needed (Winther et al., 2020).

*Antigua and Barbuda's coastline (IUCN).*

# 2. CASE STUDY INTRODUCTION

Antigua and Barbuda is a dual island country in the north-eastern heart of the Caribbean archipelago (UN, 2019). Barbuda is located 40 kilometres north of Antigua and has a total land area of 161 km² (Boger et al., 2014). Antigua, having 80% of the total population, has a total land area of 281 km² (UNFPA, 2017) (**Map 1**). The country had a total population of 97,115 in 2019 (World Bank, 2020a). **Table 1** provides an overview of some key data in Antigua and Barbuda.




*Source: ESRI.*

***Map 1 – Location map of Antigua and Barbuda***

***Table 1 – General data of Antigua and Barbuda***

| Key Facts | |
|---|---|
| Official name | Antigua and Barbuda |
| Exclusive Economic Zone | 111,568 km$^2$ |
| Coastline | 153 km |
| Capital | St John's |
| Climate | Tropical maritime year-round |
| Terrain | Partly volcanic and partly coral, mostly low-lying, highest elevation 405 m |
| Currency | East Caribbean dollar (XCD or EC$) |
| GDP (2019) | USD 1.662 billion |
| GDP per capita (2019) | USD 17,113 |

*Sources: FAO, 2022; Government of Antigua and Barbuda, 2021a; Government of Antigua and Barbuda, 2020; Momsen, 2021; World Bank, 2020b.*

Antigua and Barbuda, like most of the other Caribbean countries, is a biodiversity hotspot (Government of Antigua and Barbuda, 2020). Most of the population lives near the coastline, which highlights the importance of the coastal and marine ecosystem for the country's inhabitants. Its extensive ecosystems include significant mangroves, forests, seagrass beds, and coral reefs, which provide a variety of ecological functions that directly and indirectly translate to economic services and value to humans (Government of Antigua and Barbuda, 2021b). Agriculture at one time was one of the major contributors to the GDP but since the 1960s, its economy has relied on the service sector (UN, 2009). The sub-sector of agriculture, which is fisheries, still plays an important role in the nation's economic development, contributing 2% to the nation's GDP (Government of Antigua and Barbuda, 2021a). Further details on fisheries can be found in **Table 2**, below.

*Table 2 – Overview of fisheries' data from Antigua and Barbuda (2019)*

| Revenue (USD[3]) | Catch volume (tonne) | Number of Vessels |
|---|---|---|
| 15,581,051 | 3,165 | 263 |

*Sources: Statistics Division, Ministry of Finance and Corporate Governance, 2022; FAO Fisheries Division.*

However, like many other small developing islands in the Caribbean, the country's economy is shifting from an agriculturally based economy to a service based one, mainly dominated by the tourism sector, which contributes around 61.3% to the GDP and is the primary source of foreign currency (World Bank, 2022a; WTTC, 2020). In 2019, sea arrivals account for 3/4$^{th}$ of the total tourists, while 1/4$^{th}$ arrived by means of air (IMF, 2020; Ministry of Tourism, Foreign Affairs, and Immigration, 2017). The majority of tourists prefer hotels as their accommodation, followed by personal residence and villas, with an average length of stay of 10.5 days per tourist (APWC, 2021a). In 2019 the hotel industry alone contributed USD$36.52 million to the GDP in Antigua and Barbuda or 8.44% to the total GDP for the year (ECCB, 2020). Most of the international tourists come from the USA (41% of all tourists), followed by Europe (33%), Canada (13%) and 10% other Caribbean regions (10%) (Antigua and Barbuda Statistics Division, 2020). Further details on tourism can be found in **Table 3**.

*Table 3 – Overview of tourism data from Antigua and Barbuda (2019)*

| Revenue (USD[4]) | International tourists (Number) | Expenditure per international tourist (USD) | Coastline (km) |
|---|---|---|---|
| 1,036,500 | 1,035,000 | 1,001 | 153 |

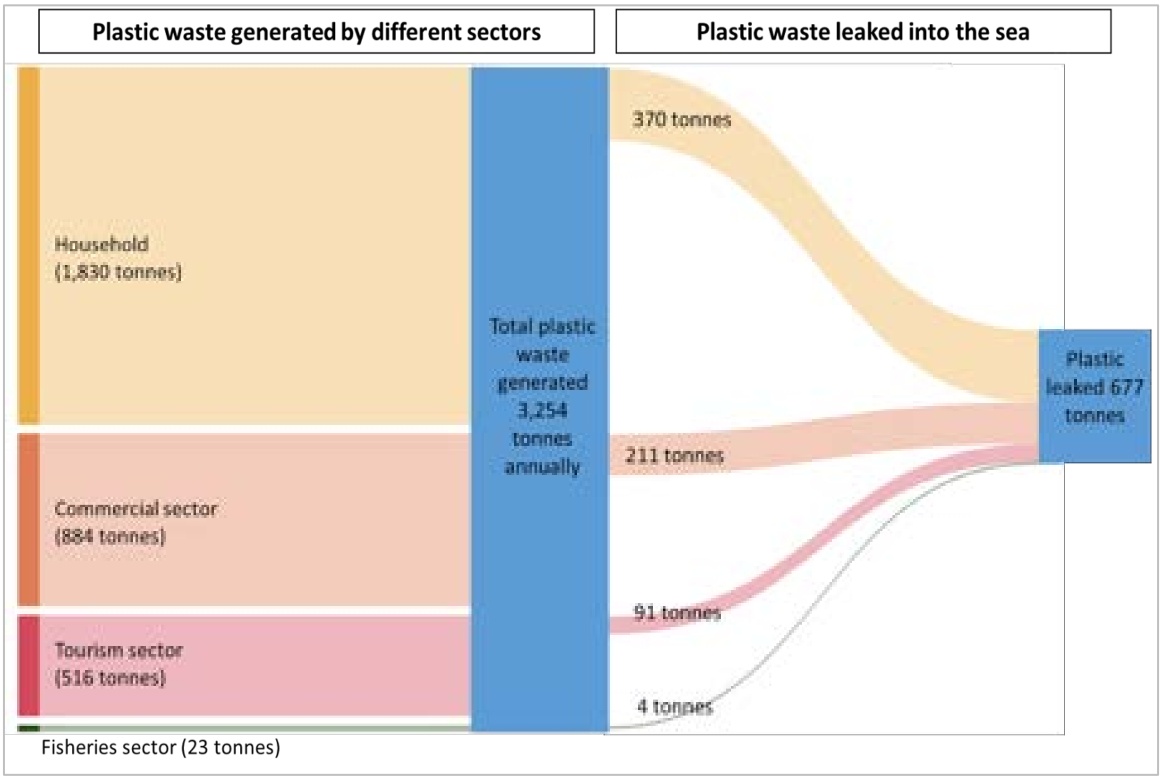
*Sources: WTTC, 2022 and World Bank, 2022b.*

Driven by the tourism sector, the construction industry has also become a large employer and important contributor to the national economy as well, contributing around 62% to the nation's economy (Government of Antigua and Barbuda, 2021b). However, this advancing economy is becoming a threat for the very ecosystems which promote these economic activities to prosper. The principal stressors that are contributing to the decline of its ecosystem are: the development of tourism and new housing, improper land use practices, destructive fishing methods, and poor waste management, including plastic pollution (MAFBA, 2013).

[3] The exchange rate considered in this study is the average rate for 2019, USD 1 = XCD 2.702 (Source: https://www.exchangerates.org.uk/XCD-USD-spot-exchange-rates-history-2019.html). Accessed on 25 July 2022.
[4] The exchange rate considered in this study is the average rate for 2019, USD 1 = XCD 2.702 (Source: https://www.exchangerates.org.uk/XCD-USD-spot-exchange-rates-history-2019.html). Accessed on 25 July 2022.

## 2.1. PLASTIC LEAKAGE ESTIMATES ANTIGUA AND BARBUDA

As per a report by APWC (2021b), 102,453 tonnes of waste was disposed of in Antigua and Barbuda in 2019, out of which 3.1%, 3,254 tonnes was plastic waste. More than half of this figure is disposed of by households, followed by the commercial and tourism sectors (**Figure 3**). Although the household and commercial sectors dispose the largest quantities of general waste and plastic waste, tourists dispose twice as much waste as a local resident per capita, largely contributed by land-based tourism. The main reasons for marine litter in Antigua and Barbuda are the local people's lack of waste segregation and recycling, inappropriate waste disposal behaviours, the lack of public awareness, tourism activities as well as inadequate waste management (Spencer, 2021). Most of the plastic waste leaked are single-use plastics, predominantly plastic bottles, and containers and bags made of PET and HDPE, as represented in **Table 4** (APWC, 2021b). Approximately, 20.8% of all plastics disposed is leaked into the oceans each year (APWC, 2021b).




*Source: APWC, 2021b.*

***Figure 3 – Plastics disposed leaked from different sectors (2019)***

*Table 4 – Plastic waste leakage rates (tonnes per year) per plastic polymer type and per sector in Antigua and Barbuda (2019)*

| Plastic Polymer | Household leakage rates (tonne/year) | Commercial waste leakage rates (tonne/year) | Tourism leakage rates (tonne/year) | Fisheries leakage rates (tonne/year) |
|---|---|---|---|---|
| PET | 73.6 | 24.0 | 26.8 | 2.29 |
| HDPE | 50.1 | 16.7 | 24.8 | 0.32 |
| PVC | 73.3 | 77.8 | 3.9 | 0.0 |
| LDPE | 32.7 | 28.4 | 7.3 | 0.6 |
| PP | 25.2 | 7.0 | 8.2 | 0.0 |
| PS | 19.1 | 4.5 | 4.3 | 0.0 |
| Other | 96.6 | 52.9 | 16.2 | 0.6 |
| **Total** | **370.6** | **211.4** | **91.5** | **3.8** |

*Source: APWC, 2021b.*

Significant measures have been undertaken by the government to control plastic waste and to improve overall waste management in the country, more specifically, the passing of the following national legislations and policies (FAO, 2019; Banhan, 2021):

- Environmental Protection Levy Act (2002) – introduced levy fees on imported cans and bottles.
- Environmental Protection and Management Act (2015) – defines the allocation of administrative responsibilities for the coordination of environmental management and related activities, and the incorporation of international treaty obligations with respect to the environment into national and law-related regulations.
- The External Trade (Shopping Plastic Bags Prohibition) Order (2017) – prohibits the importation, distribution, sale, and use of shopping plastic bags and styrofoam.
- Litter Control and Prevention Act (2019) – makes it an offence to litter in any public place.

Despite these measures, the environment continues to be degraded by improper waste disposal and lack of waste separation (Government of Antigua and Barbuda, 2015). Currently, the recycling sector in the country is also struggling due to weak support from the government and low market prices of plastics, which makes plastics recycling less profitable. Additional government subsidies for recycling practices and development of educational programs can help improve the waste problem in the country (APWC, 2021a). Additionally, more participation and behavioural changes on the part of producers is required; this can be achieved through measures to extend producers' responsibility to absorbing the waste generated by their products (APWC, 2021a).

# 3. IMPACT OF MARINE PLASTICS IN ANTIGUA AND BARBUDA (2019)

## 3.1. METHODOLOGY 1

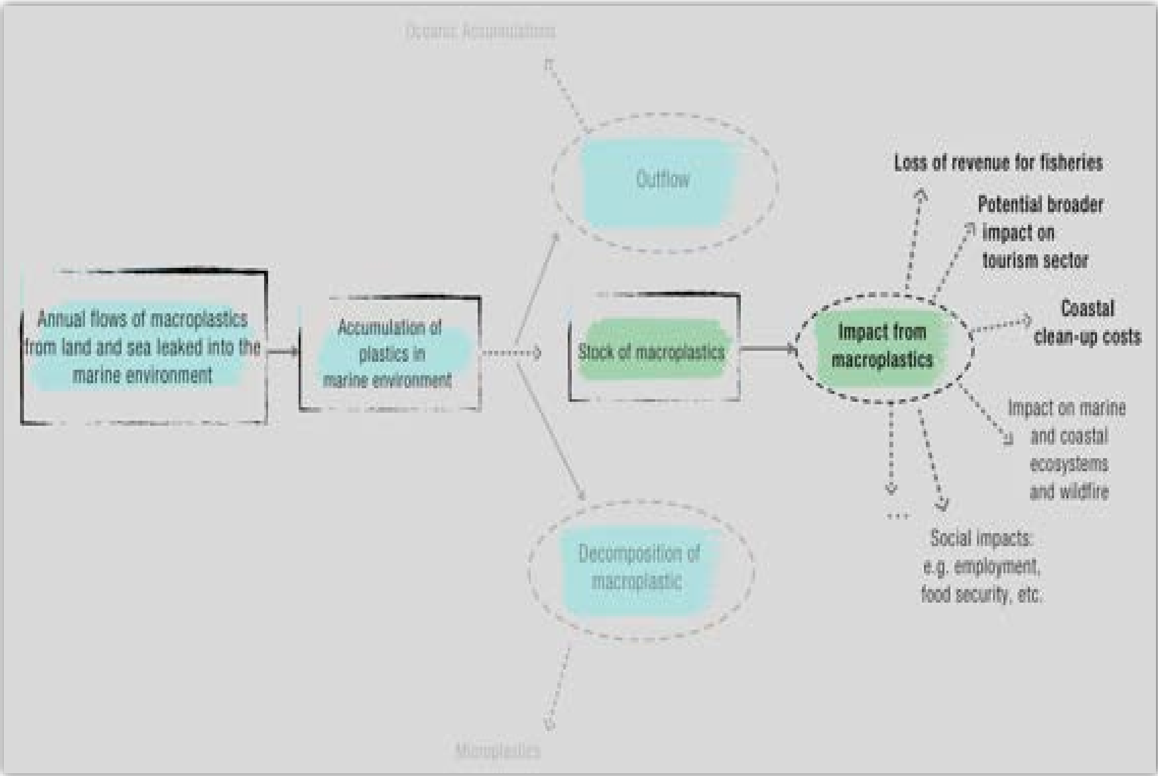
### 3.1.1. Data collection

Data collection was conducted through different means:

- Use of information developed through the PWFI project: plastic flow estimates (APWC, 2021a and b), policy analysis (APWC, 2021b; Banhan, 2021) and business cases (Searious Business, 2021);
- National and international databases, including those providing spatial data; and
- Literature review.

### 3.1.2. Plastic stock estimates (2019)

Estimating the impact of marine plastics on the tourism and fisheries sectors requires a consideration of multiple steps and factors, taking into consideration that the impact of marine plastics is caused not only by its annual leakage (flow) into the marine environment, but by the stock of marine plastics already present (McIlgrom et al., 2009). For the purposes of this Report, the following steps were taken: (1) estimating plastic leakage; (2) estimating plastics flowing into the marine system considered (Caribbean Sea) from other sources or flowing out; (3) estimating a first stock of plastics; (4) considering decomposition and plastics floating out of the system and that accumulate in oceanic accumulation zones; and (5) estimating the stock of marine plastics accumulating in different parts of Antigua and Barbuda's territory and impacting different sectors (**Figure 4**). In order to include inter-countries interactions, the focus is the Caribbean Sea, which is considered as a semi-closed system, whereas a simplification it is assumed that the same amount of plastics that enters this system, floats out of it.




*Source: McIlgrom et al., 2009.*

***Figure 4 – A conceptualisation of the sources, stock, and fate of debris in the marine debris cycle***

The stock of marine plastics in the Caribbean Sea at time (t) can be represented by the **Equation 1** bellow (based on McIlgrom et al., 2009):

*Stock (t) = Stock (t-1) + Volume of plastics entering the marine environment (t-1) – Volume cleaned up (t-1) – Volume decomposed (t-1) – Volume floating out of the system[5] (t-1) (**Equation 1**)*

This plastic stock is then divided among countries bordering the Caribbean Sea based on the size of their exclusive economic zone (EEZ), shallow waters, and coastlines (see **Map A1** in **Annex A1**).

Both the amount of plastics presents in the waters of Antigua and Barbuda and its annual flow leaking into the marine environment are estimated based on (i) APWC estimates for Antigua and Barbuda (2021b), and (ii) regional leakage into the Caribbean Sea based on Lebreton and Andrady (2019) and APWC (2021c and 2021d) (for Grenada, and Saint Lucia). To estimate the current amount of plastics present, the following factors were considered: historical accumulation, degradation into microplastics, regional exchanges, and outflow towards oceanic plastic accumulation zones (Lebreton et al., 2019; Eriksen et al., 2014; Lebreton et al., 2018). **Annex A1** provides a more detailed overview of the different assumptions and calculations that

[5] This refers to plastics leaked into the system from sources bordering the Caribbean Sea (see **Annex A1**). For sources outside this system, we assume that the same amount of plastics enter, as leave the system.

were applied to estimate the amount of plastics present in the waters of Antigua and Barbuda.

Plastic accumulation in different parts of the marine environment was estimated based on two different plastic accumulation scenarios. These distributions of plastics in different areas are considered fixed over time.

1. **Plastic accumulation scenario 1**: Based on GRID-Arendal, (2018) and presented in **Table 5** (supporting papers: Jang et al., 2015; Lebreton et al., 2012; Jambeck et al., 2015; Cózar et al., 2014; Eriksen et al., 2014; van Sebille et al., 2015).

***Table 5 – Areas of plastic accumulation according to plastic accumulation scenario 1***

| Accumulation area | Percentage (%) |
|---|---|
| Sea surface | 0.50 |
| Coastline and seafloor[6] | 33.70 |
| Coastal waters | 26.80 |
| Open ocean | 39.00 |

2. **Plastic accumulation scenario 2**: Based on Lebreton et al., (2019) and presented in **Table 6**.

***Table 6 – Areas of plastic accumulation according to plastic accumulation scenario 2***

| Accumulation area | Percentage (%) |
|---|---|
| Shoreline | 98.62 |
| Coastal waters | 0.18 |
| Open ocean | 1.20 |

Throughout the text, the first accumulation scenario will be referred to as “plastic accumulation scenario 1”; the second as “plastic accumulation scenario 2”.

### 3.1.3. Impact estimates

***Estimates of impact on fisheries***

Fisheries are not only a source of marine plastics, but also suffer from its impact. This impact can be directly and easily measurable through market values (McIlgrom et al., 2011), or indirectly, as related to the degradation of natural marine capital assets. Direct economic impacts can occur due to the costs to repair or replace damaged or lost gear due to encounters with marine plastics (e.g., repairing vessels with tangled propellers, clogged water intakes, etc.), as well as the loss of earnings due to lost productive time dealing with marine plastics encounters and from reduced or contaminated catches (Takehama, 1990; McIlgrom et al., 2009; Newman et al., 2015).

[6] No estimates were available on how much plastics end up on the coastline versus on the seafloor. It is assumed that the maximum amount of plastics that can end up on the coastline is 33.7% of the annual amount leaked into Antigua and Barbuda’s marine environment (from both Antigua and Barbuda and outside sources).

The impact of macroplastics on the fisheries from Antigua and Barbuda was estimated with the help of what is referred to as 'value transfer method' (VTM), which is often used in impact analyses (Johnston et al., 2018). VTM is applied by assigning existing economic estimates of a current study/region/ecosystem to a similar problem elsewhere. Following Arcadis (2013) and UNEP (2014a), who estimated the impact of marine plastics on European Union (EU) and global fisheries respectively, in this study Mouat et al (2010) is used as the reference study. Mouat et al. (2010) estimated the impact of marine plastics on Scottish net fisheries specifically. Here, a VTM was applied based on values from Mouat et al., (2010), and separating impact on net fisheries, from the impact on trap and line fisheries.

Mouat et al., (2010) conducted a survey study of Scottish net fisheries to investigate the extent by which this sector is impacted by marine litter, concluding that marine litter negatively impacted Scottish fisheries' 2008 revenue by 5%. Globally, an average of 80% of all marine litter is composed of plastics (Dunlop et al., 2020). Therefore, it can be considered that the impact of marine plastics on Scottish fisheries' revenue was 4%, i.e., 80% of 5%. This impact is broken down into four cost categories: dumped catch, net repairs, fouling incidents, and time lost clearing nets (Mouat et al., 2010).

Mouat et al., (2010) impact estimates are then transferred to the fisheries of Antigua and Barbuda. Although there is a relation between the amount of plastics present in Scottish waters versus what is present in the waters of Antigua and Barbuda, and how it impacts both countries' fisheries, fisheries from Scotland and Antigua and Barbuda are different in terms of the number and type of fishing vessels, the size of the fishing area, the volume and value of the fish catch and type of fisheries, among other factors. Thus, the value (or impact) transfer is not merely based on the amount of marine plastics present to transfer the size of the impact, but it also adjusts for a series of other variables or proxies that needs to be considered, for example: types of fishing gear used. The detailed methodology which presents the adjustment of fisheries size and impact estimation is presented in **Annex A1.3**.

### *Estimates of impact on tourism*

As with fisheries, tourism is another sector that is a source of mismanaged plastics but is also impacted by the presence of marine plastics. One of the main impacts on tourism from marine litter comes from the pollution of beaches and coastal areas. These can have a negative impact on tourists' willingness to visit (WTV) beaches, leading to a loss in revenue (Jang et al., 2014; Kosaka and Steinback, 2018). Ballance et al., (2000) state that tourist behaviour, including WTV, can change according to different numbers of plastic items present on beaches. Two studies estimating tourists' WTV in other countries as related to the presence of marine plastics on the beaches are used in order to evaluate the potential risks to Antigua and Barbuda's tourism industry. These studies generated their WTV impact by taking surveys of how tourists' WTV varied according to the number of plastic items present on beaches.

A study conducted by Krelling et al., (2017) used a contingent valuation to assess the WTV of a beach under different littering scenarios on two beaches in Brazil. Ballance et al., (2000) used a travel cost method to assess the impact of plastics on tourism in Cape Town, South Africa. These different studies constitute options to estimate the risk of marine plastic pollution to the tourism sector and were applied to Antigua and Barbuda. **Annex A1.4** provides more details on the results of these studies.

In this study, the focus is solely on international tourism. Although domestic tourism does exist in Antigua and Barbuda, the impact of marine plastics on beach visits from the local population is not as clear as the potential reduction in international arrivals due to pollution. Furthermore, no distinction of behaviour has been made between land-based tourism, which includes air travellers as well and sea-based tourism (yachting and cruise ships). This means that the impact is considered the same regardless of the tourist category. However, it could be argued that sea-based tourism may be more impacted by marine plastic pollution since plastics floating around can also cause damages to vessels.

Applying the VTM using results from the Ballance et al. (2000) and Krelling et al. (2017) studies can result in a negative impact estimate on the tourism sector that has not yet occurred in Antigua and Barbuda. Despite increasing amounts of plastics in the Caribbean Sea, the Caribbean tourism industry has continued to grow in recent decades (Diez et al., 2019). Thus, the potential impact on tourism is a risk that has not (yet) fully materialised.

For the purposes of this study, this potential negative impact on tourism revenue is described as a risk (potential losses in tourism revenue). It is an avoided cost for the tourism sector as large accumulations of plastics on beaches, deterring tourism visits, is not yet occurring. This is due to two factors: First, actions are undertaken to reduce the potential impact of plastic pollution of beaches on the tourism industry, including, but not limited to: voluntary beach clean-ups (Hidalgo-Ruz and Thiel, 2015), and actions undertaken by the waste management authorities to keep beaches clean (Newman et al., 2015), among others.

Second, plastics may also accumulate in less visible areas than on sandy beaches, such as in mangroves or between rocks or underneath the sand, get buried in other parts of the shoreline, both above and below water, are taken out to the open ocean to accumulate elsewhere, or degrade into smaller, less visible particles. It is challenging to account for the costs of the different actions and how much plastics end up in each accumulation area. Thus, instead of only estimating the risk to the tourism sector if beaches are left uncleaned – and as a proxy for the minimum costs incurred by plastic pollution on Antigua and Barbuda's coastline - this study estimates the costs of cleaning up all plastic items that could at one point in time (during a given year) accumulate on the coast-or shoreline. This should be understood as the cost estimate of a continuous effort throughout the year, not a one-time clean-up.

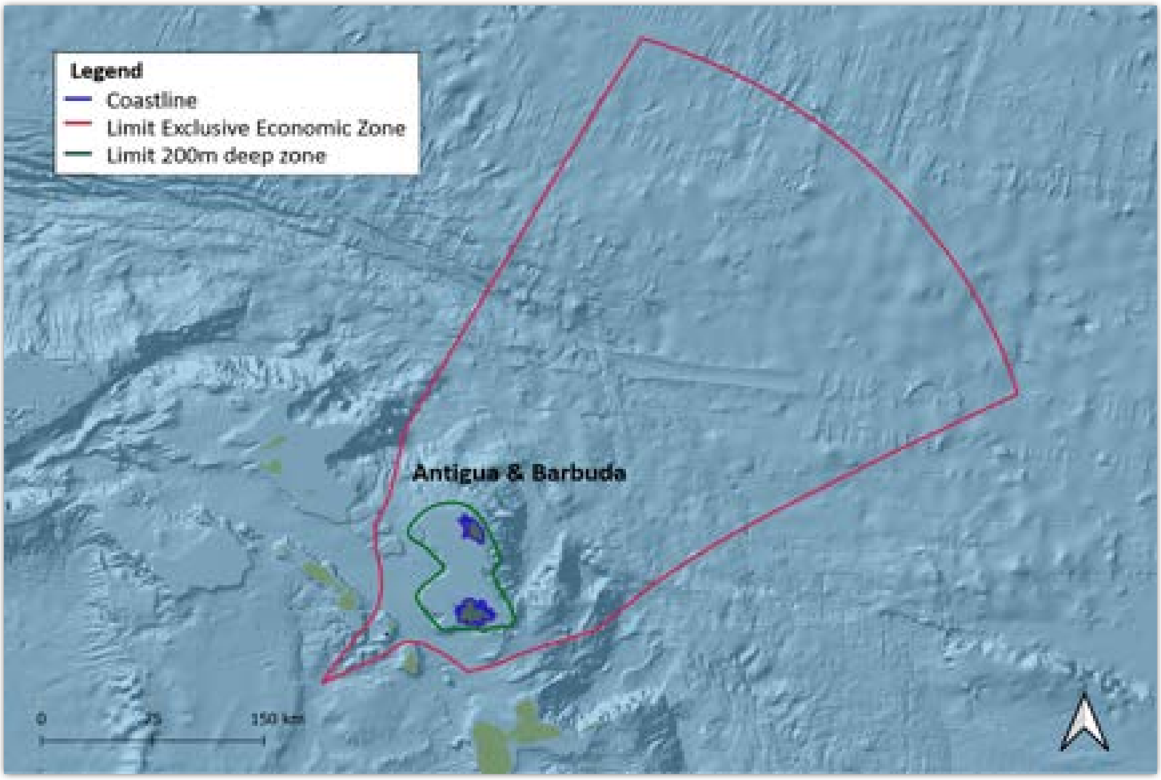
Since no clear budget allocation on the different beach clean-up efforts could be estimated (considering the combined cleaning efforts of municipalities, non-profit organisations (NGOs), hotels, etc.), and considering that no studies were available on where on the shore-or coastline plastics end up exactly during a specific time period, a proxy for this cost was developed. The costs of cleaning the entire coastal area of Antigua and Barbuda were calculated using the estimated amount of plastics that could end up on the coastline in one year (here 2019), followed by estimating the labour costs of cleaning plastics from beaches, based on data available through the

Trash Information and Data for Education and Solutions (TIDES) database[7]. UNEP (2014a) used the opportunity cost of volunteered time to estimate the global clean-up costs imposed by plastic litter on beaches. This study considers that both volunteers and paid costs are potentially involved in cleaning efforts and assumes that the whole coastline is cleaned. This potentially creates an overestimation of this cost, but it is a proxy for the minimum effort needed to prevent further plastics from accumulating along Antigua and Barbuda's coastline, potentially impacting tourism in the future.

## 3.2. RESULTS (2019)

### 3.2.1. Plastic accumulation scenarios

The application of the previously described methodology requires not only estimating the stock of plastics, but also knowing where it is accumulating, as different accumulation areas will impact different sectors (fisheries or tourism in this study). **Map 2** presents the marine regions of Antigua and Barbuda where plastics could accumulate depending on the scenario considered (plastic accumulation scenario 1: **Table 7**, or plastic accumulation scenario 2: **Table 8**). More details on the construction of plastic stocks are provided in **Annex A1**.




*Sources: Flanders Marine Institute, 2022; University of California Berkeley library geo data, GEBCO, 2012.*

***Map 2 – Marine regions of Antigua and Barbuda***

[7] Available at: https://www.coastalcleanupdata.org/reports.


*Left picture: plastics on a beach in Antigua. Right Picture: plastics collected on 20 meters of beach in 5 minutes in A & B (Raes, L.).*

***Table 7 – Estimate of plastic accumulation (plastic accumulation scenario 1) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---:|
| Sea surface | 1,141 |
| Coastline and seafloor | 16,200 |
| Coastal waters | 19,570 |
| Open ocean | 88,975 |

***Table 8 – Estimate of plastic accumulation (plastic accumulation scenario 2) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---:|
| Shoreline | 51,485 |
| Coastal water (less than 200m) | 132 |
| Offshore (more than 200m) | 2,744 |

### ***Marine plastics impacting fisheries***

For plastic accumulation scenario 1, the sum of plastics present on the sea surface, coastal waters, and open oceans within the EEZ is considered as marine plastics that will impact fisheries. The total amount of plastics **impacting fisheries** under this scenario is: <u>109,686 tonnes.</u>

For plastic accumulation scenario 2, the sum of plastics present in coastal waters and offshore is considered for the fisheries impact analysis. The total amount of plastics **impacting fisheries** under this scenario is: <u>2,875 tonnes.</u>

Additionally, the amount of plastics leaked in 2019 and impacting the fisheries sector is also estimated. Under plastic accumulation scenario 1, an average of **8,587 tonnes** of plastics, and under plastic accumulation scenario 2, an average of **225 tonnes** are estimated to have leaked into the EEZ in 2019 and accumulated in areas where plastics cause an impact on the fisheries of Antigua and Barbuda.

For estimating the results by transferring the impact calculations presented in the study by Mouat et al. (2009), plastic accumulation scenario 1 is used. The relative difference between the amount of plastics in Scotland and Antigua and Barbuda under both plastic accumulation scenarios remains more or less unchanged when the proposed methodology is applied; the results of the 'rule of three' under any individual plastic accumulation scenario are similar (see **Annex A1.3** for detailed explanations).

***Marine plastic risk to the tourism industry and coastal clean-up costs***

In this study, it is considered that, based on the plastic accumulation scenarios, a part of the 2019 annual plastic leakage, will end up on the coast or shoreline (see **Tables 5** and **6**) at a certain moment during the year. The assumption applied is that the percentage of plastic flow that accumulates on the coastline in that particular year is what could potentially impact tourism after being deposited. Although plastics could become degraded, buried in the shoreline, taken away by animals, etc., the largest potential accumulation during a one-year period is used to estimate the highest potential impact, or maximum risk, to the tourism industry. From the annual leakage estimate of the countries of the region, the amount of plastics considered to accumulate on the coastline (that could potentially impact tourism) is calculated based on plastic accumulation scenario 1. According to this scenario 33.7% of the plastics in the sea could end up on the coastline (or seafloor). Applying the second plastic accumulation scenario, 98.68% of the plastics in the sea ends up on the shoreline. We assume that during the year the plastics are leaked, it could accumulate on the coast or shoreline for some time.

Thus, according to plastic accumulation scenario 1, an estimated maximum amount of 1,295 tonnes of plastics could end up on the coastline of Antigua and Barbuda in 2019. According to plastic accumulation scenario 2, the total maximum amount is estimated to be 3,790 tonnes.

To transfer the studies from Krelling et al. (2017) and Ballance et al. (2000), who estimate impact based on plastic items present on beaches, to the potential impact estimates for this study, the amount (tonnes) of plastics needs to be translated to the number of items (see **Annex A1.4** for more details). To estimate how many items there could be per km of coastline, the number of items present in one tonne of plastics is estimated using the TIDES database[8]. Data from the last five (5) coastal clean-ups in Antigua and Barbuda (tonnes of plastics and items of plastics collected) were downloaded and compared to the maximum amount of plastics that could have ended up on the coastline under each plastic accumulation scenario in 2019 (see **Tables 9** and **10** for details). The number of items per tonne collected in 2018 were used for the analysis focusing on 2019 only. For the 2023-2040 period (see **Chapter 5**), the average from 2016-2020 was used. **Table A8** in the Annex gives a more detailed overview of the location (above or below water) from which the items were retrieved (land or sea).

[8] https://www.coastalcleanupdata.org/. Accessed on 15 October 2021.

*Table 9 – Number of items in one tonne of plastics (2019-2020)*

| Year | Plastics collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|
| 2020 | 1.91 | 6,276 | 3,280 |
| 2019 | 1.43 | 8,712 | 6,107 |
| Average items per tonne collected | | | 4,694 |

*Source: Ocean Conservancy, 2021.*

*Table 10 – Number of plastic items per metre of coastline (2019)*

| Data on Antigua and Barbuda | Values |
|---|---|
| Coastline (km) | 153 |
| Plastics (in tonnes) (plastic accumulation scenario 1) | 1,295 |
| Plastics (no. of items) | 7,908,764 |
| Plastic items per km | 51,691 |
| Plastic items per m | 52 |
| Plastics (in tonnes) (plastic accumulation scenario 2) | 3,790 |
| Plastics (no. of items) | 23,143,569 |
| Plastic items per km | 151,265 |
| Plastic items per m | 151 |

*Figures might not add up due to rounding.*

According to plastic accumulation scenario 1, there could be a maximum of 52 plastic items per metre of coastline in Antigua and Barbuda, while according to plastic accumulation scenario 2, this could be up to 151 plastic items per metre.

The results for Antigua and Barbuda are similar to those found for Saint Lucia (Raes et al., 2022a), applying the same methodology, but much higher (more than double) as those found for Grenada (Raes et al., 2022b). The above estimated accumulation frequency of plastic items for Antigua and Barbuda is large when compared to the average amount of plastic items collected during a single beach clean-up and reported in the TIDES database for the Lesser Antilles in 2019. According to this database, during coastal clean-ups an average of 1.5 plastic items per metre were recorded (see **Table A6** in annex for more details). Overall, these numbers are significantly lower than the estimates presented in this study, except for Saint Maarten, where a value of 162 items/metre was reported for 2021-2022[9].

There are a few explanations for these differences. First, the allocation of plastics following GRID-Arendal (2018) and Lebreton et al., (2019) may not only consider plastics ending up in areas accessible for clean-ups (for example by ending up in coastal areas where the water is too deep). Second, this study uses the maximum potential number of items that could end up on the coastline in a given year. Plastics can get buried, degraded, etc. and thus no longer be visible for beach cleaners. Finally, research has shown that the more plastic items are surveyed on a beach in a given year, the higher the estimated annual number of plastic items (Smith and Markic, 2013; Schernewski et al., 2018).

[9] Retrieved from https://www.coastalcleanupdata.org/reports, for 54 clean-ups that took place between August 4, 2021 and August 4, 2022 in Saint Maarten.

### 3.2.2. Impact of marine plastics on fisheries (2019)

For the fisheries sector, this study only estimates the results using plastic accumulation scenario 1, since the methodology gives a similar result regardless of the scenario (see **Annex A1.3** for details). The impact on fisheries for 2019 is based on data on the types of vessels and fishing methods, (see **Annex A1.3** for more details). The results are presented in **Table 11**.

***Table 11 – Estimated Impact of plastic pollution on fisheries' revenue (2019)***

| Type of impact | Percentage of fisheries' revenue |
|---|---|
| Dumped catch | 2.8% |
| Net repairs | 0.3% |
| Fouling incidents | 0.2% |
| Time lost clearing nets | 5.8% |
| **Total impact** | **9.2%** |

The total impact of 9.2% is much greater than the 4% revenue impact estimated by Mouat et al., 2010 for Scottish fisheries. The main reason behind the higher impact stems from the fact that there are much more plastics per $km^2$ per boat for Antigua and Barbuda compared to Scotland in the scenarios used (around 59 times the amount in plastic accumulation scenario 1). This difference is due to Antigua and Barbuda having more plastics impacting fisheries for a smaller EEZ and fewer boats than Scotland.

Other studies also used Mouat et al. (2010). For example, Arcadis (2014) estimated and adjusted the impact of marine litter on EU fisheries at 0.9% of the revenue. UNEP (2014a) and Trucost (2016) calculated that those marine plastics caused an annual global revenue loss of 2% in marine fisheries. Overall, the impact on Antigua and Barbuda's fishery sector is larger than what these studies found. However, the costs of fouling incidents, here estimated at 0.2 % for Antigua and Barbuda, is an impact also analysed by Takehama (1990), who estimated that the cost of damage on Japanese fishing vessels caused by marine debris, based on statistics from the insurance system, resulted in an estimated impact on fisheries' revenue at 0.3% of gross annual value.[10] This estimate was also used by McIlgorm et al. (2011, 2009) to estimate the economic cost of marine debris damage in the Asia-Pacific region. Based on the methodology used in this study, fishing boats in Antigua and Barbuda suffer slightly less from fouling incidents than what was found in Japan by Takehama (1990), although using a different methodology, even when adjusting for the amount of plastics (80%) in marine debris.

Given Antigua and Barbuda's fisheries' revenue during 2019[11], **the estimated 9.2% revenue impact of the plastic stock on fisheries' revenue was XCD 3,861,103** (USD 1,428,980).

[10] McIlgrom et al. (2020) update this impact estimate to 1% in their more recent study on marine plastics impact in the APEC Region.
[11] **XCD 42,100,000** (USD 15,581,051).

*ALDFG and other plastics on Antigua & Barbuda coastline (IUCN).*

Antigua and Barbuda's fisheries sector and others fishing in the Caribbean Sea, also contribute to marine plastics through abandoned, discarded, or lost fishing gear (ALDFG) (APWC, 2021b), which in return impacts the fishing industry (Lusher, 2017). ALDFG can perform "ghost fishing," which means it can continue to trap fish and crustaceans, as well as ensnaring and capturing other species, while this gear is no longer being controlled (Edyvane and Penny, 2017; National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program, 2015). Ghost fishing, despite not being addressed in this study, which looks only at the direct costs to the fishing sector, is an important aspect to consider when looking at fisheries and marine plastics. Fish ensnared in lost fishing gear can lead to increased fish mortality, reduced fish catch, reduced sustainability of the catch (Erzini, 1997; Butler et al. 2013; 1997) and revenue losses of 5% or even higher (Mathews et al., 1987, Nakashima and Matsuoka, 2004; Tschernij and Larsson, 2003). A Caribbean study reported that traps were the most common type of gear becoming ALDFG, 41%, followed by various types of nets (25%) (Matthews and Glazer, 2009). APWC, based on fisheries statistics and a study by Richardson et al. (2019a), estimated leakage of fishing gear in 2019 in Antigua and Barbuda as follows: (i) 44 nets, (ii) 59 traps and (iii) 1,236 lines. This quantity of gears corresponds to an estimated 6.2 tonnes of plastic gear leaked that year (APWC, 2021b). In a second estimate, using trade statistics, APWC (2021b) calculations suggest an average of around 1.73 tonnes of fishing gear could leak annually in Antigua and Barbuda's marine environment from its fisheries, providing two estimates of the potential size of ALDFG.

In addition to the rates at which fishing gear is lost, other factors that contribute to the likelihood of ghost fishing are the gear's degradation rate, which depends on different factors, including for example: water temperature, catch efficiency of the gear, susceptibility of species to ghost fishing, depth where the gear is lost, and/or the tidal and current conditions, which influence whether nets ball up faster or slower (Antonelis et al., 2011; Brown and Macfadyen, 2007; Erzini et al., 1997; Kaiser et al., 1996; Masompour et al., 2018). Thus, although ghost fishing is not included in this study as a direct cost to the fisheries sector, if included, ghost fishing would increase the cost estimates by increasing the estimated losses to the fisheries sector due to marine plastics.

### 3.2.3. Potential risk of marine plastics to tourism (2019)

**Table 12** presents the results on the maximum potential loss that Antigua and Barbuda could suffer if the estimated amount of coastline plastics were accumulating without being removed or ending up on the seafloor. For Antigua and Barbuda, results are the same for each impact transfer, regardless of the plastic accumulation scenario used.

*Table 12 – Estimated results of maximum potential impact on international coastal tourism in Antigua and Barbuda (2019)*

| Result based on | Plastic accumulation scenario | Percentage of tourists not willing to visit | Number of tourists not willing to come | Potential loss in revenue (XCD) | Potential loss in revenue (USD) |
|---|---|---|---|---|---|
| Ballance et al., 2000 | Both accumulation scenarios give the same results | 97% | 1,003,950 | 2,716,604,310 | 1,005,405,000 |
| Krelling et al., 2017 | Both accumulation scenarios give the same results | 82.4% | 852,840 | 2,307,713,352 | 854,076,000 |

Relative to the contribution of the tourism sector to GDP, the potential risk (i.e., the potential loss in revenue from international tourists visiting Antigua and Barbuda) was estimated to be **XCD 2,716,604,310** (USD 1,005,405,000) based on Ballance et al. (2000), and **XCD 2,307,713,352** (USD 854,076,000) based on Krelling et al. (2017). Thus, the maximum risk to the tourism industry was estimated to be a potential loss equivalent to 60.5% and 51.4%, respectively, of Antigua and Barbuda’s GDP.

The estimate of the potential impact on tourism is very large. Although marine plastics can have a negative impact on tourism in the Caribbean (see for example Schuhmann, 2011), the actual impact may not be of the magnitude of the potential impact as presented above. For example, UNEP (2014a) and Trucost (2016), assumed that 3% of global marine tourism revenue was lost because of marine litter, including plastics, while McIlgrom et al., (2020) used a value of 1.5% of marine tourism GDP for their study on the economic costs of marine debris to the Asia-Pacific Economic Cooperation (APEC) economies. These; however, are studies that focus on a global or regional impact, including many countries that are not as dependent on beach-going tourists as Antigua and Barbuda. Conversely, Jang et al., (2014) found that visitor numbers at Geoje island’s beaches, in the Republic of Korea, decreased by 63% after litter washed up on the beaches after a storm. This is an impact value closer to what was found by Ballance (2000) and Krelling et al. (2017) and is used here in this study to estimate the highest potential impact or overall risk to Antigua and Barbuda’s tourism sector.

The potential revenue loss estimates for Antigua and Barbuda are based on the premise that all plastics that could end up on the shoreline accumulate sufficiently to have a visible impact on the aesthetic value of Antigua and Barbuda’s marine environment, and particularly its beaches and coastal areas. It also assumes all plastic items have a size that relates to this visible impact. This illustrates the magnitude of risk for Antigua and Barbuda’s economy. As a proxy for the actual cost of marine plastics on Antigua and Barbuda’s tourism economy in 2019, the costs of cleaning up the entire amount of plastics estimated to end up on Antigua and Barbuda’s shoreline is estimated.

### 3.2.4. Coastal clean-up costs (2019)

According to the data from the last five years of the International Coastal Clean-up, 510-person days were used to clean 3.4 tonnes of plastics from the coastline of Antigua and Barbuda (Ocean Conservancy, 2019). This study considers that one person works eight hours a day. Given that Antigua and Barbuda had an estimated 1,295 tonnes (plastic accumulation scenario 1) of plastics ending up on its coastline in 2019, it is estimated that approximately 156,933 person-days would have been needed to clean all the plastics from the coastline in 2019. Minimum daily wage for 2019 was at XCD 65.6 (WageIndicator, 2022). Based on these data, the cost of coastal clean-ups in 2019 – so as not to have an impact on tourism – is estimated to be **XCD 12,868,519** (USD 4,762,590) for plastic accumulation scenario 1. **Table 13** displays the details for both plastic accumulation scenarios.

***Table 13 – Estimated coastal clean-up costs according to the two plastic accumulation scenarios (2019)***

| | Plastics (in tonnes) | Coast cleaning cost (XCD) | Coast cleaning cost (USD) |
|---|---|---|---|
| Plastic accumulation scenario 1 | 1,295 | 12,868,519 | 4,762,590 |
| Plastic accumulation scenario 2 | 3,790 | 37,657,395 | 13,936,860 |

These estimated ICC costs will be used in the future scenarios presented in **Chapter 5** to obtain the gross benefit of reducing plastics in the marine environment.

Although these clean-up costs are potentially an overestimation, they should be understood as the minimum cost necessary to prevent plastic accumulation that could potentially impact the tourism industry in the future.

**Figure 5** presents the risks due to potential losses and the estimated clean-up costs, as well as the total revenue from tourism for 2019 under plastic accumulation scenarios.

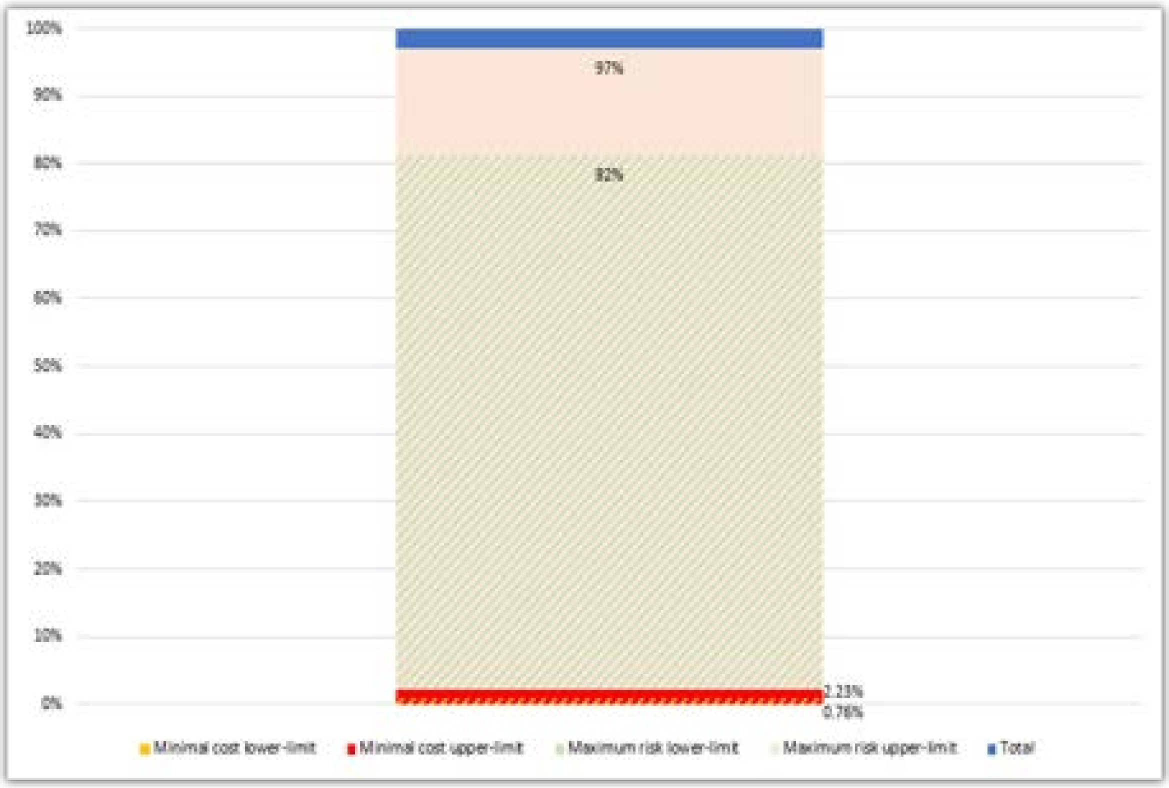



***Figure 5 – Actual and potential costs of plastic pollution to the tourism industry in 2019 and total tourism receipts under plastic accumulation scenarios***

### 3.2.5. Summarised impact (2019)

The impact of marine plastics can be divided into direct costs, which are the cost on fisheries, through loss of revenue, and coastal clean-up costs[12]; and the risk or potential impact (loss in tourism revenue, should plastic accumulation be left unchecked).

The estimated impact in Antigua and Barbuda in 2019 (looking at the direct costs) amounts to **XCD 16,729,622** (USD 6,191,569) under plastic accumulation scenario 1 and **XCD 41,518,498** (USD 15,365,839) under plastic accumulation scenario 2. This impact is equal to 0.37% and 0.92% respectively of Antigua and Barbuda's GDP.

The broader impact (costs to fisheries, and potential loss to tourism revenue) is estimated at between **XCD 2,311,574,455** (USD 855,504,950) or 51.5% of Antigua and Barbuda's GDP and **XCD 2,720,465,413** (USD 1,006,833,980) or 60.6% of Antigua and Barbuda's GDP.

[12] The proxy for the effort needed to keep the complete coastline clean by removing all plastic items.

# 4. PROPOSED SOLUTIONS

A broad range of instruments and policies have the potential to decrease the use of plastics and especially reduce plastic leakage into the marine environment, including bans of certain types of plastics, substitutions, or deposit-refund schemes, among others.

Among the recommendations for Antigua and Barbuda to improve its waste management system, APWC (2021b) proposes strengthening the current recycling system by improving waste collection, segregation at the source and further separation. In addition, for Antigua and Barbuda APWC (2021b) proposes establishing a regional recycling hub, something that could also be of use for Antigua and Barbuda. Thus, in the next sections, the solution that will be analysed is establishing a system to collect, separate and transport recyclable plastics, to a yet to be established regional recycling hub[13].

Currently, recycling in Antigua and Barbuda is very limited, with only one company presently operating in the country, Antigua and Barbuda Waste Recycling Corporation (ABWREC). There is no separation at the source of recyclable materials (plastics, glass, paper, and cardboard) or organic waste prior to collection from households or commercial businesses (APWC, 2021b). There are, however, several waste pickers that pick recyclables from waste arriving at the landfill facility used for waste disposal. These waste pickers could become part of a broader recycling effort, such as being employed in waste separation before shipping.

In order to include a broader focus on economies of scale, in this study the impact of recycling will be considered first for Antigua and Barbuda alone, but then also from a regional cooperation point of view. The main focus, however, will be the costs and benefits of implementing a broader recycling system in Antigua and Barbuda.

[13] As such a hub does not yet exist, transport costs to Miami are used, which currently already has recycling infrastructure and a well-established container transport system to Antigua and Barbuda.

# 5. IMPACT OF MARINE PLASTICS IN ANTIGUA AND BARBUDA UNDER BUSINESS-AS-USUAL (BAU) AND PROPOSED SOLUTIONS (2023-2040)

## 5.1. METHODOLOGY 2 (RECYCLING SCENARIOS)

### 5.1.1. Forecasting of plastics, fisheries, avoided cost on tourism and coastal clean-ups

To estimate the impact of implementing a broader recycling system, two recycling scenarios are proposed, and compared to a business-as-usual (BaU) scenario. The two recycling scenarios are:

1. **National recycling scenario**: Only Antigua and Barbuda will implement strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC (2021b).
2. **Regional recycling scenario:** All the countries of the region will cooperate and start to better manage their mismanaged plastic waste (MPW) as their GDP per capita increases. This scenario is based on Lebreton and Andrady (2019). (See **Annex A3**, where **Table A10** provides the estimated growth rate for each country).

Future plastic flows under a BaU scenario have been estimated using the growth rate of mismanaged waste used by Lebreton and Andrady (2019) for the period 2020-2040 for the non-PWFI countries, while estimates from APWC data have been used for data of Antigua and Barbuda (APWC, 2021b), as well as Grenada and Saint Lucia, where needed (APWC, 2021c and d).

For the national recycling scenario, the potential amount of recycled plastics by Antigua and Barbuda has been obtained from APWC (2021b) data. It corresponds to 58% of the total plastic usage per year. The simulation assumes that Antigua and Barbuda would gradually implement the recycling system (25% implementation rate in 2023, which means that 14.5% of the plastics would be recycled – up to 100% in 2026 and thereafter). In this study it is assumed that a recycling rate of 100% will generate an estimated average reduction of leakage of approximately 60% (U.S. GAO, 1990; Iowa the Policy Project, 2008; Waste et al., 2013; DEC, 2020; COEX, 2020). Thus, a 58% recycling rate implies that, according to the national recycling scenario, Antigua and Barbuda's plastic leakage would be reduced by 34.8%.

In addition, for the fisheries sector, the analysis considers two different scenarios regarding fish stocks:

- Constant fish catch during the period considered.
- Fish catch decreases by 0.5% per year, because of climate change, whereby fish stock is estimated to decrease by 0.5% per year (FAO, 2018).

For tourism, to illustrate potential future risk of marine plastic pollution to revenue from the tourism sector, the expected number of tourists without any impact from marine plastic pollution is estimated for the coming decades. The expected growth from 2031 to 2040 in the tourism sector for Antigua and Barbuda is based on an extrapolation of the UNWTO (2011) estimates until 2030, combined with past data on annual growth in this sector (see **Annex A2.2.4** for more details on the extrapolation). This study assumes that tourism will be back to pre-Covid figures in 2025 (**Figure 6**) (McKinsey & Company, 2020).

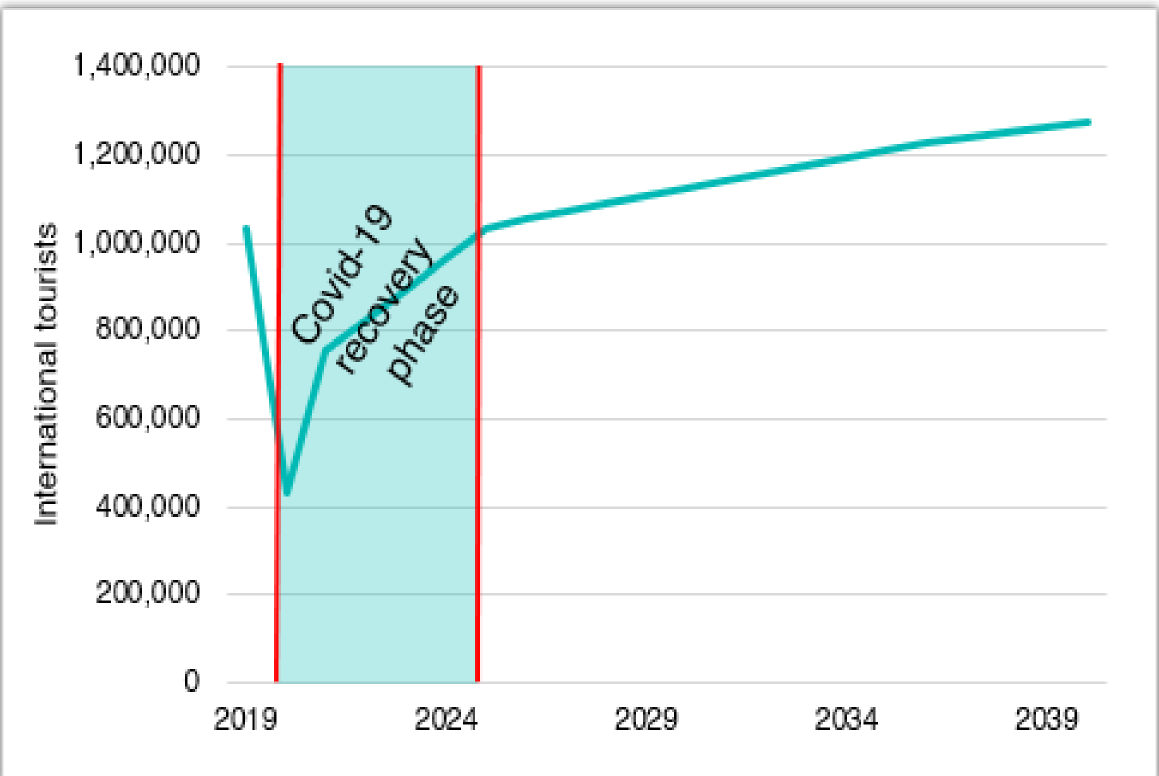



***Figure 6 – Estimated number of international tourists in Antigua and Barbuda (2020-2040)***

The expected continuous increase of tourists in the coming decades indicates that the potential loss of tourism revenue caused by the existence of polluted shorelines will increase, especially if plastic leakage remains the same or, even worse, increases[14]. In the next sections, this study only focuses on estimating the impact on fisheries and coastal clean-ups. However, given the importance of tourism for Antigua and Barbuda's economy, there is potentially a much higher cost related to marine plastics than what is presented here.

[14] Tourism is also an important source of marine plastics (APWC, 2021b).

Lebreton and Andrady's (2019) data on a future scenario of MPW[15] were first used to estimate the impact of marine plastic pollution for the period 2023-2040 under the BaU scenario following the steps shown in **Figure 7**.

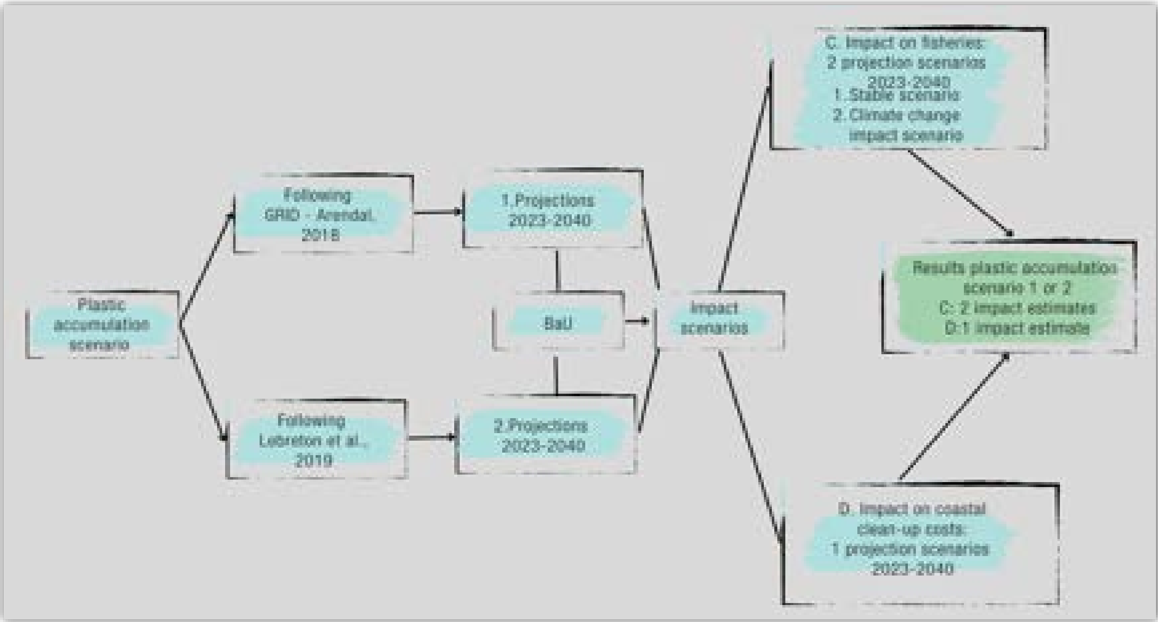



*Figure 7 – Schematic representation of the impact of marine plastic pollution under BaU*

The estimated impact for the two plastic recycling scenarios were then calculated as shown in **Figure 8**.

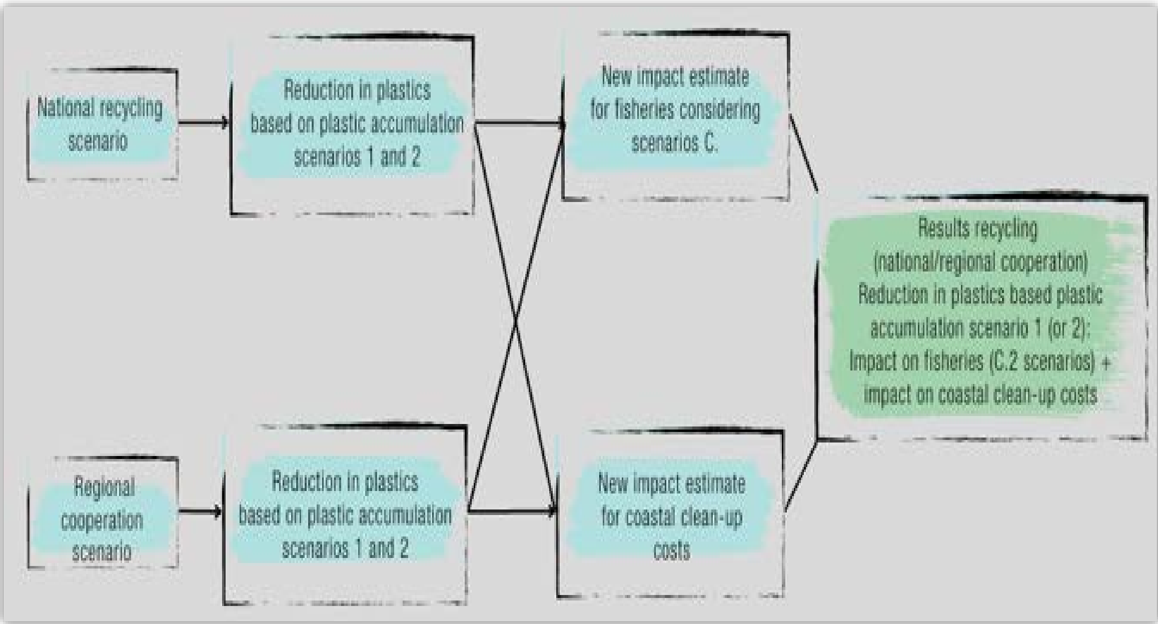



*Figure 8 – Schematic representation of the impact of both recycling scenarios (National recycling and regional cooperation scenario)*

[15] Lebreton and Andrady 2019 published scenarios called "Future emission scenarios". For the BaU scenario, the scenario called "MPW Scenario A" was applied. It assumes that countries will not implement any measures to mitigate plastic emissions.

### 5.1.2. Cost-benefit analysis of BaU versus recycling

To estimate the impact of recycling, and compare this to a BaU scenario, a cost-benefit analysis (CBA) is applied. CBA is an analytical tool used to judge the advantages and disadvantages of an investment or decision by assessing its costs and benefits to put the welfare change attributable to it in perspective. Therefore, it is often used to guide policy alternatives (European Commission, 2014). To conduct a CBA, key considerations are the period of analysis, the discount rate, the different alternatives to be considered and the estimated costs and benefits related to these alternatives.

***Period of analysis***

The period of analysis for all the CBA models was set to 17 years, from 2023 to 2040. The final year of the analysis was based on data available from Lebreton and Andrady (2019).

***Discount rate***

The discount rate is used in the CBA analysis to transform future monetary values to net present monetary values (NPV). By doing this, the cash flows of the system can be compared. There are two key reasons for applying a discount rate. First, individuals normally prefer benefits in the present compared to obtaining them in the future (Boardmand et al., 2011). This assumption is based on the uncertainty of obtaining future benefits compared to the certainty of obtaining the benefits in the present (Staehr, 2006). Second, there is an opportunity cost of forgoing the present benefits for future benefits. In this case, the discount rate represents the opportunity cost of forgoing the benefits of any other investments (Boardmand et al., 2011). Based on this, it is important to decide which discount rate is adequate to use; a higher discount rate represents a higher decrease of future values.

The process in which future values are converted and expressed in terms of present values is called discounting (Boardmand et al., 2011). The discounting process uses a discount rate to convert future values to present values. In this study, the discount rate was calculated as the average of multiple discount rates and is equal to 6.35% (see **Annex A2.1** and **Table A8** for details on its calculation).

***Net Present Value (NPV)***

CBA methodology allows the use of financial indicators to assess the performance of any investment and compare it with others. In this case, the recycling scenarios and the related BaU scenario are compared. To assess the performance of each scenario, the indicator used is the NPV of the BaU and of the two recycling scenarios.

The NPV is the difference between the benefits and cost using the discounting process to get the present net benefits. The result is the NPV of an investment. **Equation 2** shows how to calculate the NPV:

$$NPV = \sum_{t=0}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \quad (\textbf{Equation 2})$$

Where:

*NPV* = Net Present Value of an investment
*Benefit* = gross benefits of the investment in year t
*Cost* = gross costs of the investment in year t
*T* = period of analysis
*t* = year; and
*r* = discount rate

The reference year of 2022 is used to present costs and benefits, and the resulting NPV for the analysis of the impact of recycling.

### *Benefits*

The impact of marine plastics on fisheries and coastal clean-ups for the scenarios presented previously is done in the same manner as presented for the impact assessment in 2019. Benefits of implementing the recycling scenarios are based on the reduction of negative impact by implementing recycling on a national or regional basis. Thus, the benefits are calculated based on the difference between the impacts under BaU versus recycling. **Figure 9** illustrates the different steps taken to estimate the benefit of implementing recycling only on a national basis in Antigua and Barbuda under recycling scenario 1 (national recycling scenario):

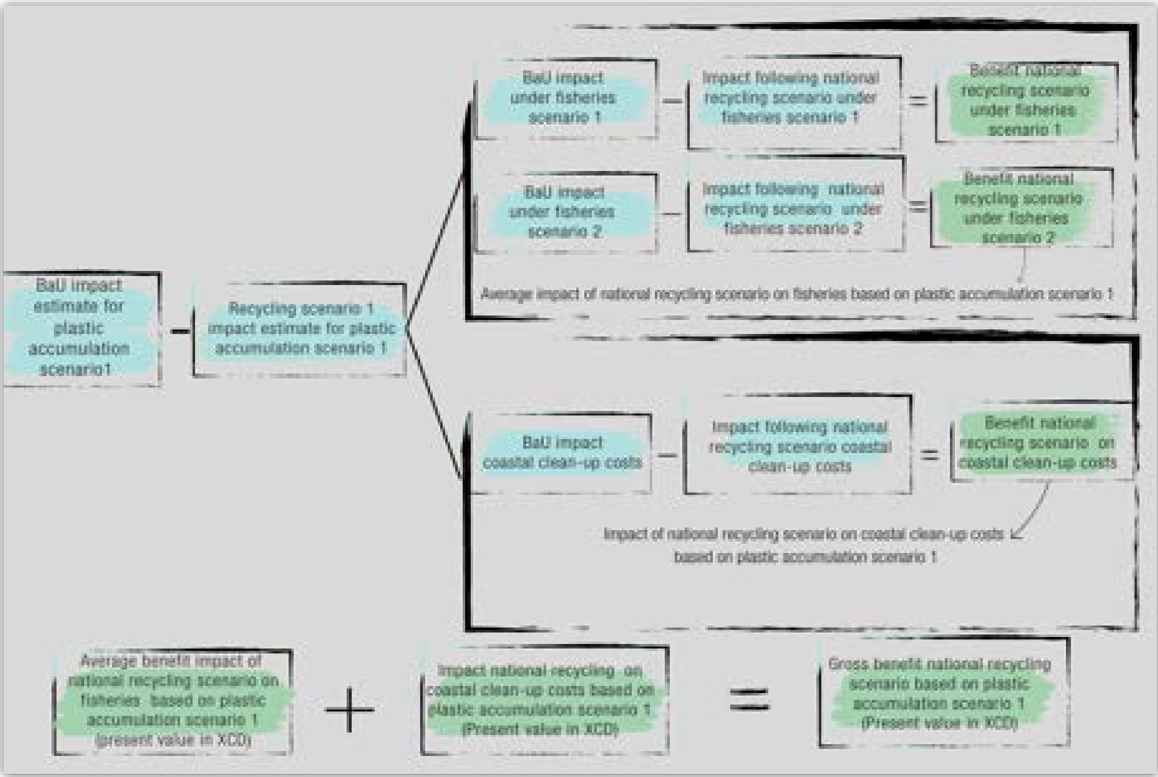



***Figure 9 – Schematic representation of the estimation of the gross benefit for a given recycling and plastic accumulation scenario***

### *Costs*

Under BaU, costs were estimated using the total waste management budget (WMB) provided by APWC (2021b).

Under the national recycling and regional cooperation scenario, the final cost of recycling plastics was estimated as follows in **Equation 3**:

$$Final\ Cost_{recycling\ plastic} = (Cost^{WMB}_{recycling\ plastic} + Cost_{recycling\ plastic}) - Cost^{WMB}_{BaU}$$
(*Equation 3*)

Where,

$Cost_{recycling\ plastic}$ was estimated by including the cost of collection and sorting of plastics as well as its shipping to Miami for treatment (and potential sale afterwards). For collection cost, data from Searious Business (2021) on labour, investment, and fixed costs were used. Sorting costs were estimated using PEW (2020). Finally, Satney, M. (2022) provided data for the shipping costs. As a simplification, no impacts of scale (neither economy nor diseconomy) were considered for the cost of recycling plastics. This means that for any amount of plastics that needs to be recycled, the costs remain constant.

$Cost^{WMB}_{BaU}$ was estimated using the average cost per tonne during 2019 provided by APWC (2021b). An assumption applied was that general waste grows at the same rate as plastic waste.

$Cost^{WMB}_{recycling\ plastic}$ was estimated considering a simplified assumption of a linear relationship between cost and amount of waste collected (i.e., x tonnes of plastics recycled induce a decrease by y% of waste ($\frac{plastic\ recycled}{Total\ waste}$) leading to a savings of y% to the WMB). The same assumption as above was applied, namely that general waste grows at the same rate as plastic waste.

## 5.2. Results recycling scenarios

### 5.2.1. Plastic accumulation scenarios under BaU (2023-2040)

To measure the benefits for the fisheries sector and of a reduction in coastal clean-up costs of increased recycling of plastics, a counterfactual BaU scenario is first constructed (see **Figure 10** for plastic accumulation scenario 1, and **Figure 11** for plastic accumulation scenario 2) (see **Annex A1** for the assumptions used to construct plastic stocks). These figures allow for **isolating which part of the plastic stock that is accumulating is impacting the sectors analysed in this study**; it can either be costs for the fisheries sector or coastal clean-ups. The impact that is not captured corresponds to the plastics that previously got buried into the seabed or shoreline according to the plastic accumulation scenarios[16].

For instance, in 2023, following this study's methodology, 157,832 tonnes of plastics could be found within Antigua and Barbuda's jurisdiction. This study captures the impacts of plastics on the economy in two ways: loss of revenue for the fisheries sector and costs of coastal clean-ups. Fisheries will be impacted by 156,448 tonnes of that

[16] For 2019 and future scenarios, coastal clean-up costs are used as a proxy for overall costs, considering the minimum costs to not continue the increase in plastic accumulation on coast and shoreline, but does not consider plastics that accumulated in the past. This does not imply it is considered this plastic does not create any impacts, it is just not captured here in this study.

stock (shown by the blue part in **Figure 10**). Coastal clean-ups will be impacted depending on the amount of plastics that washes up on land; in this example, the plastics should amount to 1,384 tonnes (shown by the blue part in **Figure 10**). A certain amount of plastics (equal to 20,556 tonnes, shown by the grey hashed section in **Figure 10**) are already buried in the sea floor or shoreline, thus not impacting any of the two activities/sectors considered.

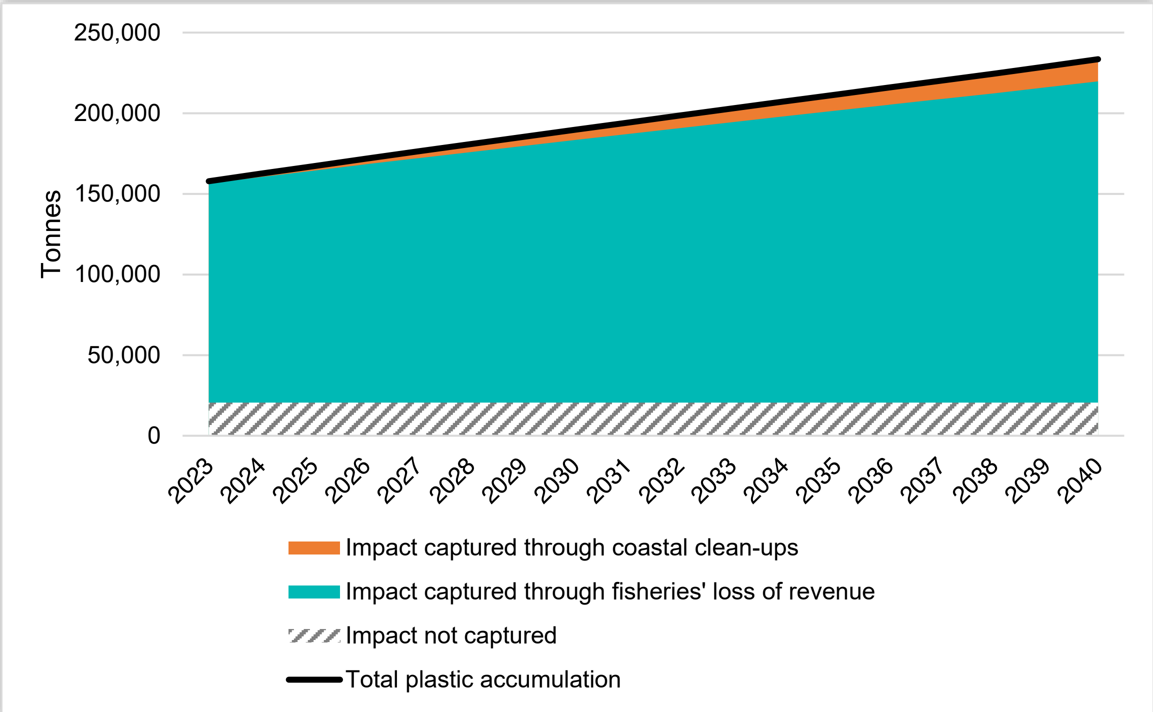



*Figure 10 – Future plastic accumulation under plastic accumulation scenario 1, BaU*

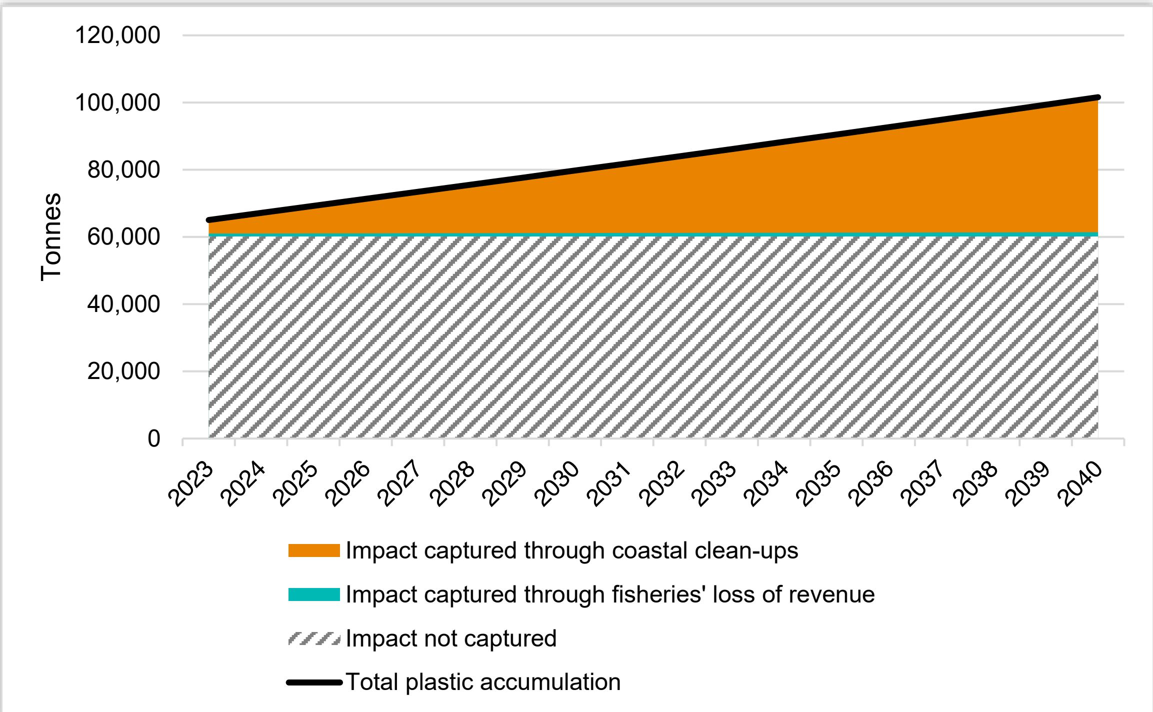



*Figure 11 – Plastic accumulation under plastic accumulation scenario 2*

According to Lebreton and Andrady (2019), leaked plastics in the Caribbean region could increase by an estimated 82% by 2040. Analysing the results for Antigua and Barbuda based on the two different plastic accumulation scenarios yields the results displayed in **Tables 14** and **15** (see **Annex A1.3** for more explanation on the construction of future plastic stocks).

*Table 14 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 1 (tonnes)*

| Location | Plastics (tonnes) | Percentage increase compared to 2019 |
|---|---|---|
| Sea surface | 2,072 | 81.6% |
| Coastline and seafloor | 34,286 | 111.6% |
| Coastal waters | 35,541 | 81.6% |
| Open ocean | 161,584 | 81.6% |
| **Total** | **233,482** | **85.5%** |

*Table 15 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 2 (tonnes)*

| Location | Plastics in tonnes | Percentage increase compared to 2019 |
|---|---|---|
| Shoreline | 100,336 | 94.9% |
| Coastal water (less than 200m) | 239 | 80.8% |
| Offshore (more than 200m) | 4,972 | 81.2% |
| **Total** | **105,547** | **94.2%** |

### 5.2.2. Impacts under BaU (2023-2040)

***Impacts fisheries BaU (2023-2040)***

Having estimated the future stock of plastics for each year between 2023 and 2040 (see **Annex A2, Annex A2.2.1, Annex A2.2.2** and **Annex A2.2.3** for details), the impacts, benefits, and costs of recycling for that period can also be estimated. In the following sections, these estimates will always be presented twice. First, by giving their future value, and second by presenting them in present value using a discount rate of 6.35%.

The total future value of the costs for the period (2023-2040) to the fisheries sector is estimated at **XCD 104,749,511** (USD 38,767,398). By using the average discount rate of 6.35%, the present value is estimated to amount to **XCD 57,397,154** (USD 21,242,470). This value is more or less the same for both plastic accumulation scenarios, so only one value is used for both.

***Coastal clean-up costs BaU (2023-2040)***

The total value of the **coastal clean-up costs is** estimated to amount to **XCD 284,818,719** (USD 105,410,332) in future value and **XCD 157,263,336** (USD 58,202,567) in present value under the **plastic accumulation scenario 1,** and to **XCD 833,496,203** (USD 308,473,798) in future value and **XCD 460,216,920**

(USD 170,324,545) in present value under **plastic accumulation scenario 2**. **Annex A2.2.5** and **Annex A2.2.6** provides more details.

***Overall direct cost mismanaged plastics (2023-2040)***

The future and present values of the overall impact, direct cost to the fisheries sector and clean-up costs are displayed in **Table 16**. They depend on which plastic scenario is chosen; thus, four different values are presented.

***Table 16 – Future and present values of the overall direct costs to fisheries and coastal clean-ups (2023-2040) (discount rate: 6.35%)***

| Plastic Accumulation Scenarios | | |
|---|---|---|
| | **Scenario 1 (XCD)** | **Scenario 2 (XCD)** |
| Future value | 389,568,230 | 938,245,714 |
| Present value | 214,660,490 | 517,614,074 |

### 5.2.3. Cost of implementing the recycling scheme

The operating cost of the general waste management system is estimated to amount to XCD 110.3 per tonne of waste (details in **Annex A3.5**).

Establishing improved infrastructure to collect and store general waste, such as bins with lids for all households comes at a cost. This estimated cost per tonne of recycling plastics is presented in **Table 17** (details in **Annex A3.4**). **Figure 12** compares the WMB under the BaU scenario with the WMB under the recycling scenario, which is combined with the cost of recycling. The difference between the two waste management scenarios is presented in **Figure 13** and is equal to the actual cost of recycling.

***Table 17 – Estimated costs of recycling per tonne of plastics (2019)***

| Types of cost | | XCD per tonne | USD per tonne |
|---|---|---|---|
| Collecting cost | Labour cost | 272.9 | 101.0 |
| | Investment cost | 13.3 | 4.9 |
| | Fixed cost | 7.9 | 2.9 |
| Sorting cost | | 201.5 | 74.6 |
| Shipping cost | | 68.8 | 25.5 |
| **Total** | | 564.4 | 208.9 |

*Source: Searious Business, 2021; PEW, 2020*

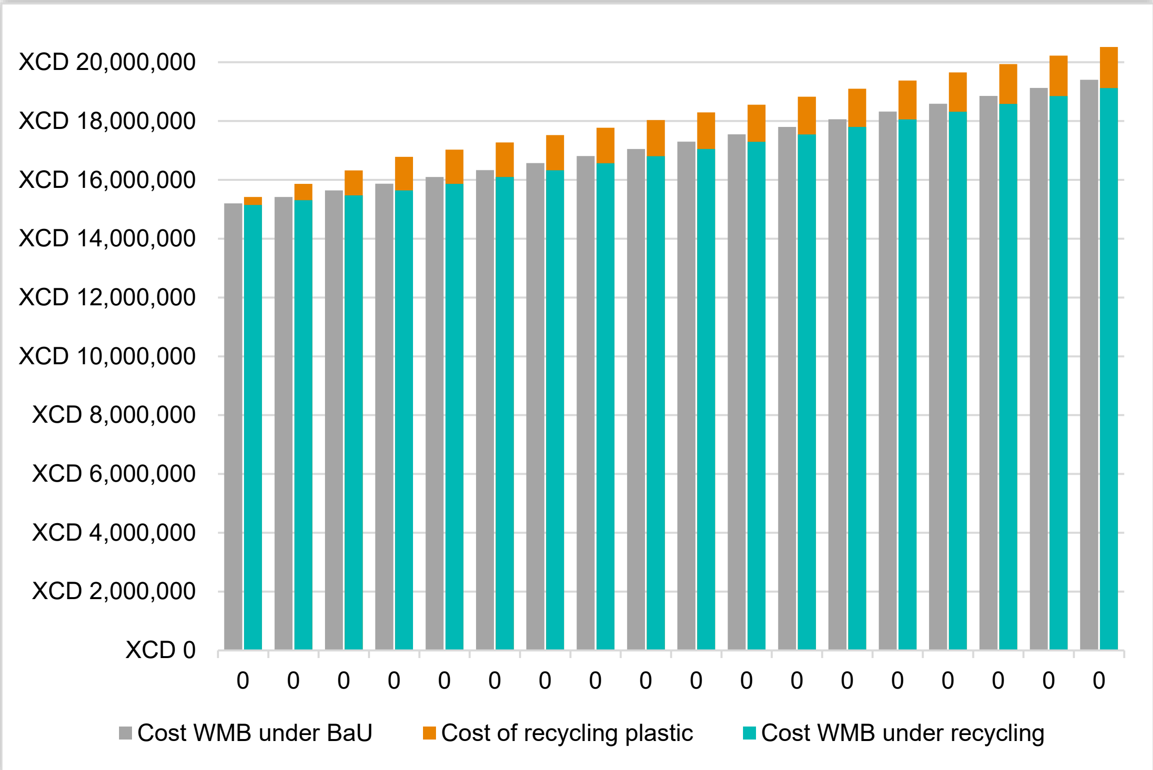



***Figure 12 – Estimated cost of recycling, and the waste management budget under BaU scenario and the national recycling scenario (XCD/year)***

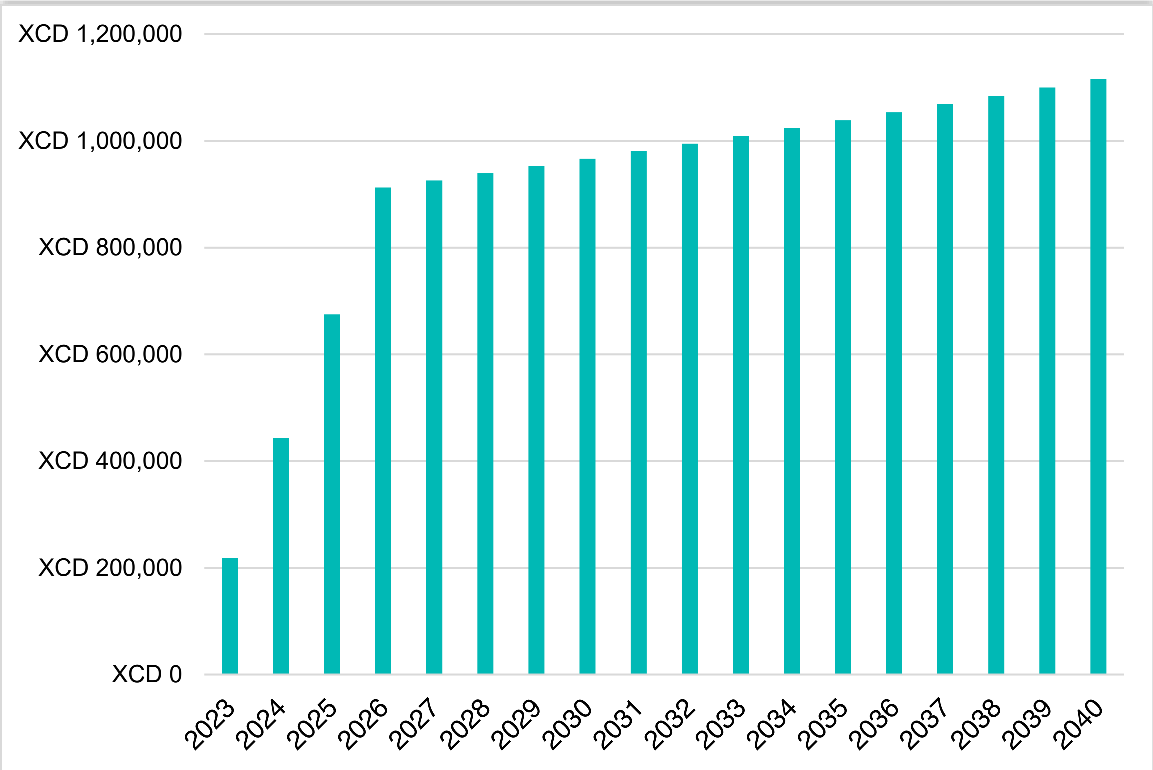



***Figure 13 – Actual cost of recycling (XCD/year)***

The future value of the overall cost is estimated to be **XCD 25,473,259** (USD 9,427,556). Applying the discount rate of 6.35% results in an estimated present value of **XCD 13,495,094** (USD 4,994,483).

### 5.2.4. Recycling scenarios – plastic stocks (2023– 2040)

The impact in terms of the amount of plastics under the two recycling scenarios (national recycling and regional cooperation) is displayed in **Figure 14** for the fisheries sector and in **Figure 15** for the coastal clean-ups.

*Tire dumpsite in Antigua and Barbuda (IUCN).*

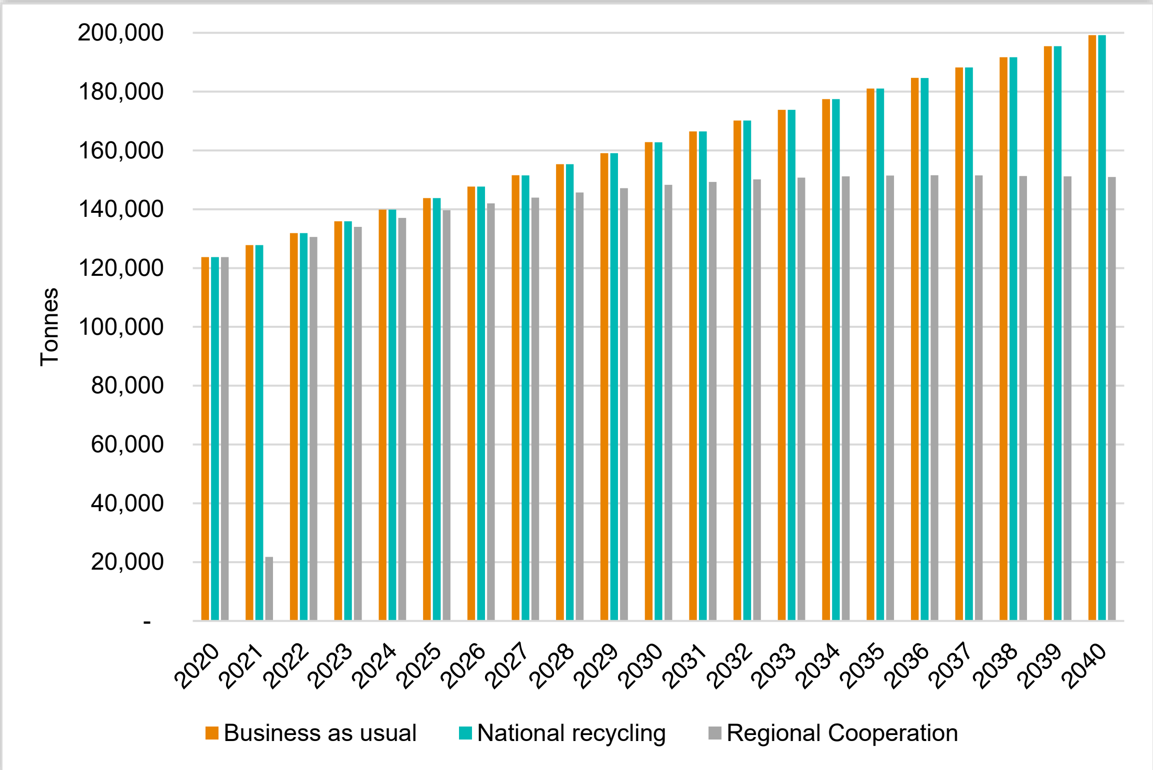



***Figure 14 – Estimated tonnes of plastics in Antigua and Barbuda's waters under the three future plastic management scenarios***

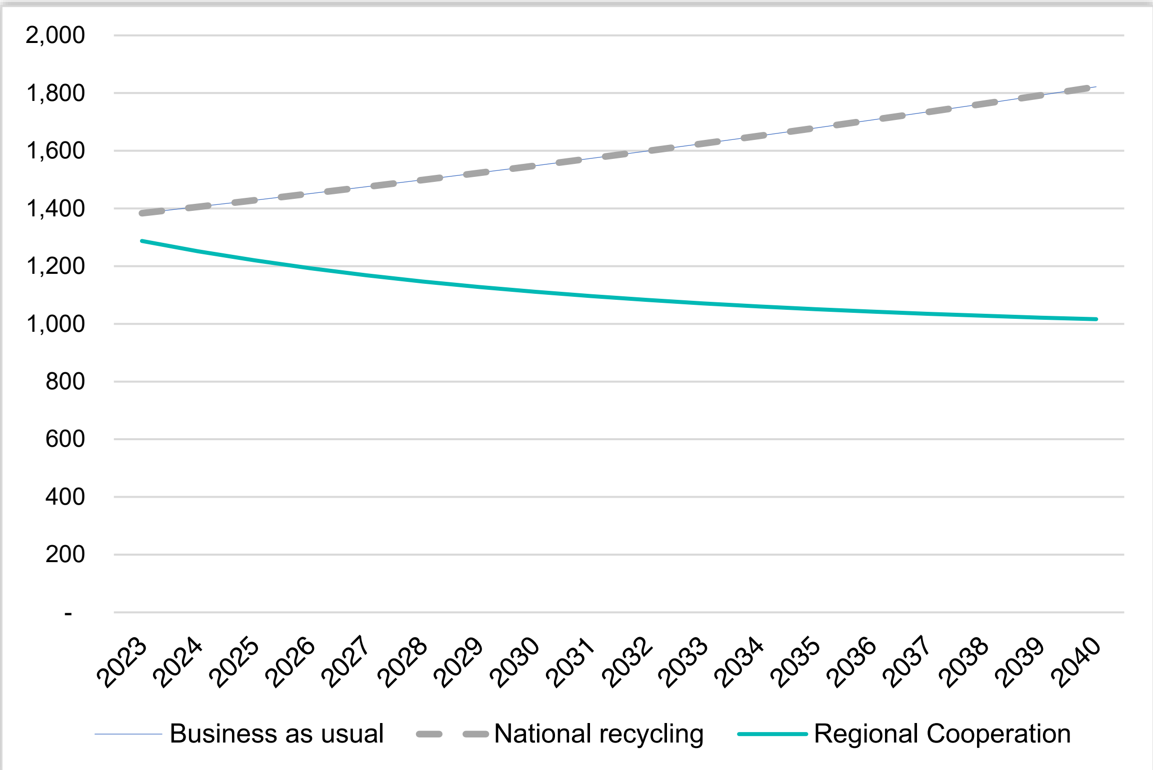



***Figure 15 – Estimated tonnes of plastics ending up on Antigua and Barbuda's shoreline each year under the three future plastic management scenarios***

### 5.2.5. National recycling scenario: costs and benefits of national recycling

The estimated future value of the reduction in loss of revenue for the fisheries sector is **XCD 9,271** (USD 3,431) while the present value is **XCD 4,470** (USD 1,654). **Table 18** presents the future values of the reduction of coastal clean-up costs under the two plastic accumulation scenarios compared to the BaU scenario while **Table 19** shows the present value of the same estimations (discount rate of 6.35%). Details are available in **Annex A3.1**, **Figure A6** for the fisheries sector and **Annex A3.2, Table A12** for the coastal clean-ups.

***Table 18 – Future value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 29,714 | USD 10,997 | XCD 86,955 | USD 32,182 |

***Table 19 – Present value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 15,866 | USD 5,872 | XCD 46,429 | USD 17,183 |

### 5.2.6. Regional recycling scenario: benefits of regional implementation of recycling

The future value of the reduction in loss of revenue for the fisheries sector is **XCD 12,500,805** (USD 4,626,500), while the present value is **XCD 5,444,630** (USD 2,015,037).

The future values of the reduction of the coastal clean-up costs are displayed in **Table 20. Table 21** shows the present value of the benefits of a reduction in coastal clean-up costs in Antigua and Barbuda. The calculations follow the same methodology used for the national recycling scenario, details of which are available in **Annex A3.3**, **Figure A7** for the fisheries sector and **Annex A3.2**, **Table A13** for the coastal clean-ups.

***Table 20 – Future value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 85,979,799 | USD 31,820,799 | XCD 251,612,100 | USD 93,120,688 |

***Table 21 – Present value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 41,600,243 | USD 15,396,093 | XCD 121,739,345 | USD 45,055,272 |

The benefits of the national recycling scenario alone for both sectors are relatively low. This result stems from the fact that the existing stock (impacting fisheries) and the additional plastics accumulating every year (impacting both fisheries and clean-up costs) – based on this study's assumptions – come mostly from elsewhere. The Lebreton and Andrady (2019) dataset on countries' MPW shows that Antigua and Barbuda occupies the 29th rank out of 35 counties of the Caribbean region in terms of MPW. Therefore, Antigua and Barbuda's efforts to reduce its plastic pollution will only contribute to decreasing the amount impacting the country by a small fraction; hence, the relatively low benefits displayed above. Contrasting the national recycling scenario results with the benefits from the regional cooperation scenario. Results also highlight the importance of nations working together to efficiently tackle marine plastic pollution.

### 5.2.7. Overall results national and regional recycling scenarios

**Figures 16** and **17** show the annual benefits of both recycling scenarios (national and regional cooperation) as well as the annual costs of implementing a national recycling system. **Figure 16** shows the results under plastic accumulation scenario 1, while **Figure 17** shows results under plastic accumulation scenario 2. Results are displayed both in discounted and non-discounted values. **Table 22** shows the net future and present values of the regional cooperation and national recycling scenario. Negative values are highlighted in light orange whereas positive values are highlighted in turquoise.

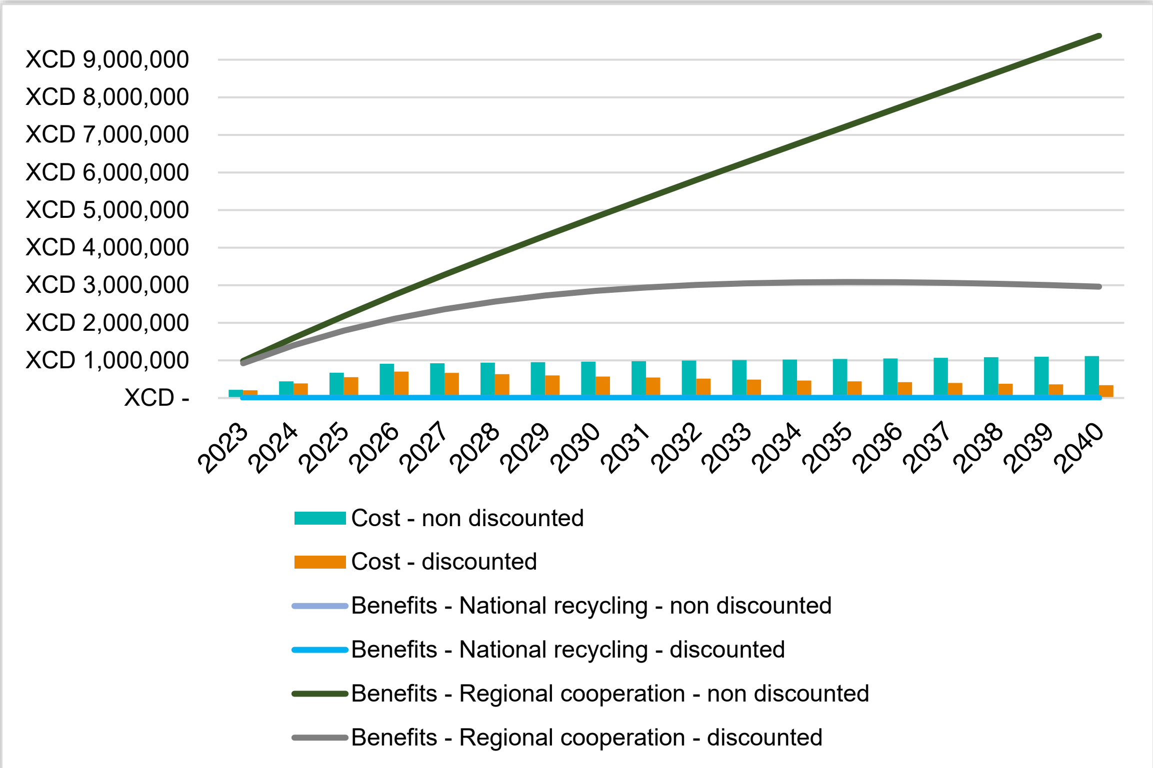



***Figure 16 – Cost of recycling plastics for Antigua and Barbuda (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 1 (future and present values) (discount rate: 6.35%)***

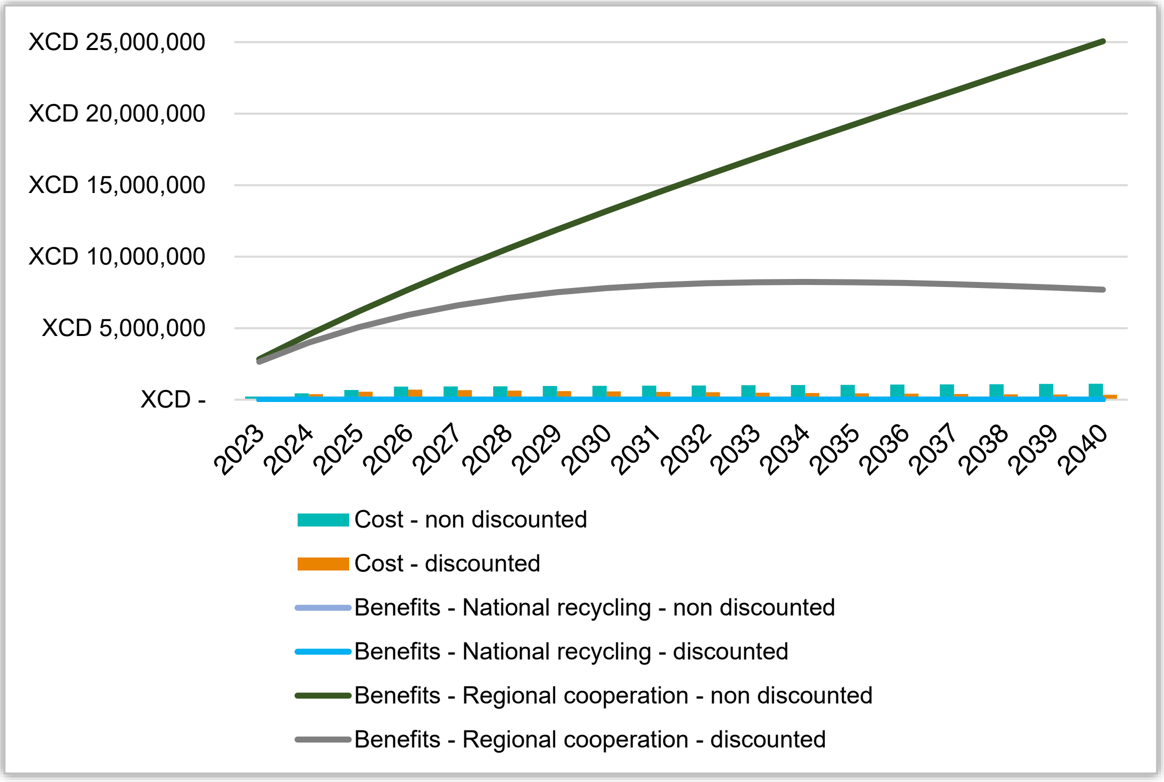



***Figure 17 – Cost of recycling plastics for Antigua and Barbuda (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 2 (future and present values) (discount rate: 6.35%)***

**Table 22** shows that none of the national recycling scenarios are profitable based on the benefits and costs considered, and without or with applying the discount rate used. However, under the regional cooperation scenario, for both plastic accumulation scenarios, the benefits of a regional reduction in MPW greatly overcome the costs of implementing recycling in Antigua and Barbuda.

***Table 22 – Net future and present values of the national and regional cooperation scenario under both plastic accumulation scenarios (discount rate used: 6.35%)***

| Recycling Scenario | Plastic Accumulation Scenarios | Net Future Value | | Net Present Value | |
|---|---|---|---|---|---|
| | | XCD | USD | XCD | USD |
| National recycling | 1 | -16,466,210 | -6,094,082 | -8,667,780 | -3,207,913 |
| | 2 | -16,408,969 | -6,072,898 | -8,637,216 | -3,196,601 |
| Regional Cooperation | 1 | 81,975,409 | 30,338,789 | 38,351,629 | 14,193,793 |
| | 2 | 247,607,709 | 91,638,679 | 118,490,732 | 43,852,973 |

This result diverges from the outcome of Saint Lucia (Raes et al., 2022a) (where no scenario is profitable when looking at the net present value). This difference stems from the fact that the minimum wage of Antigua and Barbuda used here is higher (more than 4.8 times the Saint Lucian one); and that according to the data used, less plastics per person per day is collected (42% the amount collected in Saint Lucia). In Antigua and Barbuda – as compared with Saint Lucia – more people at a higher wage are required to collect the same amount of plastic during coastal clean-ups, making initiatives to reduce plastic pollution more cost efficient there

However, not all benefits from recycling and reducing plastic leakage have been considered thus far. For instance, plastic scraps can be sold on the appropriate market, the price depending on various factors such as the country, the type of polymer, and/or the quality. Antigua and Barbuda could resell some or all its recycled plastics. For example, if the average price of USD 245.5[17] per tonne, observed in the EU is applied (Eurostat, 2021), then the present value of the recycled plastics for Antigua and Barbuda would amount to **XCD 14,069,971** (USD 5,197,625) for the period considered, creating additional benefits. This price is potentially higher than what could be obtained in a market accessible for Antigua and Barbuda's plastic scrap material. To breakeven in NPV over the 18-year period considered, Antigua and Barbuda would need to resell the plastics at least at a constant price of **XCD 436.14** (USD 161.41) per tonne under the least profitable scenario (national recycling under plastic accumulation scenario 1) and **XCD 434.6** (USD 160.84) per tonne under the best case (regional cooperation under plastic accumulation scenario 2).

Furthermore, sending containers with recyclable plastics back to the port of origin can potentially have a positive price effect. As many goods in Antigua and Barbuda are imported, sending back full containers (with plastics for recycling) could potentially reduce the costs of marine transport for imported goods within the country.

Additional benefits could also be generated not only through the sale of plastics as raw materials for recycling, but by directly using collected plastics for the development of new value chains. For example, within the PWFI project, Searious Business (2021) has developed a product concept for bottle-to-bottle recycling as an alternative value chain for Antigua and Barbuda. An improved recycling system and especially the development of alternative value chains can also generate employment opportunities.

Finally, Antigua and Barbuda has one functioning landfill (the Cook's Landfill), which has exceeded its capacity since 2018 (APWC, 2021b). Waste is currently being deposited at an old dumpsite (with no sanitary cell), which was originally closed in 2003. By combining a reduction of the amount of waste that ends up at that landfill with better waste compaction practices, current pressure on the environment surrounding the landfill can be reduced and lower the costs of alternative sites to Cook's landfill. This would provide another financial benefit for the waste management system (Graham et al., 2022).

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influence costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example, to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Antigua and Barbuda.

[17] Exchange rate of 1.0031 USD per EUR used to convert Eurostat (2021) data (Exchange rate retrieved on 15 July 2022).

*Landfill, Antigua and Barbuda (IUCN).*

# 6. OTHER ASPECTS OF THE IMPACT OF MARINE PLASTIC POLLUTION AND INSTRUMENTS TO REDUCE IT

## 6.1. ADDITIONAL ECONOMIC AND SOCIAL BENEFITS

***Employment***

If plastic pollution accumulating on the coastline decreases the number of visitors, this will not only reduce the revenue generated by the tourism sector but can also have a significant impact on the number of people employed in this sector. The Statistics Division of the Government and Antigua and Barbuda reported that hotels and restaurants employed 6,922 people in 2015, or 16.3% of the workforce. However, tourism accounts for about 70% of direct and indirect employment in the country (Government of Antigua and Barbuda, 2021b), with estimates considering all indirect contributions put it as high as 90% of the workforce (WTTC, 2020).

Marine plastic pollution has a negative impact on fisheries revenue, and consequently as also on the number of people employed in the fisheries sector. In 2019, an estimated 8,612 people were employed in the fisheries sector. Of these, 2,149 were employed directly in capture fisheries (with 4% being women), and 6,459 in other fisheries dependent activities[18] (CRFM, 2020, FAO, 2022). Around 17 percent of the labour force is employed in fisheries. In addition, fisheries communities are an important part of the population. According to FAO (2022), around 25 percent of the population is somewhat involved in the fishery sector or is part of a family that is involved. The fishing sector is an important security net for the population, especially in moments when means of income vanish (FAO, 2022).

***Food security***

In the Caribbean, fisheries not only contribute to employment and household income, but also to food security (Bovarnick et al. 2010). Antigua and Barbuda have a per capita consumption of around 50 kilograms, among the highest levels of consumption in the world (FAO 2022). Marine plastics can impact food security both directly through reduced fish stock, but also by contaminating fish with macro- and microplastics.

[18] The fisheries sector also provides employment for many persons who supply services and goods to the primary producers. This includes persons engaged in processing, preserving, storing, transporting, marketing and distribution or selling fish or fish products, as well as other ancillary activities, such as net and gear making, ice production and supply, vessel construction and maintenance as well as persons involved in research, development and administration linked with the fisheries sector.

***Balance of trade***

Tourism is responsible for contributing between 42.7% to 80% of the GDP and is the primary source of foreign currency (Government of Antigua and Barbuda, 2020; Government of Antigua and Barbuda, 2021b; WTTC, 2020). Although smaller in magnitude in terms of contribution to the GDP (between 0.9 to 2% in 2020), a reduction in fish capture will also have an impact on the balance of trade, as reduced local production may increase fish imports (CRFM, 2021; Government of Antigua and Barbuda, 2021a). Fish imports complement domestic production and are much higher than exports on the other hand, are negligible (FAO, 2022).

***Other impacts***

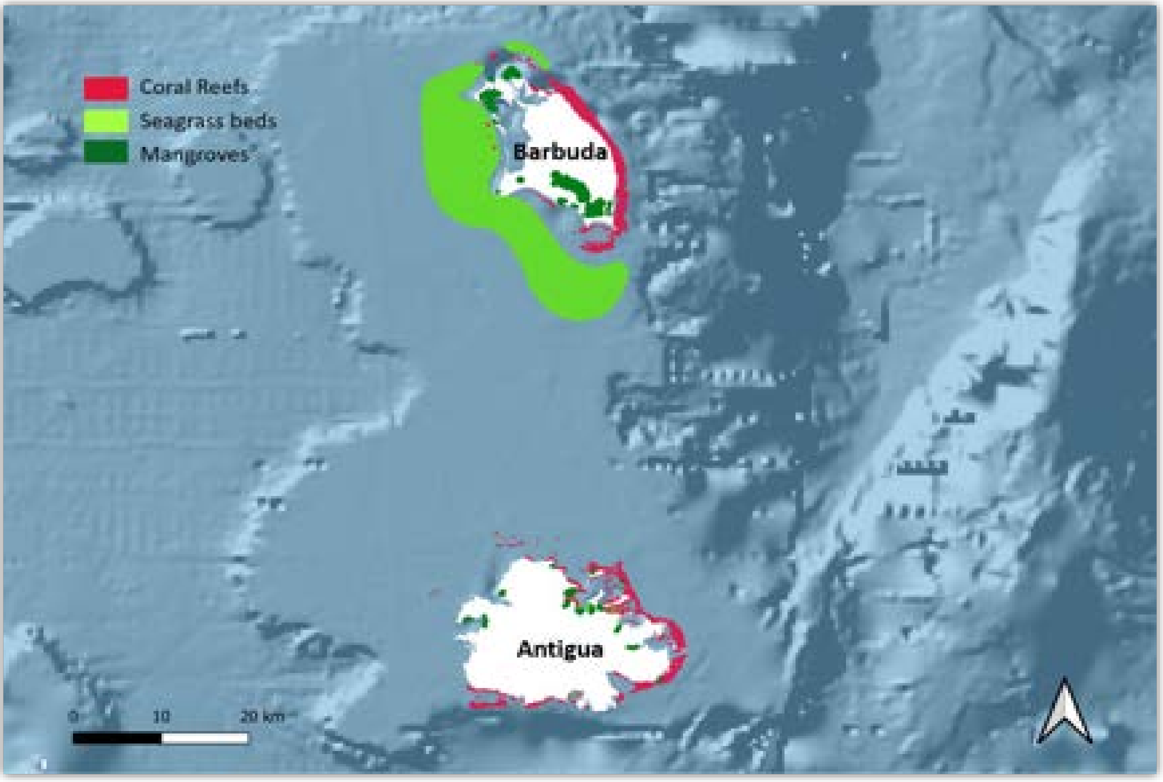
Although the aim of this study was to analyse the direct cost of marine plastics on the fisheries and tourism sectors, and the potential effects from activities to reduce this, marine plastics is not the only problem affecting these sectors and the economy of Antigua and Barbuda in general. the biggest impact on the tourism sector in Antigua and Barbuda have been Hurricane Irma in 2017 (Government of Antigua and Barbuda, 2018), and the global travel restrictions following the outbreak of covid-19, creating the worst economic crisis in a century (UNDP, UNICEF, and UN Women, 2020). Although improving, the tourism sector has not yet fully recovered. In addition, the tourism sector is also vulnerable to the impact of climate change (Government of Antigua and Barbuda, 2021b), manifested by: sea level rise, an increased frequency and intensity of storms, which can deter tourists from visiting the island, and coastal erosion, which can create a loss or degradation of tourism resources such as beaches (Simpson et al., 2010; Government of Antigua and Barbuda, 2021b).

While this study includes a climate change impact scenario in the future fisheries revenue estimates, the full extent of the impact of climate change – including for example: shifting fish migration and distribution patterns, changes in reproduction of certain fish species, or altered habitats of fish species, and impacts of more frequent extreme weather events on fishing efforts (CANARI, 2019; Palacios-Abrantes et al., 2022) – has not been considered. Furthermore, in addition to the potential long-term impact of ghost fishing, Caribbean fishery resources are among the most overexploited in the world; regional production has declined by more than 40% over the last two decades (FAO, 2014). 54% of species or species groups in the Caribbean are considered overfished or over-to-fully fished (Western Central Atlantic Fishery Commission 2017). Overexploitation is the main threat to bony fishes in the Caribbean; it directly affects half the species in the greater Caribbean listed by IUCN as globally ‘threatened’ or ‘near threatened’ (Linardich et al., 2017).

## 6.2. IMPACT ON MARINE AND COASTAL ECOSYSTEMS

Beyond the direct impact of marine plastics on fish stocks, there are several challenges that could seriously impact the future of marine natural assets. Antigua and Barbuda’s coastal zone and marine ecosystems are not only characterised by beaches, but also by mangroves (670 ha, FAO, 2020), seagrass beds (593 ha, Chatenoux and Wolf, 2013) and coral reefs (616,200 ha, Sea Around Us, 2005) (**Map 3**). These ecosystems not only play an increasingly vital role in tourism but are also an integral component in natural coastal defence and the ecology of the island. Coastal and marine resources also provide for livelihoods in several rural communities in the fisheries sector, as well as for recreation, sports, and enjoyment, and are an overall source of employment for many people (Ruttenberg et al., 2018; Government of Antigua and Barbuda, 2021b).

Coral reefs, mangroves and seagrass beds provide a range of key ecosystem services, such as protection of the shoreline from erosion and storm damage, breeding grounds for many species of fish and other marine species, water purification, disease control, carbon sequestration, nutrient cycling, sediment reduction, and recreation (Barbier et al., 2011; Luisetti et al., 2013; Ondiviela et al., 2014; Dudley et al., 2010, 2015; Mtwana Nordlund et al., 2016; Ruiz-Frau et al., 2017; Himes-Cornell et al., 2018; CANARI, 2019; Government of Antigua and Barbuda, 2020). These essential ecosystem services underline the importance of conserving and restoring these ecosystems. In addition, some species – specifically certain coral species – have a critical or vulnerable conservation status (**Figure 18**).




*Source: Giri et al., 2011; UNEP-WCMC, 2021a, UNEP-WCMC, 2021b.*

***Map 3 – Areas of coral reefs, seagrass beds, and mangroves in Antigua and Barbuda***

| RED LIST | Warm-water corals | Mangroves | Seagrasses | Coral-water corals |
|---|---|---|---|---|
| CR Critically Endagered | 2 | 0 | 0 | 0 |
| EN Endangered | 3 | 0 | 0 | 0 |
| VU Vulnerable | 6 | 0 | 0 | 1 |
| NT Near Threatened | 0 | 0 | 0 | 0 |
| LC Least Concern | 41 | 7 | 4 | 7 |
| Data Deficient | 4 | 0 | 0 | 0 |
| Total | 56 | 7 | 4 | 8 |

*Source: Ocean Plus, Habitats, 2021.*

***Figure 18 – IUCN Red List status of coral, mangrove and seagrass species in Antigua and Barbuda (2022)***

Coral reefs, seagrasses and mangroves are affected by marine plastics (NOAA Marine Debris Program, 2016; Tekman et al., 2022). For example, plastic debris interferes directly with the ecological role of mangrove forests (Ivar do Sul et al., 2014) and obstructs water flows in mangrove areas (Kantharajan et al., 2018). Coral populations can decrease significantly as the amount of litter increases (Richards and Beger, 2011; Yoshikawa and Asoh, 2004). Plastics can also increase the degree of disease contracted by corals (Lamb et al., 2018). Marine litter can also negatively affect seagrass ecosystems (Ganesapandian et al., 2011). Abandoned fishing gear damages seagrass beds by re-suspending sediments, disturbing rhizomes, and impacting the root structure of seagrasses (Barnette, 2001). In addition, mangrove forests and seagrass beds function as both traps and filters for marine plastics, including microplastics (Debrot et al., 2013; Sanchez-Vidal et al., 2021).

The impact of plastics should not be seen as an isolated effect. Plastic pollution is an additional stressor on marine ecosystems that are already dealing with multiple stressors (Lartaud et al., 2020; Tekman, 2022). Climate change causes coral bleaching (CANARI, 2019; Petit and Prudent 2010), ocean acidification (Bégin et al., 2016), and rising sea levels, accompanied by more frequent and severe storms (Sippo et al., 2018; Hughes et al., 2017). Further impacts occur through pollution from leakage of sediments, fertilisers and pesticides, and chemicals (Orth et al., 2006; Silbiger et al., 2018; van Dam et al., 2011), as well as due to overfishing (Burke et al., 2011; Zaneveld et al., 2016), unsustainable tourism (Burke et al., 2011; Lamb et al., 2014), algal blooms (Franks et al. 2016), sand mining (Government of Antigua and Barbuda, 2013), and invasive species (Biswas et al., 2018; Unsworth et al., 2019).

An ecosystem's degradation caused by plastic pollution in marine and coastal habitats impacts tourism, the fish stocks that depend on these habitats, as well as marine wildlife in general. Marine biodiversity that is not directly targeted by fisheries – such as seabirds and marine mammals – are not only impacted through habitat degradation, but also suffer directly from marine plastic pollution.

## 6.3. IMPACT ON MARINE WILDLIFE

There are seven marine mammals that are found in the waters of Antigua and Barbuda, three of which are currently listed as threatened and one that has gone extinct (CBD, 2014; NOAA, 2008). There are also four sea turtle species found, two of which (Green Turtle and Hawksbill Turtle) are known to nest on the nation's sandy beaches and forage in nearshore waters (Daltry et al. 2007). Approximately 182 species of birds (including land and seabirds) have been recorded in Antigua and Barbuda. About two-thirds are migratory and one-third represents year-round residents. (Joseph et al. 2020). There are 36 seabird species in Antigua and Barbuda, out of which 33 are listed as "least concerned" and 3 as "Threatened (**Table 23**) (BirdLife International, 2022).

*Table 23 – IUCN Red List status of threatened marine species in Antigua and Barbuda (2022)*

| | | |
|---|---|---|
| **Marine mammals** | | |
| Sperm Whale | *Physeter microcephalus* | Vulnerable |
| American Manatee | *Trichechus manatus* | Vulnerable |
| Hooded Seal | *Cystophora cristata* | Vulnerable |
| Caribbean Monk Seal | *Neomonachus tropicalis* | Extinct |
| **Sea turtles** | | |
| Green Turtle | *Chelonia mydas* | Endangered |
| Olive Ridley | *Lepidochelys olivacea* | Vulnerable |
| Leatherback | *Dermochelys coriacea* | Vulnerable |
| Hawksbill Turtle | *Eretmochelys imbricate* | Critically endangered |
| **Seabirds** | | |
| Black-capped Petrel | *Pterodroma hasitata* | Endangered |
| Black-legged Kittiwake | *Rissa tridactyla* | Vulnerable |
| Leach's Storm-petrel | *Hydrobates leucorhous* | Vulnerable |

*Sources: Taylor et al., 2019; Deutsch et al., 2008; Kovacs et al., 2016; Lowry et al., 2015; Seminoff et al., 2004; Abreu-Grobois et al., 2008; Wallace et al., 2013; Mortimer et al., 2008; BirdLife International, 2019; BirdLife International, 2018.*

Marine plastics can also be a danger to marine fauna. Kanhai et al., 2022, classify the impact of marine plastics on biodiversity as follows: (1) Biological effects (e.g., plastic ingestion); (2) Physical effects (e.g., entanglement); (3) Ecological effects (e.g., introduction of invasive alien species); and (4) Chemical effects (e.g., transporter of pollutants). Tekman et al. (2022), in their extensive literature review on the effects of plastic debris and hazardous substances on marine species, classify these impacts on marine fauna as: (i) Physical interactions, specifically: entanglement, ingestion, colonisation, and contact or coverage; and (ii) Chemical interactions: additives and absorbed substances.

The interactions have impacts on marine species such as seabirds, sea turtles, marine mammals, sharks, rays, and sponges (Tekman et al., 2022). According to the Convention on Biodiversity (CBD) Report, 'Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity' (2016), the total number of species known to be affected globally by marine debris (mainly plastics) is around 800; of those, the proportion of cetacean and seabird species affected by marine debris ingestion is 40% and 44%, respectively (CBD, 2016).

**Ingestion:** A wide range of animals ingest plastics. Certain marine animal populations – especially those that feed exclusively at sea, such as seabirds and sea turtles - present plastic debris in their stomachs (Hammer et al., 2012; Wilcox et al., 2015). Sea turtles can, while feeding, ingest plastic debris at all stages of their lifecycle (Mascarenhas et al., 2004), which can potentially have lethal consequences (Schuyler et al., 2014). For example, Wilcox et al. (2018), found a 50% probability of mortality once the sea turtles they analysed had 14 pieces of plastics in their digestive system. Discarded and semi-inflated, floating bags are of particularly hazardous as they are often mistaken for jellyfish and can block the oesophagus once ingested (Gregory, 2009). Tekman et al. (2022), analysing the studies collected in the LITTERBASE database[19], found a total of 272 seabird species had encountered plastic debris by ingestion. Reinert et al. (2017), found that 11% of 6,561 examined manatees had ingested marine debris or had become entangled, 50 of which died as a direct result.

**Entanglement:** happens if a plastic item wraps itself around the body, for example abandoned or lost fishing gear (Macfadyen et al., 2009; Richardson et al., 2019b). Marine mammals are among the species most affected by entanglement (Hammer et al., 2012). Fishing gear poses special risks for large, air-breathing marine animals, such as whales, dolphins, seals, sea lions, manatees, and dugongs, drowning after they become entangled in the nets (Laist, 1997; Lusher et al., 2018). Other species that are affected through entanglements are sharks, rays, and chimaeras (Parton et al., 2019).

**Colonisation** by alien species can be facilitated by plastic debris, which can be a threat to marine biodiversity and ecosystems. Aggressive invasive species can be dispersed by free-floating marine plastics. Their introduction can endanger sensitive or at-risk coastal environments (García-Gómez et al., 2021). Plastic debris can function as vectors, transporting viral and bacterial pathogens (harmful to both humans and animals), potentially spreading them to new areas (Bowley et al., 2021).

**Contact** or **coverage** with plastics, also called smothering, is another type of interaction. For example, coverage of sponges with plastics can impair prey capture and growth rates (Mouchi et al., 2019).

**Chemical** impacts occur: (1) because of harmful substances associated with plastics, such as Bisphenol A (BPA) or flame retardants; and (2) through sorption and desorption of chemical pollutants (Hermabessiere et al., 2017, Tekman et al., 2022).

According to Tekman et al. (2022), plastic pollution should always be considered in the context of the many other stressors affecting the marine environment. At present, plastic pollution alone may, by itself, not drive critical decreases in populations; it may just push an individual, population or ecosystem into decline and possibly over a critical threshold. For example, habitat destruction impacts all marine wildlife in Antigua and Barbuda (Government of Antigua and Barbuda, 2013, 2021). Globally, seabirds are threatened by bycatch and overfishing, climate change, and invasive species (Croxall et al., 2012; Dias et al., 2019). Turtles are also threatened by climate change (Laloë et al., 2016), as well as by predation by pigs and dogs, human harvesting of turtles and their eggs, and beach erosion (Department of Sustainable

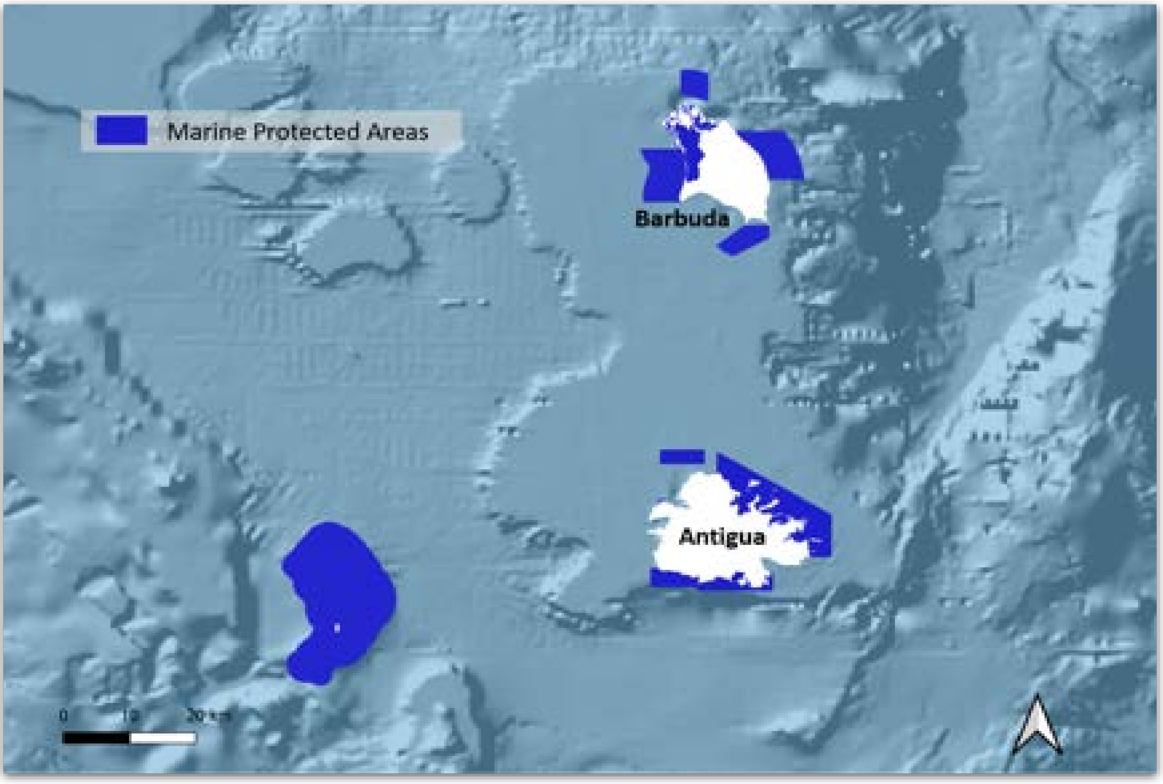
[19] https://litterbase.awi.de/.

Development, 2018; Tekman et al., 2022). Other impacts on marine wildlife come from collisions with boats (Jägerbrand et al., 2019), chemical pollution (Arzaghi et al., 2020), noise pollution (Badino et al., 2016) and ocean deoxygenation (Laffoley and Baxter, 2019).

The impact analyses on fisheries and tourism sectors, as well as the presentation of the effects on marine ecosystems and wildlife discussed above, focus mainly on interactions with macroplastics. However, **microplastics** are also of concern. Marine plastics, specifically those with a lifetime of hundreds of years, tend to degrade into micro- and nano-plastics over time. The size of these plastic pieces facilitates their uptake, can block the digestive tract, and contribute to the chemical body burden eliciting toxicological effects (Carbery et al., 2018; Tekman et al., 2022). These plastics may contain chemical additives and contaminants, some of them with suspected endocrine disrupting effects that when ingested may be harmful for marine animals (Gallo et al., 2018; Prokić et al., 2019). In addition to the direct ingestion of plastic debris, larger animals, higher in the food chain also ingest plastics. Microplastics are easily ingested by small organisms, such as plankton; contaminants leach from plastics tend to bioaccumulate in those organisms that ingest them – the higher the trophic level, the higher the chemical concentrations (Hammer et al., 2012).

## 6.4. MARINE PLASTICS IN MARINE PROTECTED AREAS

Marine protected areas (MPAs) are an essential tool in the recovery and protection of marine ecosystems and the vital services they provide (Reuchlin-Hugenholtz, 2015). MPAs protect marine biodiversity and ecosystems by limiting the economic activities in the area (IUCN, 2013). In Antigua and Barbuda there is a significant proportion of MPAs inside and outside of the 200m deep sea limit. Around 73% of Antigua and Barbuda's coastline is designated as MPAs, which provide protection to the coastal ecosystem and habitats, comprising coral reef areas, seagrass beds, mangroves, and marine species therein (Government of Antigua and Barbuda, 2019) (see **Map 4**, below). The area coverage of MPAs for Antigua and Barbuda is estimated to be 641 km² (UNEP-WCMC, 2021).




*Sources UNEP-WCMC, 2021c ; Marine Conservation Institute, 2021.*

***Map 4 – Marine protected areas in Antigua and Barbuda***

MPAs in Antigua and Barbuda are impacted by several factors, including poor demarcation and non-enforced management practices (MEPA, 2022). However, in addition, the global pervasiveness and high abundance of plastic debris in the marine environment are growing threats for MPAs (OECD, 2016). The delineated boundaries for MPAs cannot stop plastics from entering and posing risks to vulnerable habitats and species (Giuseppe, 2022).

The estimated amount of plastics present in 2019 in Antigua and Barbuda's MPAs (**Map 4**) is presented in **Tables 24** and **25**.

***Table 24 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 1***

| Accumulation areas | Plastics in MPA (tonnes) |
|---|---|
| Sea surface | 3,3647 |
| Coastline and seafloor | 10 437 |
| Coastal waters | 54 516 |
| Open ocean | 262,376 |

***Table 25 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 2***

| Accumulation Areas | Plastics in MPA (tonnes) |
|---|---|
| Offshore – Deeper water | 151,823 |
| Shallow water | 9,418 |
| Shoreline – Dry land | 1 768 |

# 7. SUMMARY AND CONCLUSIONS

The results of this study show the estimated impact of marine plastics on fisheries in 2019 to be 9.2% of revenue, excluding the impact of ghost fishing. The estimated losses due to plastic leakage in the marine environment for Antigua and Barbuda's fisheries sector is **XCD 3,861,103** (USD 1,428,980).

For tourism, the potential percentage of tourists who would no longer be willing to visit the country if all plastics accumulated on beaches is estimated to be between 82.4% and 97%. To avoid this loss, the cleaning of beaches and coastline is estimated to cost between **XCD 12,868,519** and **37,657,395** (USD 4,762,590 and 13,936,860), which is equal to between 88.4% and 258.6% of the 2019 waste management budget.

The total direct cost of mismanaged waste in Antigua and Barbuda in 2019, looking at fisheries and coastal clean-ups, is estimated to be between **XCD 16,729,622** (USD 6,191,569) under plastic accumulation scenario 1 and **XCD 41,518,498** (USD 15,365,839) under plastic accumulation scenario 2.

From 2023 to 2040 and under a BaU scenario, the estimated direct impact -which is the sum of the revenue loss for the fisheries sector and the estimated coastal clean-up costs in present value is **XCD 214,660,490** (USD 79,445,037) under plastic accumulation scenario 1 and **XCD 517,614,074** (USD 191,567,014) under plastic accumulation scenario 2.

The present value of the overall cost of recycling is estimated to be **XCD 8,688,116** (USD 3,215,439). The present value of the benefits under plastic accumulation scenario 1 of the national recycling scenario alone is estimated to be **XCD 20,336** (USD 7,526) compared to **XCD 50,900** (USD 18,838) as estimated under plastic accumulation scenario 2. The present value of the benefits of the regional cooperation scenario, is estimated to be **XCD 47,039,745** (USD 17,409,232) under plastic accumulation scenario 1 and **XCD 127,178,848** (USD 47,068,411) under plastic accumulation scenario 2.

The cost-benefit analysis resulted in an estimated net present value that varies between **XCD -8,667,780** (USD -3,207,913) (national recycling and plastic accumulation scenario 1) and **XCD 118,490,732** (USD 43,852,973) (regional cooperation and plastic accumulation scenario 2) for the period 2023-2040. The results of the cost-benefit analysis highlights the importance of regional collaboration, due to the transboundary nature of the marine litter. This is consistent with what was found by Macias et al., 2022 for the Mediterranean.

This study mainly focused on estimating direct costs for the economy of Antigua and Barbuda, looking at costs for the fisheries and tourism sectors. Some costs, such as the impact of ghost fishing, and benefits, such as the potential of selling plastics on the market for recyclables, were not included. In addition, mismanaged plastics also have broader impacts on blue natural capital assets and marine biodiversity, which can generate additional impacts to the economy. With this said, it is difficult to quantify the impact on marine ecosystems and biodiversity (Tekman et al., 2022). The impact of marine plastics must be seen in light of the multiple stressors, which impact the marine environment and the blue economy that depends on it.

The results showed the potential positive social, economic and environmental impact of implementing a national recycling system for Antigua and Barbuda, especially if this is part of a regional effort to reduce mismanaged plastic waste. However, the multiple actors, sources, pathways, and different types of plastics require a range of solutions and tools to address the problem. These include, for example: reducing and substituting plastic use, systems such as extended producer responsibility, market-based instruments such as deposit refund schemes or landfill taxes, and the improvement of waste collection systems and infrastructure, including fishing systems and gear (Newman et al., 2015). Further cost-effectiveness and cost-benefit analyses will be needed to understand trade-offs among different alternatives and continue supporting the decision-making process, including further work around the cost-and benefits of establishing a regional recycling hub in the Caribbean Region. Additional analyses can also look at how to assure a recycling system does not create a negative impact on livelihoods, so it can evaluate how to integrate local waste pickers into a national system.

There is also a need for further data on mismanaged plastics and leakage, and where it accumulates in the marine environment. Additional work is also needed to understand the real cost of plastics, including microplastics. Although efforts have been undertaken, such as the studies conducted by Trucost (2016) and WWF (2021), more empirical evidence is needed on the costs of marine plastics to fisheries, tourism, and the blue economy as a whole. In addition, the inclusion the impact of mismanaged plastic waste in measurement tools such as the Multidimensional Vulnerability Index[20] will help highlight specifically how SIDS are in general disproportionately impacted.

Finally, a broader accounting framework is needed to provide a more comprehensive picture of how marine plastics, together with multiple stressors, affect the national economy. Ocean Accounting[21] seems particularly suited for this. Future national assessments should aim to include this accounting system as part of economic impact estimates and scenario analyses.

### *Remarks*

This study uses survey-based data available on the plastic leakage for Antigua and Barbuda, Grenada, and Saint Lucia (APWC, 2021b, 2021c and 2021d), and is complemented by data on global estimates (Lebreton and Andrady, 2019), which can potentially be less accurate. The more local and national data are available, the stronger the understanding of plastic leakage into the marine environment.

Different models exist on global plastic accumulation (e.g., Lebreton et al., 2012 and Eriksen, 2014) and where these plastics accumulate within the marine environment (e.g., GRID-Arendal, 2018 and Lebreton et al., 2019 as used in this study). More evidence is needed on what types of plastics are accumulating in which location to improve the understanding of the impacts of marine plastics on the economy and the blue natural capital on which it depends.

[20] https://www.undp.org/publications/towards-multidimensional-vulnerability-index.

[21] https://www.oceanaccounts.org/.

Within the limitations of this study, it was not possible to estimate the amount of plastics that enter the Caribbean Sea and accumulate. Instead, only exchanges among countries bordering the Caribbean Sea were considered, while equating inflow with outflow was assumed for the rest. Given that the focus of this study was to estimate the benefits of a national and a regional recycling system, and not a broader Atlantic Ocean wide system, this assumption should not affect these impact estimates. However, it may create an underestimation of the current impact caused by marine plastics. However, the highest plastic accumulations in the Atlantic take place in the North Atlantic gyre, in an area located around the Yucatan Peninsula and North of Cuba, outside of the research area (Eriksen, et al, 2013).

The allocation of plastics among the different countries limiting the Caribbean Sea was done based on the size of the EEZ and coastline. However, for the Lesser Antilles, the complete area of the EEZs was considered, including both areas within the Caribbean Sea, and those in the Atlantic Ocean. This provides these relatively smaller countries, with a comparatively larger share of EEZs and coastline, and thus of plastics allocated to each of them, as compared to countries where only the area within the Caribbean Sea was considered. This was necessary, given the focus on the complete EEZs and coastlines for the PWFI project countries in this study. Although this could cause a potential overestimation of the percentage of plastics allocated to these countries as compared to other countries bordering the Caribbean Sea, for the actual impact estimates, this additional allocation may somewhat offset the no consideration of plastics accumulating from outside the Caribbean Sea in the EEZs and on the coastlines of the countries that are the focus of this study.

The impact of marine plastics on fisheries of Antigua and Barbuda was done transferring the impact estimates of a study conducted elsewhere. The study of Mouat et al. (2010) was also used by others (Arcadis, 2013; UNEP, 2014a). There is a clear need for more field survey data on the impact on fisheries to strengthen an understanding of this issue.

Estimates of the amounts of plastics potentially affecting tourism through beach pollution differed from field data reported in the TIDES database. More data on marine plastic accumulation on beaches and coastal areas will improve the accuracy of the potential impact on tourism.

The potential impact on tourism was illustrated with studies from South Africa and Brazil, not based on empirical evidence on how plastic pollution affects the behaviour of international tourists visiting the Caribbean.

No actual impact on the tourism sector was included in the assessment of the recycling scenarios, only a maximum impact scenario to illustrate the potential risk to the tourism industry if plastics accumulate on beaches. Even a 3% impact (see UNEP 2014a) would have increased the positive impact of recycling as compared to the BaU scenario. However, as this impact estimate could not be accurately transferred to the beach-oriented tourism industry in Antigua and Barbuda, this study only considers impacts that could be explained based on plastic stock estimates.

This study focused on the impact of marine plastics on two sectors of the economy, versus a broader range, which would include the impact on property values, or the impact caused by greenhouse gas emissions from plastic production (see for example UNEP, 2014a and Graham et al., 2022).

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influenced costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example: to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Antigua and Barbuda).

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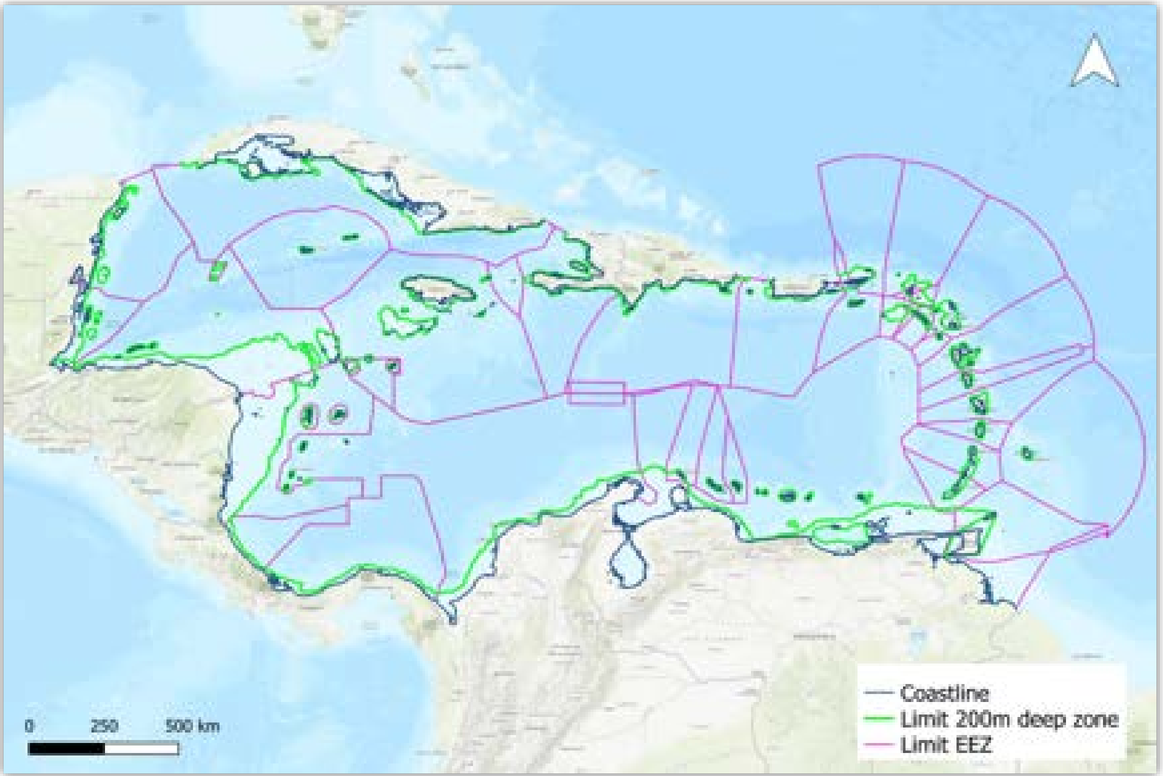
# Annexes

## ANNEX A1. METHODOLOGY USED FOR IMPACT ESTIMATIONS

### Annex A1.1. Plastic stock estimation

As a starting point, a semi-closed marine system is defined to estimate plastic stocks. This definition is used since plastics present in a country's EEZ or shoreline, often does not only come from a country's own terrestrial and marine mismanaged plastic waste but can from other countries as well. In addition, plastics will also flow out, accumulating in one of the oceanic accumulation zones (see for e.g., Lebreton et al., 2012[22], Eriksen et al., 2014[23]). For Antigua and Barbuda, the interactions between countries bordering with the Caribbean Sea (**Map A1**), based on a shared marine area, proximity, currents (Gyory et al., 2008[24]), as well as additional impacts of hurricanes in the region were mainly considered.




***Map A1 – Presentation of the Caribbean Region as used in this study***

[22] Lebreton, L.C.M., Greer, S.D., and Borrero, J.C. (2012). Numerical modelling of floating debris in the world's oceans. Marine Pollution Bulletin, 64 (3), 653-661 https://doi.org/10.1016/j.marpolbul.2011.10.027.
[23] Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J. (2014). Plastic Pollution in the World's Oceans: More than 5 trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLoS ONE 9(12): e111913. doi:10.1371/journal.pone.0111913.
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To estimate the amount of plastics, present in 2019, the following steps were taken, and assumptions made:

- Use of data on MPW floating into the Caribbean Sea for non-PWFI countries provided by Lebreton et al. (2019)[25] and estimates by APWC for PWFI countries.
- Regressive analysis going back to 1950 (**Figure A1**):
  - Consider annual growth rate of plastic production based on data from Geyer et al. (2017) (1950-2015)[26]
  - Average annual growth rate of plastic production from 2015 to 2020 of 4% as predicted by Ryan (2015)[27]

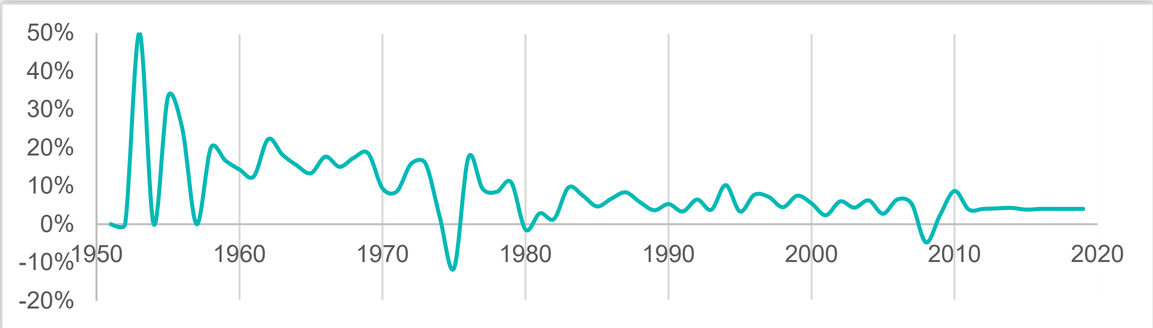



***Figure A1 – Plastic growth used for each year (1950-2019)***

- Two assumptions:
  - After 30 years, plastics either move to accumulation zones or get buried in the seafloor (Eriksen et al. (2014)[28].
  - Macroplastics deteriorate into microplastics at an annual rate of 3% (Lebreton et al. (2019); Lebreton et al. (2018))[29,30].
- Finally, once the total amount of plastics is estimated, it is distributed among countries according to the relative area of their EEZ, area of their coastal waters (i.e., less than 200 metres deep), and length of their coastline compared to the total areas of the region analysed in the report. In the case of Antigua and Barbuda, these values are respectively equal to 3.1%, 1.0%, and 0.3% of the total area/length of the Caribbean region. Each parameter used to distribute plastics is related to one of these figures.

[25] Lebreton, L., Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. *Palgrave Commun* 5, 6 (2019). Available at: https://doi.org/10.1057/s41599-018-0212-7.
[26]Geyer, R., Jambeck, J.R., Law, K.L., (2017). Production, use, and fate of all plastics ever made. *Science Advances* 3, e1700782. Available at: https://doi.org/10.1126/sciadv.1700782.
[27] Ryan, P.G., (2015). *A Brief History of Marine Litter Research*, in: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 1–25. Available at: https://doi.org/10.1007/978-3-319-16510-3_1.
[28] Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., (2014). Plastic Pollution in the World's Oceans: More than 5 trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLOS ONE* 9, e111913. Available at: https://doi.org/10.1371/journal.pone.0111913.
[29] Lebreton, L., Egger, M., Slat, B., (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. *Sci Rep* 9, 12922. Available at: https://doi.org/10.1038/s41598-019-49413-5.
[30] Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., Debeljak, P., Maral, H., Schoeneich-Argent, R., Brambini, R., Reisser, J., (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Sci Rep* 8, 4666. Available at: https://doi.org/10.1038/s41598-018-22939-w.

- For GRID-Arendal (2018)[31]:
  - The amount of plastics on the coastline and seafloor is dependent on the relative length of the coastline (Antigua and Barbuda has 0.3% of the Region's total);
  - The amount of plastics in the coastal ocean waters is dependent on the relative size of the coastal water (Antigua and Barbuda has 1.0% of the Region's total); and
  - The amount of plastics in the open ocean waters and floating on sea surface is dependent on the relative size of the EEZ (Antigua and Barbuda has 3.1% of the Region's total).
- For Lebreton and Andrady (2019):
  - The amount of plastics on the shoreline – dry land depends on the relative length of the coastline (Antigua and Barbuda has 0.3% of the Region's total);
  - The amount of plastics in the coastal – shallow water depends on the relative size of the coastal water (Antigua and Barbuda has 1.0% of the Region's total); and
  - The amount of plastics in the offshore – deeper water depends on the relative size of the EEZ (Antigua and Barbuda has 3.1% of the Region's total).

## Annex A1.2. PLASTIC ACCUMULATION ESTIMATES

**Table A1** displays the amount of plastics that has accumulated in Antigua and Barbuda's jurisdiction until 2019 for both plastic accumulation scenarios.

***Table A1 – Plastic waste accumulated within Antigua and Barbuda's jurisdiction for both plastic accumulation scenarios (2019) (tonnes)***

| Plastic accumulation scenario | MWP scenario | Average | Low | Midpoint | High |
|---|---|---|---|---|---|
| Scenario 1 | Coastline and seafloor | 16,200 | 13,830 | 16,395 | 18,375 |
| | Coastal ocean waters | 19,570 | 16,707 | 19,806 | 22,198 |
| | Open ocean waters | 88,975 | 75,959 | 90,045 | 100,921 |
| | Floating on sea surface | 1,141 | 974 | 1,154 | 1,294 |
| | **Total** | **125,886** | **107,471** | **127,399** | **142,787** |
| Scenario 2 | Offshore – Deeper water | 2,744 | 2,342 | 2,777 | 3,112 |
| | Coastal – Shallow water | 132 | 112 | 133 | 149 |
| | Shoreline – Dry land | 51,485 | 43,954 | 52,104 | 58,397 |
| | **Total** | **54,360** | **46,408** | **55,014** | **61,659** |

## Annex A1.3. FISHERIES IMPACT ESTIMATES, METHODOLOGY

To estimate the impact of marine plastics on fisheries revenue from Antigua and Barbuda, results from Scotland presented by Mouat et al. (2010)[32] were transferred to

[31] GRID-Arendal, (2018). How much plastic is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907. Accessed on 10 June 2021.
[32] Mouat, T., Lopez-Lozano, R. and Bateson, H. (2010). Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).

Antigua and Barbuda. Value (or impact) transfer is done using the 'direct rule of three.' The 'direct rule of three' helps solving the problems based on proportionality. It states:

$$If\ A \equiv B \qquad \&\ X \equiv Y \qquad Then\ X = \frac{A * Y}{B}$$

Where A, B, X and Y are random variables. If the values of A, B and Y are known, one can estimate the value of X. The 'direct rule of three' states that B is related to A in the same proportion as Y is related to X.

This proportional relation is key to understanding why only one plastic accumulation scenario has been used for the fisheries sector instead of the two scenarios used for the coastal clean-ups. Indeed, even though the amount of plastics impacting fisheries under plastic accumulation scenario 1 is more than 39 times greater than the amount under plastic accumulation scenario 2, the difference is reported on B and Y of the above equation. Thus, it cancels itself out, meaning that the impact is the same regardless of the plastic accumulation scenario.

Coming back to the current relation, revenue is the function of price of the fish caught in market and quantity of fish caught.

$$Revenue = Price\ * Quantity\ (or\ volume)$$

As revenue could not be assessed, due to price differences existing between the two countries, this study estimated revenue as being the price per volume multiplied by the volume (quantity in tonnes), using fisheries' volume as a proxy. Hence, the value or impact transfer is based on a four percent impact on fisheries volume in Scotland, and then the volume is translated to fisheries' revenue.

The aim is to translate the impact estimates obtained by Mouat et al. (2010), to the data of fisheries of Antigua and Barbuda, which is achieved by applying data derived from Scottish fisheries.

The relation is expressed as follows:

- Impact% on fisheries ⇐ Amount of plastics present in the sea (in tonnes)
- Impact% on fisheries ⇐ Quantity of fish catch (in tonnes)

The relation between amount of plastics and amount of fish catch, where both have an influence on the estimated impact, can also be written as:

$$Impact_1 = PL_x * FC_x$$

*Where"* $Impact_1$ *is the impact % of marine plastics on fisheries;*

$PL_x$ *is the amount of plastics present in the fishing zone in tonnes; and*

$FC_x$ *is the amount of fish caught in tonnes.*

Plastics' impact is not only related to the amount of catch, but also related to a number of other factors such as net size, existing fish stocks, time spent on sea by each vessel, etc. As a proxy for this range of factors, the number of vessels and the total size of the fishing area are used. Thus, the impact relation can be represented by the equation below:

$$Impact_1 = \frac{Pl_x}{V_x * EEZ_x} * \frac{FC_x}{V_x * EEZ_x}$$

Where, $V_x$ is the number of vessels in Antigua and Barbuda's fishing zone, and $EEZ_x$ is the size of the fishing zone in km².

Given that both countries have a different amount of plastics present in their fishing zones, and each country catches different amounts of fish, the relation of two countries can be stated as follows:

$$Impact_1 = \frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}$$

$$Impact_2 = \frac{PL_{Antigua\ and\ Barbuda}}{V_{Antigua\ and\ Barbuda} * EEZ_{Antigua\ and\ Barbuda}} * \frac{FC_{Antigua\ and\ Barbuda}}{V_{Antigua\ and\ Barbuda} * EEZ_{Antigua\ and\ Barbuda}}$$

Applying the 'direct rule of three,' and solving for 'PI impact 2' (i.e., impact on fisheries' volume in Antigua and Barbuda in percentage), it can be represented as follows:

$$\%Impact_2 = \%Impact_1 * \frac{\frac{PL_{Antigua\ and\ Barbuda}}{V_{Antigua\ and\ Barbuda} * EEZ_{Antigua\ and\ Barbuda}} * \frac{FC_{Antigua\ and\ Barbuda}}{V_{Antigua\ and\ Barbuda} * EEZ_{Antigua\ and\ Barbuda}}}{\frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}}$$

### *Input data from Scotland: Scotland fisheries overview*

Mouat et al., 2010[33] conducted a study through a survey on the Scottish fisheries that use net gears, to understand the extent by which this sector is impacted by marine litter. The study estimated that the impact on fisheries' revenue losses from marine litter was 5% in 2008, or 4% of the revenue if only considering marine plastics (Dunlop et al., 2020)[34].

**Table A2** provides the information that is needed to perform the impact transfer.

***Table A2 – Overview of data from Scottish net fisheries (2008)***[35]

| Vessels | Annual catch (tonnes) | Fishing area (km²) |
|---|---|---|
| 653 | 331,440 | 462,263 |

[33] Mouat, T., Lopez-Lozano, R. and Bateson, H. 2010. Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).
[34] Dunlop, B.J. Dunlop, M. Brown, (2020) plastics pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles, Marine Pollution Bulletin, Volume 151, 110803, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2019.110803.
[35] Scottish Government statistics, 2008. A National Statistics Publication for Scotland: Scottish Sea Fisheries Statistics 2008.

### *Input data from Scotland: amount of plastics present in Scottish fishing area*

Every year, a certain amount of plastics are leaked into the oceans due to factors such as inadequate waste management system, illegal waste disposal, littering, urbanisation, etc. These leaked plastics impact many economic activities, including fisheries (Boucher et al., 2019[36]). The estimated amount of plastics present in Scotland's fishing zone was 24,161 tonnes in 2008, based on the estimates from Lebreton and Andrady (2019)[37], and the plastic allocation from GRID-Arendal (2018)[38]. Thus, the assumption is that in 2008 the impact on Scottish fisheries of a 4% decrease in revenue was due to the presence of an estimated 24,161 tonnes of plastics in their fishing area.

### *Input data for refined analysis on fishing gear and types of boat*

**Table A3** shows the details used to refine the data for the fisheries based on the context of Antigua and Barbuda. As a reminder, the direct application of the rule of three in this study implies that fisherfolks are only using net gear. The following correction allows a better restitution of the context of Antigua and Barbuda.

*Table A3 – Detailed data on the use of fish nets for refined impact on fisheries (2019)[39]*

| Fishing gear | Amount | Dumped catch | Net repairs | Fouling incidents | Time lost |
|---|---|---|---|---|---|
| Beach seine | 1 | X | X | No data was available on the types of boats. Therefore, 100% of the boats were assumed to be able to suffer fouling incidents | X |
| Traps | 84 | X | | | X |
| Gill nets | 14 | X | X | | X |
| Lines | 141 | X | | | |
| Dive | 23 | X | | | |
| | 263 | 100% | 6% | 100% | 38% |

## Annex A1.4. Tourism impact estimates, methodology

The studies from Ballance et al. (2000)[40] and Krelling et al. (2017)[41] are used for Antigua and Barbuda. Balance et al. (2000) studied the impact of marine plastics on tourism in Cape Town, South Africa. Krelling et al. (2017) studied the impact in Brazil.

[36] Boucher J. and Billard G., (2019). « The challenges of measuring plastic pollution », Field Actions. Science Reports Special Issue 19 October 2019. URL: http://journals.openedition.org/factsreports/53.
[37] Lebreton, L., Andrady, A., (2019). Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.
[38] GRID-Arendal (2018) How much plastics is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907. Accessed on 10 June 2021.
[39] APWC. 2021. Plastic Waste-Free Islands Project: Plastic Waste National Level Quantification and Sectorial Material Flow Analysis in Antigua and Barbuda.
[40] Ballance, A., Ryan, P., Turpie, J. 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science 96, 210–213.
[41] Krelling, A.P., Williams, A.T., Turra, A. 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Marine Policy 85, 87–99. https://doi.org/10.1016/j.marpol.2017.08.021.

Cape Town is one of the most visited cities in South Africa. Out of all the tourists visiting the country, 49% are international tourists (City of Cape Town report, 2019).[42] A study conducted on Cape Town's beaches by Ballance et al., 2000 found that a number of tourists were not willing to come to beaches if they were littered (**Table A4**).

***Table A4 – Willingness to visit (WTV) a beach under different littering scenarios in Cape Town***

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.8 items | No change |
| 1.8-8 items | 85% |
| 8 items and more | 97% |

*Source: Ballance et al. 2000.*

The different littering scenarios have been adjusted to reflect the fact that plastic items make up 80% of the litter found on the beach. Therefore, eight plastic items found per linear metre of beach shoreline imply that there are two non-plastic items along with them. This increased amount of marine litter on a given beach would make that beach fall under the last situation of Ballance et al. (2000) A 97% drop of WTV.

Krelling et al. (2017), used a contingent valuation to assess the WTV on two beaches of Brazil under different littering scenarios, as represented in **Table A5**. The same adjustment regarding the composition of littering on beaches has been made, e.g., 24 plastic items imply 30 items overall.

***Table A5 – Willingness to visit (WTV) a beach under different littering scenarios in Brazil***

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.2 items | No change |
| 1.2-9.6 items | 19.9% |
| 9.6-24 items | 42.7% |
| More than 24 items | 82.4% |

*Source: Krelling et al., 2017.*

The goal is to estimate the WTV of international tourists due to plastic beach pollution in Antigua and Barbuda. For this study, it is assumed that the behaviour of international tourists in Antigua and Barbuda will be similar to tourists in Cape Town and Brazil.

**Table A6** shows an overview of the number of items per metre in the Lesser Antilles according to the TIDES database.[43] **Table A7** shows the result of the beach clean-ups by giving details for the location of where the items were retrieved from.

[42] City of Cape Town report. 2019. Annual report. Available at 2019_20_Integrated_Annual_Report.pdf (capetown.gov.za).
[43] https://www.coastalcleanupdata.org/reports. Accessed on 15 October 2021.

*Table A6 – Marine litter collected in Lesser Antilles (2019)*[44]

| Country | Kilometres | Items | Items per metre |
|---|---|---|---|
| Antigua and Barbuda | 13.47 | 8,712 | 0.65 |
| Barbados | 12.87 | 47,355 | 3.68 |
| British Virgin Islands | 0.48 | 1,794 | 3.72 |
| Caribbean Netherlands | 15.92 | 8,050 | 0.51 |
| Cayman Islands | 0.40 | 900 | 2.24 |
| Dominica | 28.61 | 17,822 | 0.62 |
| Grenada | 1.85 | 2,753 | 1.49 |
| Guadeloupe | 1.21 | 338 | 0.28 |
| Sint Maarten | 3.40 | 1,869 | 0.55 |
| St Kitts & Nevis | 33.10 | 24,478 | 0.74 |
| Saint Lucia | 8.05 | 7,853 | 0.98 |
| St Vincent and the Grenadines | 12.47 | 5,515 | 0.44 |
| Trinidad and Tobago | 63.94 | 206,845 | 3.24 |
| US Virgin Islands | 65.45 | 46,964 | 0.72 |
| **Total** | **261.23** | **381,248.00** | **1.46** |

*Table A7 – Marine litter collected per location for Antigua and Barbuda*

| Year | Location | Plastics collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|---|
| 2020 | Land (beach, shoreline and inland) | 1.91 | 6,276 | 3,280 |
| | Underwater | - | - | - |
| 2019 | Land (beach, shoreline and inland) | 1.91 | 6,276 | 3,280 |
| | Underwater | 1.91 | 6,276 | 3,280 |

# ANNEX A2. FUTURE SCENARIOS

## Annex A2.1. DISCOUNT RATE FOR NET PRESENT VALUE

To obtain a discount rate for this study, an average of different discount rates is used. **Table A8** presents the discount rates used.

[44] Reports (coastalcleanupdata.org). Accessed on 15 October 2021.

*Table A8 – Series of discount rates used to estimate Antigua and Barbuda's discount rate*

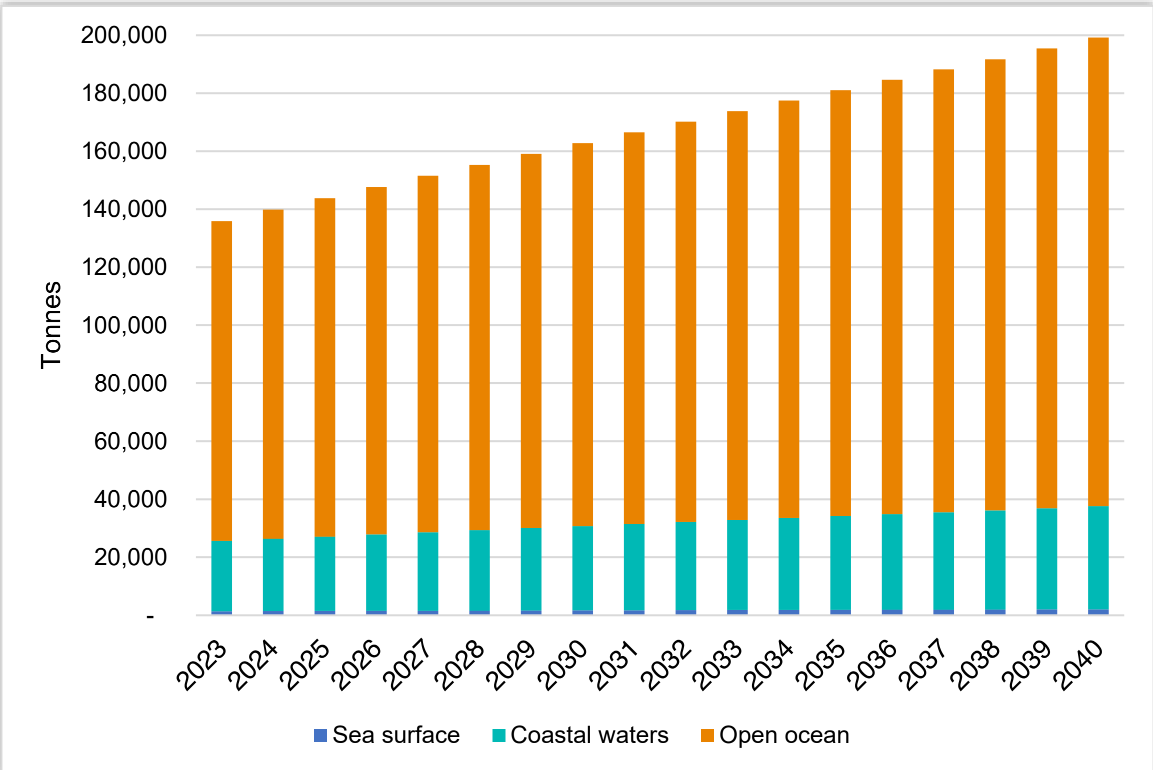
| Country | Discount Rate |
|---|---|
| European Union | 4 |
| Norway | 4 |
| UK | 3.5 |
| France | 4.5 |
| USA (CBO) | 2 |
| USA (OMB) | 5 |
| USA (EPA) | 5 |
| USA (GAO) | 0.1 |
| IDB | 12 |
| World Bank | 11 |
| Colombia | 12 |
| Costa Rica | 12 |
| Mexico | 10 |
| Calculated LA | 3.77 |

*Source: Moore et al. (2020)*[45].

## Annex A2.2. Business-as-Usual (BaU) scenarios (2023-2040)

### Annex A2.2.1. Plastics impacting fisheries (2023-2040)

**Figure A2** displays the amount of plastics impacting fisheries for each year.




[45] Moore MA, Boardman AE, Vining AR. Social Discount Rates for Seventeen Latin American Countries: Theory and Parameter Estimation. Public Finance Review. 2020;48(1):43-71. doi:10.1177/1091142119890369.

*Figure A2 – Plastics impacting fisheries under BaU scenarios for each year*

### Annex A2.2.2. Fisheries sector (2023-2040)

To predict the impact on fisheries in Antigua and Barbuda in the period 2020-2040, two different potential scenarios of how the fisheries sector will evolve are considered. **Fish scenario 1** corresponds to a BaU case where the **fish catch is stable** for the whole period considered. **Fish scenario 2** reflects a reduction in the fish catch due to climate change impacts by 2040. Therefore, **an annual decrease of 0.25% of fish catch potential** for Antigua and Barbuda's fisheries has been considered until 2040 (FAO, 2018[46]). Prices are considered constant. Both results are displayed in **Figure A3**.

**Figure A3** shows the estimated fish catch under the different "fish scenarios".

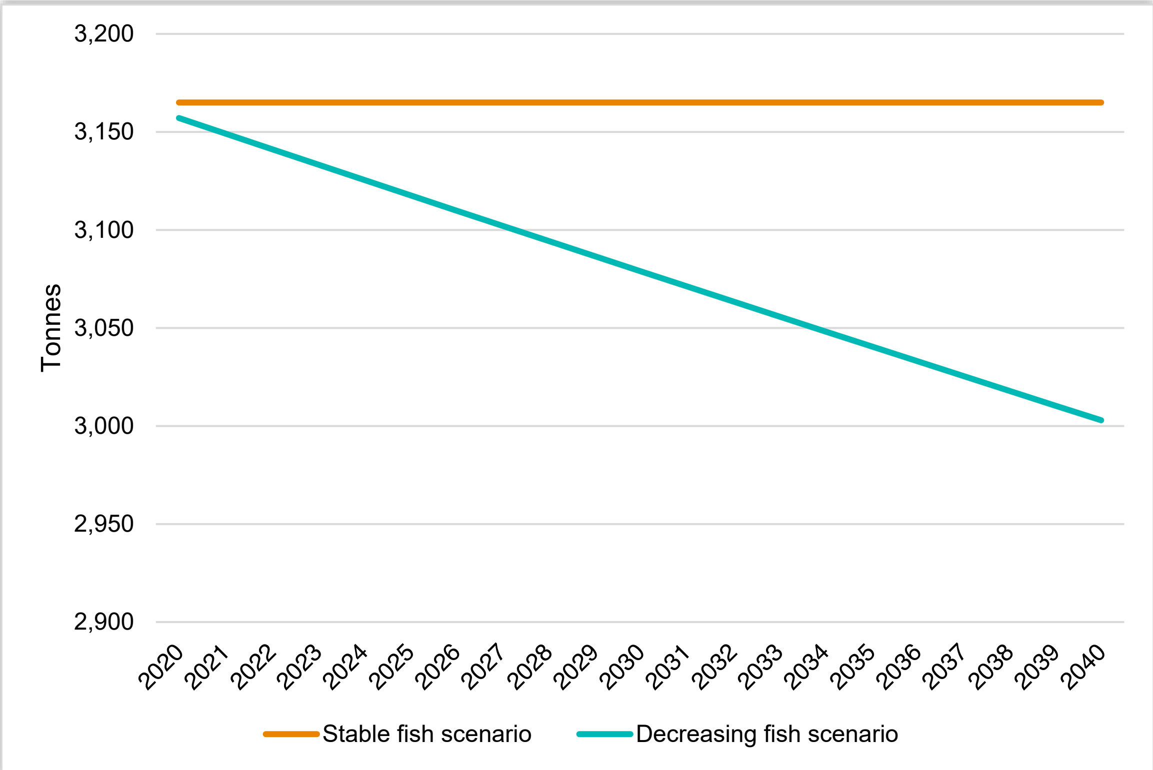



*Figure A3 – Evolution of fish catch for different fish scenarios (tonnes/year)*

### Annex A2.2.3. Impact on fisheries under BaU scenario (2023-2030)

The combination of the different plastic accumulation scenarios and fish scenarios allows for the generation of two impact scenarios (Presented in **Figure A4**):

- Fish scenario 1: Stable fish catch, no change over the period
- Fish scenario 2: Decrease in fish catch due to climate change

[46] https://www.fao.org/3/i9705en/i9705en.pdf.

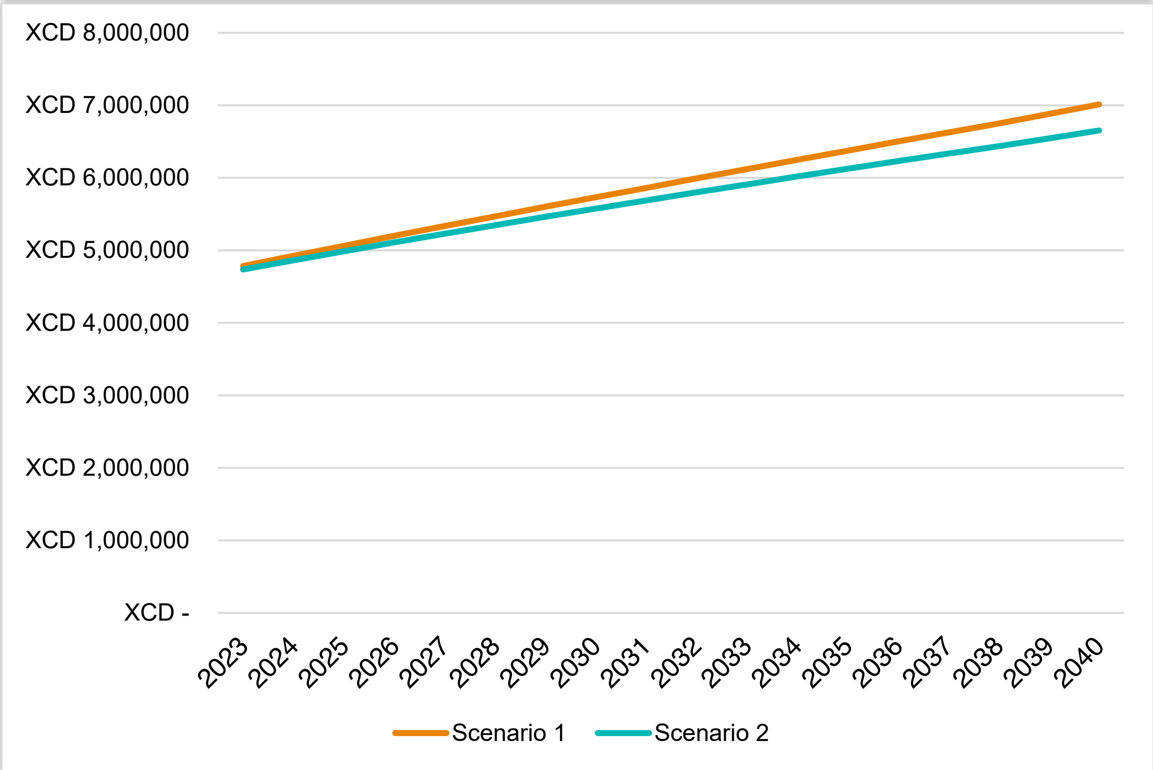



*Figure A4 – The estimated losses to the fisheries sector according to both fish scenarios (non-discounted values)*

### Annex A2.2.4. Tourism sector (2023-2040)

**Table A9** and **Figure A5** present the data used to estimate the future growth rate of the tourism sector in Antigua and Barbuda.[47]

*Table A9 – Data used for the forecast of the growth rate of tourism sector*

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 1980 | 5.0% | | | |
| 1981 | 5.0% | | | |
| 1982 | 5.0% | | | |
| 1983 | 5.0% | | | |
| 1984 | 5.0% | | | |
| 1985 | 5.0% | | | |
| 1986 | 5.0% | | | |
| 1987 | 5.0% | | | |
| 1988 | 5.0% | | | |
| 1989 | 5.0% | | | |
| 1990 | 5.0% | | | |
| 1991 | 5.0% | | | |
| 1992 | 5.0% | | | |
| 1993 | 5.0% | | | |
| 1994 | 5.0% | | | |
| 1995 | 5.0% | | | |
| 1996 | 2.4% | | | |
| 1997 | 2.4% | | | |
| 1998 | 2.4% | | | |

[47] UNWTO 2011, Tourism Towards 2030 Global Overview.

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 1999 | 2.4% | | | |
| 2000 | 2.4% | | | |
| 2001 | 2.4% | | | |
| 2002 | 2.4% | | | |
| 2003 | 2.4% | | | |
| 2004 | 2.4% | | | |
| 2005 | 2.4% | | | |
| 2006 | 2.4% | | | |
| 2007 | 2.4% | | | |
| 2008 | 2.4% | | | |
| 2009 | 2.4% | | | |
| 2010 | 2.4% | | | |
| 2011 | 2.4% | | | |
| 2012 | 2.4% | | | |
| 2013 | 2.4% | | | |
| 2014 | 2.4% | | | |
| 2015 | 2.4% | | | |
| 2016 | 2.4% | | | |
| 2017 | 2.4% | | | |
| 2018 | 2.4% | | | |
| 2019 | 2.4% | | | |
| 2020 | 2.4% | | | |
| 2021 | 1.7% | | | |
| 2022 | 1.7% | | | |
| 2023 | 1.7% | | | |
| 2024 | 1.7% | | | |
| 2025 | 1.7% | | | |
| 2026 | 1.7% | | | |
| 2027 | 1.7% | | | |
| 2028 | 1.7% | | | |
| 2029 | 1.7% | | | |
| 2030 | 1.7% | 1.7% | 1.7% | 1.7% |
| 2031 | | 1.6% | 0.9% | 2.3% |
| 2032 | | 1.5% | 0.6% | 2.5% |
| 2033 | | 1.5% | 0.3% | 2.6% |
| 2034 | | 1.4% | 0.0% | 2.7% |
| 2035 | | 1.3% | -0.2% | 2.8% |
| 2036 | | 1.2% | -0.4% | 2.9% |
| 2037 | | 1.1% | -0.6% | 2.9% |
| 2038 | | 1.1% | -0.8% | 3.0% |
| 2039 | | 1.0% | -1.0% | 3.0% |
| 2040 | | 0.9% | -1.2% | 3.0% |

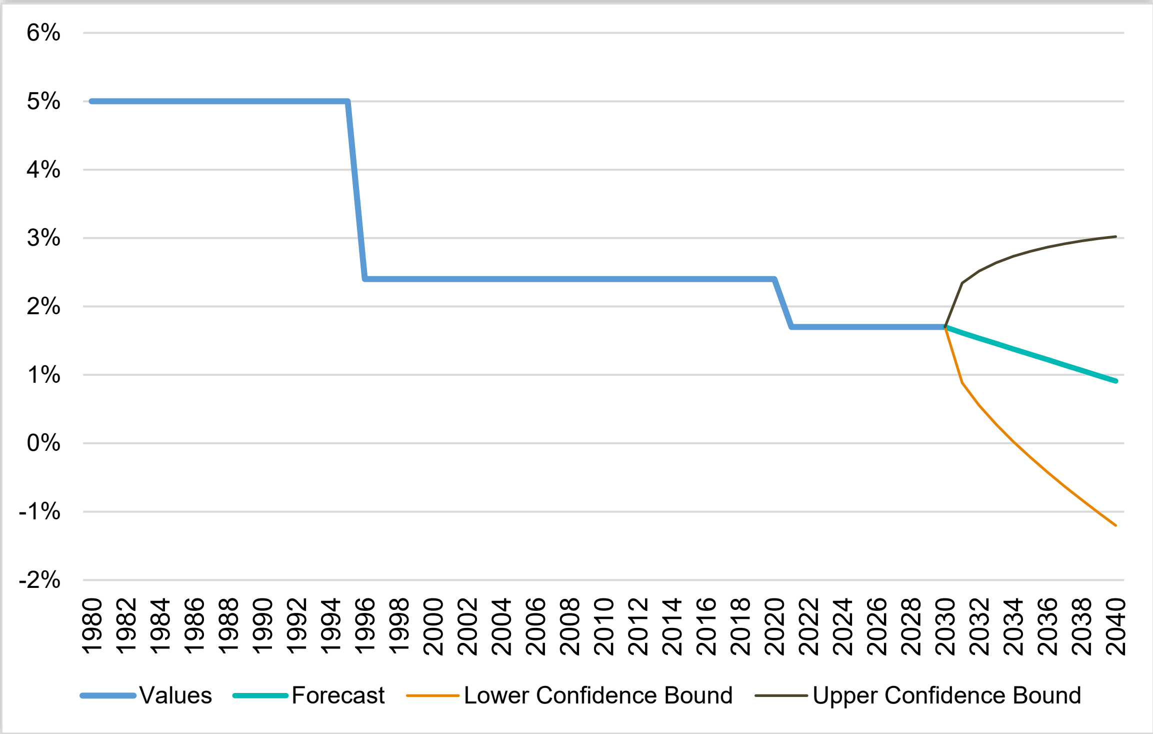



***Figure A5 – Estimated annual growth rate of the tourism sector and forecast for the years 2031 to 2040, 95% CI***

### Annex A2.2.5. Plastics impacting tourism (2023-2030)

To estimate the future impact of mismanaged plastics on tourism, only the impact on coastal clean-ups is considered. It is presented in **Figure A6**.

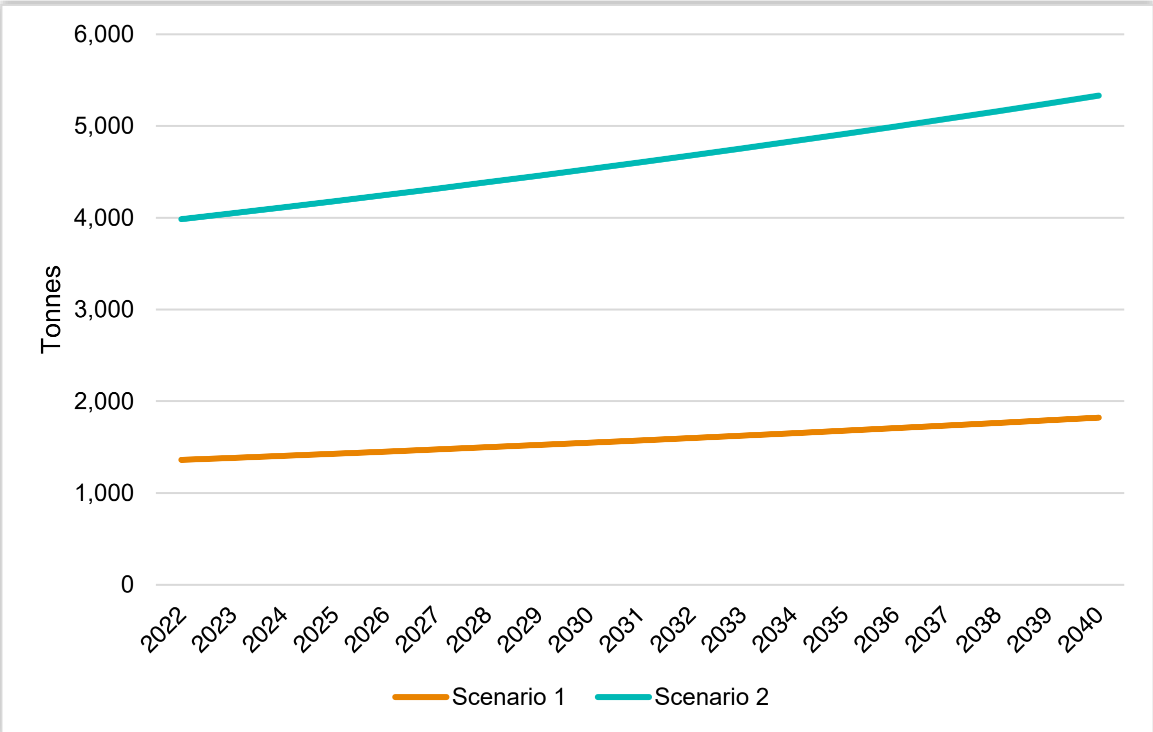



***Figure A6 – Estimated amount of plastics ending up on Antigua and Barbuda's coastline under BaU scenario (tonnes/year)***

Based on these estimates, the total amount of plastic items per metre can be calculated to obtain the coastal clean-up costs to avoid any impact on the tourism sector and is presented in **Table A10**.

***Table A10 – Estimated amount of plastics ending up on Antigua and Barbuda's coastline under BaU scenario under both plastic accumulation scenarios (items/metre)***

| Year | Items per metre according to | |
|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2020 | 40 | 118 |
| 2021 | 41 | 120 |
| 2022 | 42 | 122 |
| 2023 | 42 | 124 |
| 2024 | 43 | 126 |
| 2025 | 44 | 128 |
| 2026 | 45 | 130 |
| 2027 | 45 | 132 |
| 2028 | 46 | 135 |
| 2029 | 47 | 137 |
| 2030 | 47 | 139 |
| 2031 | 48 | 141 |
| 2032 | 49 | 144 |
| 2033 | 50 | 146 |
| 2034 | 51 | 148 |
| 2035 | 52 | 151 |
| 2036 | 52 | 153 |
| 2037 | 53 | 156 |
| 2038 | 54 | 158 |
| 2039 | 55 | 161 |
| 2040 | 56 | 164 |

### Annex A2.2.6. Impact on tourism and coastal clean-up costs under BaU scenario (2023-2030)

To maximise the probability that the predicted growth in tourism holds, coastal clean-ups will be necessary to avoid costs as presented earlier in this study. The same methodology as used for the 2019 impact is applied here for the different plastic accumulation scenarios. **Tables A11** and **A12** present how an increase in plastic flow throughout the years will change the cost of coastal clean-ups, avoiding costs in the form of loss of tourism revenue. It is presented as the non-discounted value.

*Table A11 – Coastal clean-up costs for plastic accumulation scenario 1 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 13,748,414 | 2032 | 15,890,422 |
| 2024 | 13,970,026 | 2033 | 16,150,133 |
| 2025 | 14,195,553 | 2034 | 16,414,501 |
| 2026 | 14,425,070 | 2035 | 16,683,617 |
| 2027 | 14,658,655 | 2036 | 16,957,576 |
| 2028 | 14,896,387 | 2037 | 17,236,473 |
| 2029 | 15,138,346 | 2038 | 17,520,405 |
| 2030 | 15,384,616 | 2039 | 17,809,472 |
| 2031 | 15,635,279 | 2040 | 18,103,776 |

*Table A12 – Coastal clean-up costs for plastic accumulation scenario 2 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 40,233,491 | 2032 | 46,501,882 |
| 2024 | 40,882,017 | 2033 | 47,261,902 |
| 2025 | 41,542,000 | 2034 | 48,035,550 |
| 2026 | 42,213,661 | 2035 | 48,823,096 |
| 2027 | 42,897,227 | 2036 | 49,624,812 |
| 2028 | 43,592,928 | 2037 | 50,440,977 |
| 2029 | 44,301,000 | 2038 | 51,271,878 |
| 2030 | 45,021,685 | 2039 | 52,117,807 |
| 2031 | 45,755,229 | 2040 | 52,979,061 |

## ANNEX A3. RECYCLING SCENARIOS

1. National recycling scenario: Only Antigua and Barbuda will implement in-country strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC.
2. Regional recycling scenario: This scenario is based on Lebreton and Andrady (2019)[48] and implies that **all countries** in the region will cooperate and start to better manage their MPW when their GDP per capita increases.

**Table A13** provides the linear growth rate used for the projections.

[48] Lebreton, L., Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.

*Table A13 – Annual growth rate used to estimate future MPW (2020-2040)*

| Country | Data in Lebreton and Andrady (2019) | Linear growth (2020-2040) |
|---|---|---|
| Anguilla | No data* | -4.8% |
| Antigua and Barbuda** | Yes | -8.3% |
| Aruba | No data* | -4.8% |
| Barbados | Yes | -5.1% |
| Belize | Yes | 0.7% |
| British Virgin Islands | No data* | -4.8% |
| Caribbean Netherlands (Bonaire, etc.) | No data* | -4.8% |
| Cayman Islands | No data* | -4.8% |
| Colombia | Yes | -4.5% |
| Costa Rica | Yes | -9.1% |
| Cuba | No data* | -4.8% |
| Curacao | No data* | -4.8% |
| Dominica | Yes | -5.3% |
| Dominican Republic | Yes | -13.5% |
| Grenada** | Yes | -13.7% |
| Guadeloupe | No data* | -4.8% |
| Guatemala | Yes | 0.5% |
| Haiti | Yes | 1.2% |
| Honduras | Yes | 0.9% |
| Jamaica | Yes | -1.5% |
| Martinique | No data* | -9.2% |
| Mexico/Yucatan (Nota 3) | Yes | 1.7% |
| Montserrat | No data* | -4.8% |
| Nicaragua | Yes | 0.4% |
| Panama | Yes | -9.3% |
| Puerto Rico | Yes | 1.0% |
| Saint Vincent | Yes | -5.1% |
| Saint Barthelemy | No data* | -4.8% |
| Saint Kitts and Nevis | Yes | -4.6% |
| Saint Lucia** | Yes | -10.7% |
| Saint Martin | No data* | -4.8% |
| Sint Maarten | No data* | -4.8% |
| Trinidad and Tobago | Yes | -16.6% |
| Venezuela | Yes | -1.0% |
| Virgin Island of the US | No data* | -4.8% |

**When no data is available, the growth rate is assumed to be equal to the average of the region.*
*** For PWFI countries, APWC (2021)[49] data have been used (Antigua and Barbuda – 58% of plastics might be recycled each year, Grenada – 74%, and Saint Lucia – 46%). Lebreton and Andrady (2019) data for these three countries have only been used to estimate the region average.*

[49] APWC. 2021. Plastic Waste-Free Islands Project – Plastic Waste National Level Quantification and Sectorial Material Flow Analysis in Antigua and Barbuda.

## Annex A3.1. Impact on fisheries by plastics, national recycling scenario

**Figure A7** presents the comparison for the fisheries between the BaU scenario and the national recycling scenario.

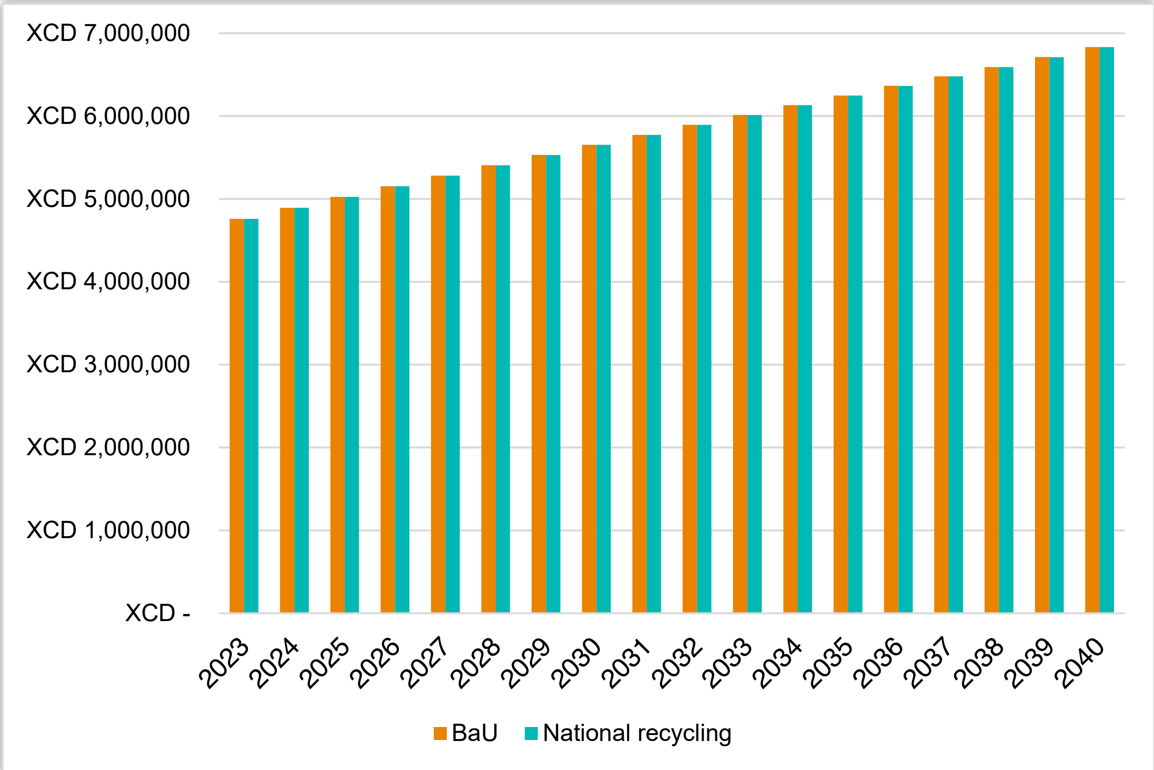



*Figure A7 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and national recycling scenarios*

## Annex A3.2. Impact on tourism (coastal clean-up costs), national recycling

**Table A14** presents the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), considering the national recycling scenario.

*Table A14 – Annual plastic flow and items per metre (2023-2040) under national recycling scenario*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,384 | 4,049 | 42 | 124 |
| 2024 | 1,406 | 4,114 | 43 | 126 |
| 2025 | 1,428 | 4,180 | 44 | 128 |
| 2026 | 1,452 | 4,248 | 45 | 130 |
| 2027 | 1,475 | 4,317 | 45 | 132 |
| 2028 | 1,499 | 4,387 | 46 | 135 |
| 2029 | 1,523 | 4,458 | 47 | 137 |
| 2030 | 1,548 | 4,530 | 47 | 139 |
| 2031 | 1,573 | 4,604 | 48 | 141 |
| 2032 | 1,599 | 4,679 | 49 | 144 |
| 2033 | 1,625 | 4,756 | 50 | 146 |
| 2034 | 1,652 | 4,834 | 51 | 148 |
| 2035 | 1,679 | 4,913 | 52 | 151 |
| 2036 | 1,706 | 4,994 | 52 | 153 |
| 2037 | 1,734 | 5,076 | 53 | 156 |
| 2038 | 1,763 | 5,159 | 54 | 158 |
| 2039 | 1,792 | 5,244 | 55 | 161 |
| 2040 | 1,822 | 5,331 | 56 | 164 |

**Table A15** presents the coastal clean-up cost estimates for the national recycling scenarios.

*Table A15 – Impact on beach cleaning cost, national recycling scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 13,747,878 | 40,231,921 | 536 | 1,570 |
| 2024 | 13,969,115 | 40,879,351 | 911 | 2,666 |
| 2025 | 14,194,256 | 41,538,205 | 1,297 | 3,795 |
| 2026 | 14,423,376 | 42,208,705 | 1,694 | 4,956 |
| 2027 | 14,656,948 | 42,892,231 | 1,707 | 4,995 |
| 2028 | 14,894,666 | 43,587,892 | 1,721 | 5,036 |
| 2029 | 15,136,611 | 44,295,923 | 1,735 | 5,077 |
| 2030 | 15,382,866 | 45,016,566 | 1,749 | 5,119 |
| 2031 | 15,633,515 | 45,750,066 | 1,764 | 5,162 |
| 2032 | 15,888,643 | 46,496,675 | 1,779 | 5,207 |
| 2033 | 16,148,338 | 47,256,650 | 1,795 | 5,252 |
| 2034 | 16,412,690 | 48,030,252 | 1,810 | 5,298 |
| 2035 | 16,681,791 | 48,817,750 | 1,827 | 5,346 |
| 2036 | 16,955,733 | 49,619,418 | 1,843 | 5,394 |
| 2037 | 17,234,613 | 50,435,534 | 1,860 | 5,443 |
| 2038 | 17,518,527 | 51,266,384 | 1,877 | 5,494 |
| 2039 | 17,807,577 | 52,112,261 | 1,895 | 5,546 |
| 2040 | 18,101,862 | 52,973,462 | 1,913 | 5,599 |

## Annex A3.3. IMPACT ON FISHERIES BY PLASTICS, NATIONAL RECYCLING

**Figure A8** presents the comparison for the fisheries between the BaU scenario and the regional cooperation scenario.

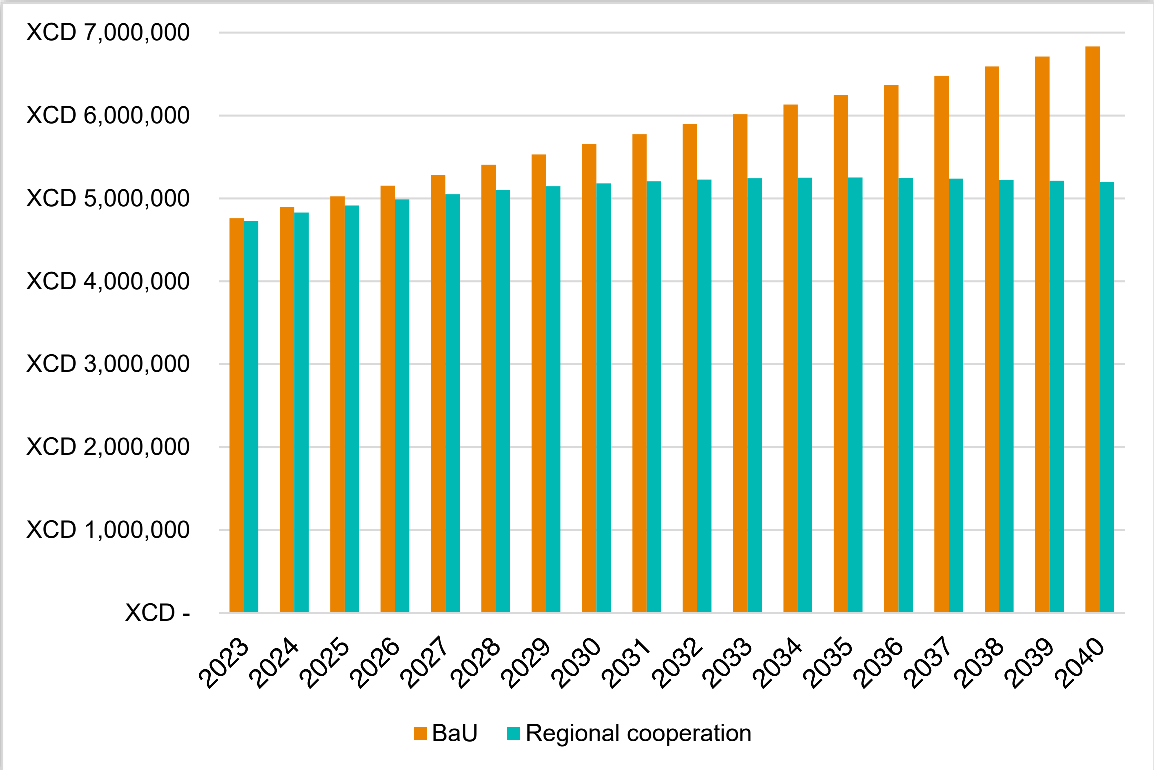



***Figure A8 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and regional cooperation scenarios***

### Annex A3.4. IMPACT ON TOURISM (COASTAL CLEAN-UP COSTS), REGIONAL COOPERATION SCENARIO

**Table A16** shows the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), under the regional cooperation scenario.

*Table A16 – Annual plastic flow and items per metre (2023-2040) under regional cooperation scenarios*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,287 | 3,767 | 39 | 116 |
| 2024 | 1,252 | 3,663 | 38 | 112 |
| 2025 | 1,220 | 3,571 | 37 | 110 |
| 2026 | 1,193 | 3,490 | 37 | 107 |
| 2027 | 1,168 | 3,419 | 36 | 105 |
| 2028 | 1,147 | 3,356 | 35 | 103 |
| 2029 | 1,128 | 3,301 | 35 | 101 |
| 2030 | 1,111 | 3,252 | 34 | 100 |
| 2031 | 1,096 | 3,208 | 34 | 98 |
| 2032 | 1,083 | 3,169 | 33 | 97 |
| 2033 | 1,071 | 3,134 | 33 | 96 |
| 2034 | 1,060 | 3,103 | 33 | 95 |
| 2035 | 1,051 | 3,075 | 32 | 94 |
| 2036 | 1,042 | 3,050 | 32 | 94 |
| 2037 | 1,035 | 3,028 | 32 | 93 |
| 2038 | 1,028 | 3,008 | 32 | 92 |
| 2039 | 1,022 | 2,990 | 31 | 92 |
| 2040 | 1,016 | 2,974 | 31 | 91 |

**Table A17** presents the coastal clean-up cost estimates, under the regional cooperation scenario (plastic accumulation scenarios 1 and 2).

*Table A17 – Impact on beach cleaning cost, regional cooperation scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 12,792,063 | 37,434,815 | 956,351 | 2,798,675 |
| 2024 | 12,437,541 | 36,397,339 | 1,532,485 | 4,484,678 |
| 2025 | 12,125,888 | 35,485,313 | 2,069,665 | 6,056,687 |
| 2026 | 11,851,322 | 34,681,822 | 2,573,747 | 7,531,839 |
| 2027 | 11,609,481 | 33,974,096 | 3,049,174 | 8,923,131 |
| 2028 | 11,396,726 | 33,351,487 | 3,499,661 | 10,241,441 |
| 2029 | 11,208,298 | 32,800,068 | 3,930,049 | 11,500,932 |
| 2030 | 11,041,086 | 32,310,738 | 4,343,530 | 12,710,947 |
| 2031 | 10,892,422 | 31,875,688 | 4,742,857 | 13,879,541 |
| 2032 | 10,760,014 | 31,488,208 | 5,130,408 | 15,013,674 |
| 2033 | 10,641,891 | 31,142,531 | 5,508,242 | 16,119,371 |
| 2034 | 10,536,356 | 30,833,694 | 5,878,144 | 17,201,857 |
| 2035 | 10,441,950 | 30,557,420 | 6,241,668 | 18,265,675 |
| 2036 | 10,357,410 | 30,310,023 | 6,600,166 | 19,314,788 |
| 2037 | 10,281,650 | 30,088,319 | 6,954,823 | 20,352,659 |
| 2038 | 10,213,729 | 29,889,554 | 7,306,675 | 21,382,324 |
| 2039 | 10,152,834 | 29,711,349 | 7,656,638 | 22,406,458 |
| 2040 | 10,098,258 | 29,551,639 | 8,005,517 | 23,427,422 |

### Annex A3.5. Cost of implementing the national recycling scheme

Satney M. (2022) (PWFI consultant and based in St. Lucia)[50] provided data on tonnes of waste collected and its attached cost. The annual average amount of waste collected between 2018 and 2021 amounts to 131,944 tonnes for an average annual cost of XCD 14,560,000. This leads to an average cost of XCD 110.3 per tonne. **Table A18** shows the base data needed to estimate the cost of the recycling of plastics.

*Table A18 – Additional data needed to perform the cost analysis (2019)*

| | |
|---|---|
| Maximum recyclable amount | 58.03% |
| Plastic waste (tonnes in 2019) | 3,254 |
| Growth rate from 2020-2040 | 1.45% |
| Discount rate | 6.35% |
| Hourly wage used (minimum wage times two) | XCD 16.4 |
| Waste management budget | XCD 14,560,000 |

[50] Satney, M., 2022. Personal communication – Data on shipping cost.

### *Collecting cost*

Given the cost/number of hours needed to collect 80 tonnes of plastics by Searious Business (2021), the following are the estimated costs corresponding to 1888.4 tonnes of plastics (**Tables A19, A20,** and **A21**).

*Table A19 – Labour costs for 1888.4 tonnes of plastics (2019)*

| Activity | Hours per week | Cost per week |
|---|---|---|
| Managing collection points and drop off sites | 472 | XCD 7,742.64 |
| Administration | 132 | XCD 2,167.94 |

*Table A20 – Investment costs for 1888.4 tonnes of plastics (2019)*

| Items | Cost | |
|---|---|---|
| Truck (3-4 ton) | XCD 25,000 | USD 9,253 |
| Sorting container | XCD 150 | USD 56 |

*Table A21 – Fixed costs for 1888.4 tonnes of plastics (2019)*

| Fixed cost | Cost per month | |
|---|---|---|
| Rent | XCD 500 | USD 185 |
| Water | XCD 200 | USD 74 |
| Electricity | XCD 300 | USD 111 |
| Car Insurance/Maintenance | XCD 100 | USD 37 |
| Gas | XCD 150 | USD 56 |

### *Cost of sorting*

Based on data by PEW (2020)[51] and presented in **Table A22**.

*Table A22 – Estimated cost of sorting, based on PEW (2020)*

| Selected Countries and Economies | Year | GDP (PPP[52] USD) | Operating expenditure per tonne (USD) | Capital expenditure per tonne (USD) | Total (USD) |
|---|---|---|---|---|---|
| Average High income | 2020 | 50,887.4[53] | 156 | 52 | 208 |
| Antigua and Barbuda | 2020 | 18,241.9[54] | 56 | 19 | 75 |

### *Cost of shipping (to Miami)*

The cost of a 40-foot container to Miami is XCD 5,000 (data provided by Satney M., 2022). This type of container has a capacity of 67m$^3$. Based on data provided by APWC (2021b) (see **Table A23**). The average density of plastic waste in Antigua and Barbuda is equal to 1.1536 tonnes per m$^3$.

---

[51] PEW. (2020). Breaking the Plastic Wave. Available at: https://www.systemiq.earth/wp-content/uploads/2020/07/BreakingThePlasticWave_MainReport.pdf.
[52] Product based on Purchasing Power Parity.
[53] GDP per capita, PPP (current international $) – High income | Data (worldbank.org).
[54] GDP per capita, PPP (current international $) – Antigua and Barbuda | Data (worldbank.org).

*Table A23 – Data to estimate average density of one tonne of plastics in Antigua and Barbuda (2019)*

| | Tonnes of total recycled | Density |
|---|---|---|
| PET | 358.79 | 1.38 |
| HDPE | 264.37 | 0.95 |
| LDPE | 188.84 | 0.925 |
| PP | 113.30 | 0.905 |

The total cost of recycling plastics in Antigua and Barbuda is displayed in **Table A24**.

*Table A24 – Cost of implementing the recycling system for Antigua and Barbuda per year*

| Year | Implementation rate of the recycling policy | Amount recycled | Amount considered (tonnes) | Amount recycled (tonnes) | Cost (XCD) (non-discounted) | Cost (XCD) (Discounted at 6.35%) |
|---|---|---|---|---|---|---|
| 2021 | 0% | 0% | 3,348.8 | - | - | - |
| 2022 | 0% | 0% | 3,397.2 | - | - | - |
| 2023 | 25% | 15% | 3,446.4 | 500.0 | 273,744 | 256,367 |
| 2024 | 50% | 29% | 3,496.2 | 1,014.4 | 555,406 | 487,131 |
| 2025 | 75% | 44% | 3,546.8 | 1,543.6 | 845,158 | 694,210 |
| 2026 | 100% | 58% | 3,598.1 | 2,088.0 | 1,143,174 | 879,393 |
| 2027 | 100% | 58% | 3,650.1 | 2,118.2 | 1,159,707 | 835,481 |
| 2028 | 100% | 58% | 3,702.9 | 2,148.8 | 1,176,478 | 793,762 |
| 2029 | 100% | 58% | 3,756.4 | 2,179.9 | 1,193,493 | 754,126 |
| 2030 | 100% | 58% | 3,810.8 | 2,211.4 | 1,210,753 | 716,469 |
| 2031 | 100% | 58% | 3,865.9 | 2,243.4 | 1,228,263 | 680,693 |
| 2032 | 100% | 58% | 3,921.8 | 2,275.8 | 1,246,027 | 646,703 |
| 2033 | 100% | 58% | 3,978.5 | 2,308.7 | 1,264,047 | 614,410 |
| 2034 | 100% | 58% | 4,036.0 | 2,342.1 | 1,282,328 | 583,730 |
| 2035 | 100% | 58% | 4,094.4 | 2,376.0 | 1,300,873 | 554,581 |
| 2036 | 100% | 58% | 4,153.6 | 2,410.3 | 1,319,687 | 526,889 |
| 2037 | 100% | 58% | 4,213.7 | 2,445.2 | 1,338,772 | 500,579 |
| 2038 | 100% | 58% | 4,274.6 | 2,480.6 | 1,358,134 | 475,583 |
| 2039 | 100% | 58% | 4,336.5 | 2,516.4 | 1,377,775 | 451,835 |
| 2040 | 100% | 58% | 4,399.2 | 2,552.8 | 1,397,701 | 429,273 |

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# The economic impact of plastic pollution

## in Grenada

Impacts on the fisheries and tourism sectors, and the benefits of reducing mismanaged waste

Leander RAES, Damien MITTEMPERGHER and Aanchal JAIN

IUCN Economics Team and Ocean Team

Norad

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# Acronym List

| Acronym | Description |
|---|---|
| ALDFG | Abandoned, Lost, or Otherwise Discarded Fishing Gear |
| ABWREC | Antigua and Barbuda Waste Recycling Corporation |
| APEC | The Asia-Pacific Economic Cooperation |
| APWC | Asia Pacific Waste Consultants |
| BaU | Business-as-Usual |
| BPA | Bisphenol A |
| CBA | Cost-Benefit Analysis |
| CBD | Convention on Biodiversity |
| EEZ | Exclusive Economic Zone |
| EU | European Union |
| GDP | Gross Domestic Product |
| HDPE | High-Density Polyethylene |
| ICC | International Coastal Clean-Up |
| MEA | Multilateral Environmental Agreements |
| MPA | Marine Protected Areas |
| MPW | Mismanaged Plastic Waste |
| NGO | Non-Profit Organisation |
| NOAA | The National Oceanic and Atmospheric Administration |
| Norad | Norwegian Agency for Development Cooperation |
| NPV | Net Present Values |
| OECD | Organisation for Economic Co-Operation and Development |
| PET | Polyethylene Terephthalate |
| PWFI | Plastic Waste-Free Islands |
| PIC | Pacific Island Countries |
| SIDS | Small Island Developing States |
| TIDES | Trash Information and Data for Education and Solutions |
| UNWTO | United Nations World Tourism Organization |
| VTM | Value Transfer Method |
| WMB | Waste Management Budget |
| WTV | Willingness to Visit |

# 1. INTRODUCTION

In 2019, with support from the Norwegian Agency for Development Cooperation (Norad), IUCN launched the Plastic Waste-Free Islands (PWFI) project. The initiative's overarching goal is to drive the circular economy agenda forward and to reduce plastic waste generation and leakage from island states. The project consists in assisting several island nations in the Pacific and Caribbean region to reduce plastic waste generation and eliminate leakage to the ocean on which they depend. The PWFI was implemented in Fiji, Samoa, and Vanuatu in the Pacific, and in Antigua & Barbuda, Grenada, and Saint Lucia in the Caribbean Region.

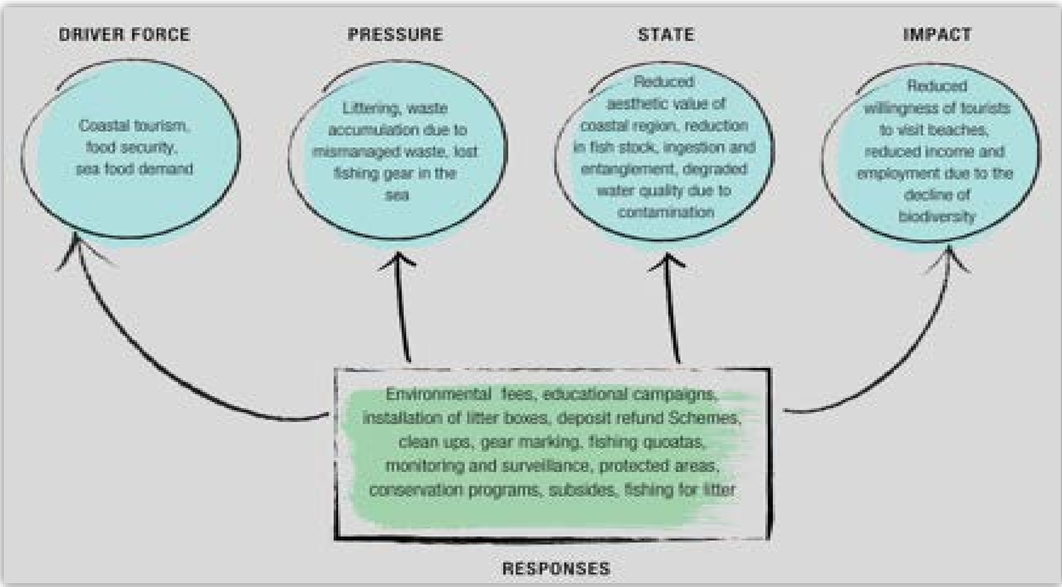
As part of the PWFI project, economic assessments were conducted. This report presents the findings of a study that aimed at estimating the impacts of marine plastics on the fisheries and tourism sectors in Grenada, and the costs and benefits of implementing a solution (a national recycling system, with and without regional cooperation) to reduce mismanaged plastic waste and its leakage into the marine environment.

*Grenada coastal tourism (IUCN).*

## 1.1. MARINE PLASTICS

Since the early 1950s, the use of plastics in everyday life has increased due to its durability, lightness, and low production cost (Filho et al., 2021). The amount of plastics produced between 2002 and 2015 was the same as the amount produced in the previous 52 years, between 1950 and 2002 (Geyer et al., 2017). At a global level, only 9% of plastics produced are recycled, and 22% of the plastic waste generated is mismanaged (Watkins et al., 2015; OECD, 2022a). According to a study by Thompson (2009), 10% of all mismanaged plastics leak into the oceans. Most of the mismanaged plastics are single-use plastics, mainly coming from food packaging, bottles, straws, and grocery bags. The main source of plastic waste flow in the oceans is land-based, contributing to approximately 80% of all marine plastics (Jambeck, 2015). Land-based litter load can come directly from the shoreline caused for example by tourism or it is transported from distant areas such as inland towns and industrial sites via watersheds and wastewater pipelines, mainly due to inefficient waste management practices (Veiga et al., 2016). The remaining 20% comes from sea-based activities (Hao wu, 2020), mainly from the fisheries sector (Andrady et al, 2012). Fisheries can add to marine plastic debris through discarded, lost, and abandoned fishing gear in the oceans and waterways (Oko-Institut, 2012). In addition to this, it is also responsible for throwing litter overboard from vessels (Hinojosa, 2011; Lusher, 2017).

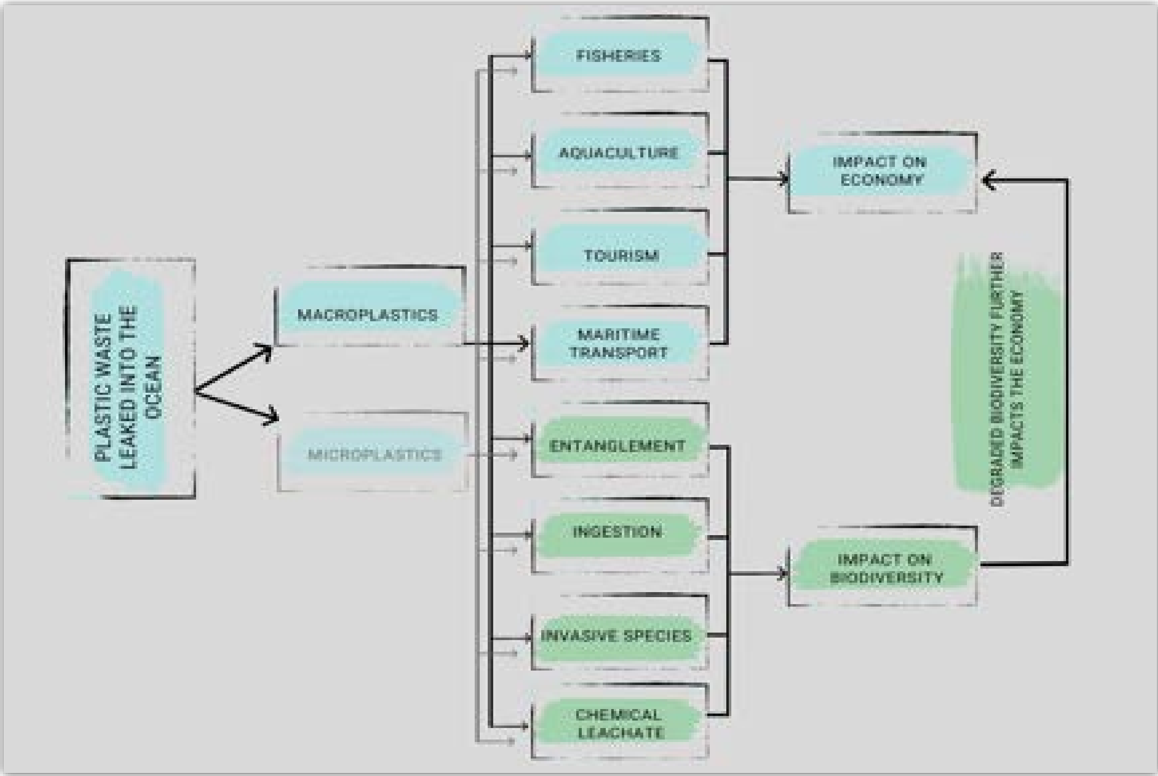
The marine plastic problem can be explained using the 'Driver, Pressures, States, Impacts and Responses' framework (Löhr et al., 2017; Miranda et al., 2019) (**Figure 1**). The drivers of plastic production originate from human needs such as food security, movement of goods and services, and shelter (Thevenon et al., 2014). These needs are fulfilled by the economic sectors where plastics are widely used (e.g., packaging of products, fishing nets for fisheries, construction, transportation, healthcare equipment, agriculture, and electronics, among others) (Abalansa et al., 2020). The use of plastics generates waste.




*Sources: Romagosa et al., 2014; Chassignet et al., 2021; Jahanishakib et al., 2021Gebremedhin et al., 2018.*

***Figure 1 – Driver-Pressure-State-Impact-Responses framework for plastic pollution with examples***

Once plastics become waste, a part of this waste is mismanaged and leaks into the oceans. This generates negative impacts to the economy and biodiversity (**Figure 2**). The plastic pollution leaked generates four types of consequences. First, it impacts the physical ocean system through contamination (e.g., reduced health of marine habitats and water quality due to the presence of plastics), and sunlight blockage (Gallo et al., 2018). Second, the reduced environmental quality impacts marine biodiversity and ecosystems (e.g., increased fish mortality rates due to ingestion and entanglement, and reduced aesthetic value of beaches due to plastic litter) (Werner et al., 2016). Third, the degraded marine biodiversity and ecosystems has an impact on the provision of marine ecosystem services (e.g., supply of seafood and raw materials, transportation, storm protection) (Beaumont et al., 2019; Barbier, 2017). Finally, the economy is directly impacted (e.g., through lower fisheries and tourism revenues) (Bailly et al., 2017).




*Source: UNEP 2014a.*

***Figure 2 – Impact of plastics ending up in the oceans[1]***

Marine plastic pollution can generate significant economic costs in the form of gross domestic product (GDP) reductions, estimated at up to US$7 billion for 2018 alone (WWF, 2021). This is driven by the loss in revenue from tourism, fishing, aquaculture, transport, and other ocean-based activities (**Figure 2**) (McIlgorm et al., 2020). The costs associated with marine litter are divided between direct and indirect costs (Newman et al., 2015). Direct costs include the expenses for repair and replacement. For instance, fisheries revenues can be impacted due to damaged gear (Macfadyen, 2009) and expenses to the government to clean beaches where recreational activities are conducted (Mouat, et al., 2010). Additionally, the shipping industry can suffer losses due to marine debris entangling with propellers, potentially obstructing the

[1] The study focuses on macroplastics.

engine (IMO, 2018). The indirect costs are related with impacts to biodiversity and habitats, including costs resulting from decreased ecosystem service provision (Rodríguez et al., 2020). For instance, the fisheries sector's revenue is further reduced due to the reduction in catches in the presence of marine plastics and lost or abandoned gear (Richardson et al., 2021). Tourism industry's revenue could be impacted due to reduction in tourists' visits and spending in the presence of marine debris (McIlgorm et al., 2020).

Moreover, plastics at every stage of its life cycle (from production to consumption to waste treatment) emits a significant amount of greenhouse gases, which together with other sources, threaten the ability of the global community to keep global temperature rise below 1.5°C (Ford et al., 2022; Hamilton and Feit, 2019). It is estimated that by 2050, the plastic life cycle could contribute up to 15% of the entire carbon budget (Zheng and Suh, 2019).

These impacts will continue to increase if no action is taken to stop plastic production, consumption, and leakage. A report by the Organisation for Economic Co-operation and Development (OECD) states that the global plastic use and waste will triple by 2060 in the absence of plastic management policies. By 2060, plastic leakage to the environment is projected to double to 44 million tonnes a year, increasing the negative impacts on marine biodiversity and ecosystems, and further contributing to climate change (OECD, 2022b). To reduce the amount of plastics, efficient political responses and legal tools are required at the local, national, and international level (Nielsen et al, 2019; da Costa, 2020). The responses can be ex-ante (i.e., before plastic production and waste generation) or ex-post (i.e., once the plastic waste is dumped) (Lachmann et al., 2017; Schmaltz et al., 2020; Van Rensburg et al., 2020). Ex-ante measures include retention and reduction of waste at source (Wang, 2018). This can be achieved through changing producers' behaviour, e.g., extended producer responsibility (Raubenheimer et al., 2020; OECD, 2022a), or changing consumers' behaviour, (e.g., through bans and taxes) (Oosterhuis et al., 2014; BFFP, 2021). Consumer choices can also be altered through positive reinforcements such as educational campaigns (Willis et al., 2017) and incentives, such as deposit refund schemes for Polyethylene terephthalate (PET) bottles and plastic bags (Schuyler et al., 2018). In the case of ex-post responses, waste treatment and management techniques need to be addressed (Willis, 2018; Rajmohan et al., 2019). A report by PEW (2020) estimated that the amount of mismanaged plastics will more than double in the next 20 years if nothing is done. Jambeck et al. (2015) mention that to achieve a 75% reduction in the mass of mismanaged plastic waste, the 35 top-ranked countries with poor waste management practices would need to improve their waste management system by at least 85% by 2025. However, improving waste management infrastructure requires substantial investments (and time), especially in low and middle-income countries. The focus of these countries should first be on improving solid waste collection (UNEP, 2018) and then implementing local/coastal clean-ups (Rochman, 2016).

Some policies also aim at reducing plastics that have already escaped into the sea. For example, incentivising the fishing industry and rewarding fishers to bring back litter has proven to be successful in some cases (OSPAR, 2017; KIMO, 2010). This said, it might be more efficient to work on economic instruments that target land-based waste to reduce a significant amount of plastics, as most of the marine litter comes from land-based activities (Sheavly & Register, 2007; Jang et al., 2014; APEC, 2019). Nonetheless, there is no one straight solution to curb the plastic problem. The choice of a set of interventions for a country depends on the source of pollution being addressed, the country's institutional characteristics and infrastructure, consumer preferences and habitual behaviour, and the economy's overall sectoral composition (Oosterhuis et al., 2014).

## 1.2. The Caribbean

The Caribbean Sea, part of the Atlantic Ocean region, is one of the largest seas in the world and has an area of about 2,753,000 $km^2$ (Menzies et al., 2022). It has rich biodiversity and marine ecosystems that are crucial for the economic growth of tourism and fisheries, and as well for the health of the inhabitants (UNEP, 2019a). Within the Caribbean Sea there is a group of states and territories, including around 7,000 islands, islets, reefs, and cays, altogether called the Caribbean Region (Otieno, 2018).

Caribbean economies depend highly on a healthy marine ecosystem, which is particularly valued for tourism (O'Brien et al., 2022). The climate and beaches help make the region one of the top tourist destinations in the world (Wong, 2015; Diez et al., 2019). The tourism sector accounts for 15% of the Caribbean Region's GDP (WTTC 2018). Aside from this, the Caribbean Sea is also a primary source of fish, providing different socio-economic opportunities for the inhabitants of the region (FAO, 2022; CANARI, 2020a). The fisheries industry represents around 4.3% of the workforce in the region (CRFM, 2021).

However, the lucrative marine and coastal ecosystems are in danger, given that the Caribbean Sea is the second most plastic-contaminated sea in the world (UNEP, 2019b). According to a 2019 report by Forbes, 10 of the top 30 global polluters per capita are from the Caribbean region (Ewing-Chow, 2019). The plastic waste leakage in these territories is driven by illegal plastic waste disposal due to poor waste management systems along with limited recycling, and weak law enforcement (UNEP, 2018). Plastic pollution could cause damaging impacts on Caribbean islands' growing economies (Diez et al., 2019). According to APWC (2021a), around half of plastic waste generated in the Caribbean region is made up of by single-use plastics, mainly composed of PET bottles and plastic bags[2]. This plastic waste mainly comes from the household and commercial sectors within each territory (AWPC, 2021a).

Small island developing states (SIDS) in the Caribbean region are particularly exposed and vulnerable to increased damage from plastic leakage, which poses a serious threat to ecosystems (Barrowclough et al., 2021; Lachmann et al., 2017). The thriving economies drive the demand for more consumer products, which exerts pressures on waste management facilities (UNEP, 2014b). Most of these islands have limited and small sized infrastructure, making the waste difficult to manage in terms of volume, composition, and recyclable potential (UNEP, 2019b).

Governments of these islands have started to recognise the impacts of this pollution on their social and economic well-being and have started to work on measures to curb

[2] This estimate is based on the estimation of single-used plastics in Antigua and Barbuda, Grenada, and Saint Lucia.

plastic pollution (UNEP, 2018). Most measures focus on bans of single-use plastics and polystyrene, which comprise around 80% of Caribbean marine litter (Clayton et al., 2020). Considering the significant amount of PET and High-density polyethylene (HDPE) plastic leakage across the Caribbean islands, container deposit and transport schemes could prove effective (Schuyler, et al. 2018) to incentivise region-wide reverse logistics and to create recycling markets for countries without such availability (APWC, 2021a). However, there is little comparative analysis of policy responses to determine their efficacy (Chen, 2015; Rochman, 2016). To ensure sustainability of the Caribbean Sea's ecosystems, an integrated management approach with local stakeholders and government as well as with other nations is needed (Winther et al., 2020).

*Schools of Creole Wrasse in corals of Grenada's coast (Shutterstock, Eric Carlander).*

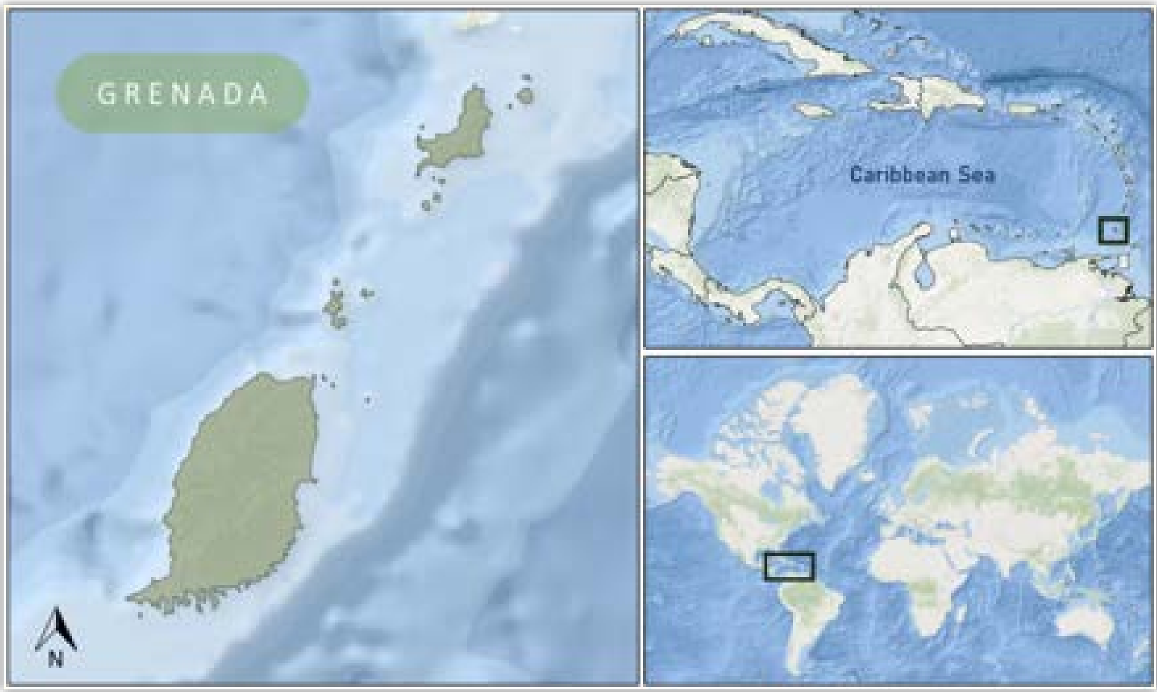
# 2. CASE STUDY INTRODUCTION

Grenada is a tri-island country comprising Grenada, Carriacou and Petite Martinique, located in the Caribbean Sea (Government of Grenada, 2017; PAHO, 2012) (**Map 1**). It has a population of 112,523 in 2020 (World Bank, 2021a). It has a total land surface area of 344 km² (CRFM, 2021) (**Table 1**).

*Table 1 – General data of Grenada*

| Key Facts | |
|---|---|
| Official name | Grenada |
| Exclusive Economic zone | 25,670 km$^2$ |
| Coastline | 121 km |
| Capital | Saint George's |
| Climate | Tropical |
| Terrain | Rugged and mountainous |
| Population distribution (2019) | 36% urban; 64% rural |
| Currency | East Caribbean dollar (XCD or EC$) |
| GDP (2019) | USD 1.211 bn |
| GDP per capita (2019) | USD 10,815 |

*Sources: CBD, 2022; Britter, 2020; UNDP, 2022; PAHO, 2012; World Bank, 2021a.*




*Source: ESRI, 2018.*

*Map 1 – Location map of Grenada*

Grenada has a diverse biodiversity which is essential for the provision of many ecosystem goods and services (Government of Grenada, 2014). Grenada's marine space is over 75 times the size of its land space which illustrates the importance of its marine and coastal ecosystem (CARICOM, 2019). They spread mainly through the coastline supporting marine life, local fisheries and preventing coastal erosion (Government of Grenada, 2016). These ecosystems themselves contain an estimated 233 marine species, 69 marine or brackish-water species, 17 freshwater species, four turtle species and several seabirds (Government of Grenada, 2009).

Grenada's rich biodiversity is important to enhance income and livelihood and supports primary sectors such as tourism and agriculture on which the national economy is dependent (World Bank, 2019; CANARI, 2020b). The country has a small and open economy which is limited in terms of natural resources (Government of Grenada, 2011). Fisheries and agriculture contribute 4.9% of the country's GDP (CARDI, 2022; Statista, 2022). More specifically, fisheries make up to 31% of the GDP of the agriculture sector. Over the last decades, Grenada's fishing industry's focus has been shifted from artisanal to commercial fisheries which is creating further employment opportunities (FAO, 2022). Further details on fisheries in Grenada can be seen in **Table 2**.

*Table 2 – Overview of fisheries' data from Grenada (2019)*

| Revenue (USD) | Catch volume (tonne) | Number of Vessels |
|---|---|---|
| 1,270,718 | 2,632 | 900 |

*Sources: Caribbean Regional Fisheries Mechanism Secretariat, 2020; FAO Fisheries Division.*

Despite the importance of the agriculture sector for Grenada, a larger bulk of the economy has shifted towards the service sector, contributing approximately 76% (2009s of national GDP (World Bank, 2021b). Tourism has become the economic base, contributing 40.7% of the nation's GDP and 44.4% of all jobs in 2019 (WTTC, 2022). The tourism sector is also the principal source of foreign exchange (Nelson, 2005; Nelson, 2012). In 2019, Grenada welcomed 529,985 tourists, around 5 times more than the national population (World Bank, 2020). An average length of stay of the tourists is nine days per visitor with the majority of tourists arriving via sea transportation (i.e., around 70% of total tourists) and the rest of 30% of tourists arriving from air transportation (APWC, 2021b). With a large pier now in place on the main island, cruise ship tourism is steadily increasing (GIZ, 2015). The largest source market of tourists in Grenada is the United States, followed by the Caribbean, the United Kingdom and Canada (Caribbean Development Bank, 2020). Further details on fisheries in Grenada can be seen in **Table 3**.

*Table 3 – Overview of international tourism data from Grenada (2019)*

| Revenue (USD[3]) | International tourists (Number) | Expenditure per international tourist (USD) | Coastline (km) |
|---|---|---|---|
| 493,200,000 | 526,000 | 937 | 121 |

*Sources: WTTC, 2022 and World Bank, 2022.*

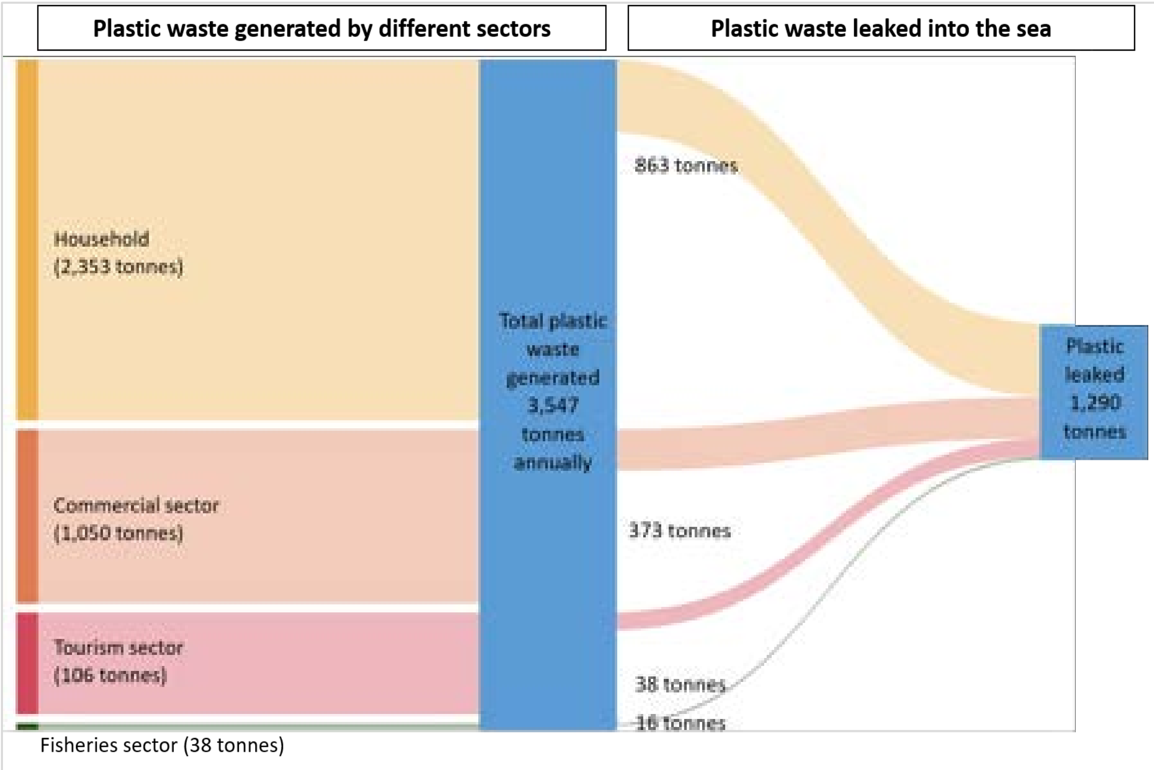
However, the large numbers of visiting tourists generate large quantities of waste that present a major challenge for local waste management and put significant pressure on the island's marine and terrestrial biodiversity (GIZ, 2015). Due to consequential overexploitation and pollution, the ecosystems of Grenada – mangroves, coral habitats and seagrass communities are already declining (McHarg et al., 2022).

[3] The exchange rate considered in this study is the average rate for 2019, USD 1 = XCD 2.70283 (source: East Caribbean Dollar (XCD) to US Dollar Spot Exchange Rates for 2019). Accessed on 1 September 2022).

Waste management is a challenge for Grenada with its limited financial, recycling and landfill capacity (Elgie et al., 2021). Plastic waste is one of the major concerns for the island (Frame et al., 2021). In Grenada, waste segregation practices are weak, in spite of household waste likely containing a significant share of recyclable materials including organic matter, plastics and paper (GIZ, 2015). Moreover, the island relies on imports to meet their consumption needs, resulting in the importation of a significant amount of packaging and non-biodegradable materials (APWC, 2021b).

## 2.1. Plastic leakage estimates Grenada

As per a report by APWC (2021b), 47,203 tonnes of waste were disposed of in Grenada in 2019, out of which 7.5%, 3,547 tonnes, was plastic waste. More than half of the disposed waste is generated by households, followed by the commercial and tourism sectors (**Figure 3**). Although the household and commercial sectors generate the largest quantities of general waste, including plastic, in Grenada, the waste generation intensity per person for tourists on land is twice compared to that of residents. The scenario worsens with tourists on yachts which contribute 16 times more than the disposal intensity of residents for household waste. The main reasons for marine litter in Grenada are the local people and tourists' lack of public awareness and inappropriate waste disposal behaviours, as well as inadequate waste management (GIZ, 2015). The majority of plastic waste leaked are single-use plastics, predominantly plastic bottles, containers, and bags made of PET and HDPE, as represented in **Table 4** (APWC, 2021b). Approximately 36% of all plastic generated is leaked into the oceans each year (APWC, 2021b).




*Source: APWC, 2021b.*

***Figure 3 – Plastic disposed leaked from different sectors (2019)***

*Table 4 – Plastic waste leakage rates (tonnes per year) per plastic polymer type and per sector in Grenada (2019)*

| Plastic Polymer | Household leakage rates (tonne/year) | Commercial waste leakage rates (tonne/year) | Tourism leakage rates (tonne/year) | Fisheries leakage rates (tonne/year) |
|---|---|---|---|---|
| PET | 106.48 | 55.24 | 5.46 | 1.19 |
| HDPE | 128.20 | 55.44 | 2.64 | 2.25 |
| PVC | 15.02 | 6.38 | 0.45 | 0.00 |
| LDPE | 125.99 | 51.91 | 6.71 | 0.06 |
| PP | 120.15 | 52.14 | 3.11 | 1.50 |
| PS | 140.76 | 63.06 | 2.86 | 2.10 |
| Other | 226.91 | 90.34 | 16.61 | 8.57 |
| **Total** | **863.5** | **373.5** | **37.83** | **15.68** |

*Source: APWC, 2021b.*

Grenada is one of the world's first countries to develop a vision for an economy based on 'blue growth' (World Bank, 2018a). Beyond the initiatives to raise awareness and to install more litter bins throughout the nation, Grenada has developed several legislative instruments to work on the waste problem, including plastic pollution (FAO, 2019):

- Grenada Solid Waste Management Authority Act (No. 11 of 1995, amended by Act No. 30 of 1995 and in 2001) by Grenada Solid Waste Management Agency (GSWMA) – responsible to develop the solid waste management facilities and improve the coverage and effectiveness of solid waste storage, collection and disposal
- Waste Management Act (No 16 of 2001) – regulates waste management with best environmental practices, including a national waste inventory
- Environmental Protection Levy Act (2007), amended by Act 6 of 2015 – a levy on goods and services to support the financial operations of the GSWMA
- Environmental Levy Order (No. 10 of 1990) – prohibits dumping of garbage in public areas
- Abatement of Litter Act (No. 24 of 2015) – outlines offences and fines in for littering
- Non-biodegradable Waste Control Act (2018) – outlines the prohibition of production, and importation of non-biodegradable products; this includes banning single-use plastics used in food premises

Many other economic instruments have already been introduced to contribute toward amortising the high costs of waste collection, such as waste management fees for households rated according to electricity use, environmental fees for goods importers, tourist fees, and fines (IUCN, 2021). Nevertheless, the cost of the waste management system is still greater than the income that it and its instruments collectively generate, while a number of issues remain to be tackled (Elgie et al., 2021). There is still no integrated approach to waste management. For example, the separation of different waste fractions has yet to be adopted, and collected waste is primarily disposed of in the perseverance Landfill, an open landfill site located close to the sea (GIZ, 2015). Moreover, the recycling system remains inadequate in the nation. Thus, implementing policies to establish guidelines for compulsory source-segregation and appropriate processing of recyclables could help Grenada to better address plastic pollution (APWC, 2021b).

# 3. IMPACT OF MARINE PLASTICS IN GRENADA (2019)

## 3.1. METHODOLOGY 1

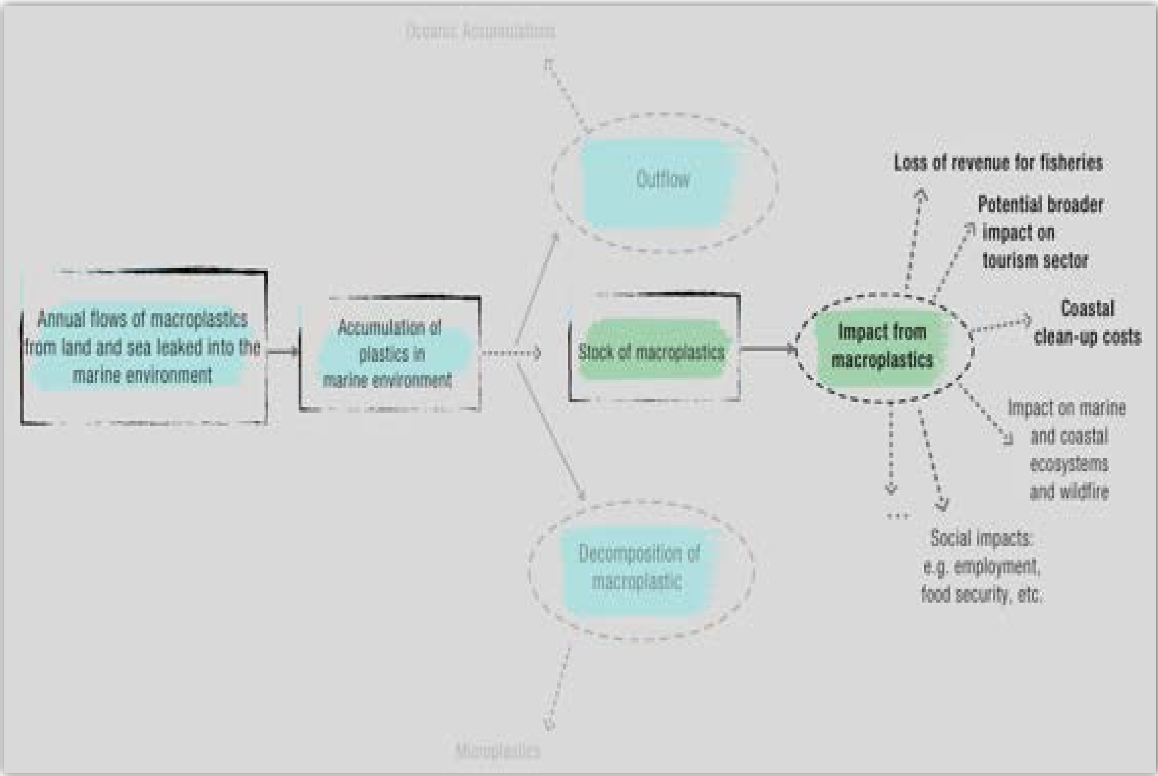
### 3.1.1. Data collection

Data collection was conducted through different means:

- Use of information developed through the PWFI project: plastic flow estimates (APWC, 2021a, b, c, and d), policy analysis (APWC, 2021b; IUCN, 2022) and business cases (Searious Business, 2021);
- National and international databases, including those providing spatial data; and
- Literature review.

### 3.1.2. Plastic stock estimates (2019)

Estimating the impact of marine plastics on the tourism and fisheries sectors requires a consideration of multiple steps and factors, taking into consideration that the impact of marine plastics is caused not only by its annual leakage (flow) into the marine environment, but by the stock of marine plastics already present (McIlgrom et al., 2009). For the purposes of this Report, the following steps were taken: (1) estimating plastic leakage; (2) estimating plastics flowing into the marine system considered (Caribbean Sea) from other sources or flowing out; (3) estimating a first stock of plastics; (4) considering decomposition and plastics floating out of the system and that accumulate in oceanic accumulation zones; and (5) estimating the stock of marine plastics accumulating in different parts of Grenada's territory and impacting different sectors (**Figure 4**). In order to include inter-countries interactions, the focus is the Caribbean Sea, which is considered as a semi-closed system, whereas a simplification it is assumed that the same amount of plastics that enters this system, floats out of it.




*Source: McIlgrom et al., 2009.*

***Figure 4 – A conceptualisation of the sources, stock, and fate of debris in the marine debris cycle***

The stock of marine plastics in the Caribbean Sea at time (t) can be represented by the **Equation 1** bellow (based on McIlgrom et al., 2009):

*Stock (t) = Stock (t-1) + Volume of plastics entering the marine environment (t-1) – Volume cleaned up (t-1) – Volume decomposed (t-1) – Volume floating out of the system[4] (t-1) (**Equation 1**)*

This plastic stock is then divided among countries bordering the Caribbean Sea based on the size of their exclusive economic zone (EEZ), shallow waters, and coastlines (see **Map A1** in **Annex A1**).

Both the amount of plastics presents in the waters of Grenada and its annual flow leaking into the marine environment are estimated based on (i) APWC estimates for Grenada (2021b), and (ii) regional leakage into the Caribbean Sea based on Lebreton and Andrady (2019) and APWC (2021c and 2021d) (for Antigua and Barbuda, and Saint Lucia). To estimate the current amount of plastics present, the following factors were considered: historical accumulation, degradation into microplastics, regional exchanges, and outflow towards oceanic plastic accumulation zones (Lebreton et al., 2019; Eriksen et al., 2014; Lebreton et al., 2018). **Annex A1** provides a more detailed overview of the different assumptions and calculations that were applied to estimate the amount of plastics present in the waters of Grenada.

[4] This refers to plastics leaked into the system from sources bordering the Caribbean Sea (see **Annex A1**). For sources outside this system, we assume that the same amount of plastics enter, as leave the system.

Plastic accumulation in different parts of the marine environment was estimated based on two different plastic accumulation scenarios. These distributions of plastics in different areas are considered fixed over time.

1. **Plastic accumulation scenario 1**: Based on GRID-Arendal, (2018) and presented in **Table 5** (supporting papers: Jang et al., 2015; Lebreton et al., 2012; Jambeck et al., 2015; Cózar et al., 2014; Eriksen et al., 2014; van Sebille et al., 2015).

***Table 5 – Areas of plastic accumulation according to plastic accumulation scenario 1***

| Accumulation area | Percentage (%) |
|---|---:|
| Sea surface | 0.50 |
| Coastline and seafloor[5] | 33.70 |
| Coastal waters | 26.80 |
| Open ocean | 39.00 |

2. **Plastic accumulation scenario 2**: Based on Lebreton et al., (2019) and presented in **Table 6**.

***Table 6 – Areas of plastic accumulation according to plastic accumulation scenario 2***

| Accumulation area | Percentage (%) |
|---|---:|
| Shoreline | 98.62 |
| Coastal waters | 0.18 |
| Open ocean | 1.20 |

Throughout the text, the first accumulation scenario will be referred to as “plastic accumulation scenario 1”; the second as “plastic accumulation scenario 2”.

### 3.1.3. Impact estimates

***Estimates of impact on fisheries***

Fisheries are not only a source of marine plastics, but also suffer from its impact. This impact can be directly and easily measurable through market values (McIlgrom et al., 2011), or indirectly, as related to the degradation of natural marine capital assets. Direct economic impacts can occur due to the costs to repair or replace damaged or lost gear due to encounters with marine plastics (e.g., repairing vessels with tangled propellers, clogged water intakes, etc.), as well as the loss of earnings due to lost productive time dealing with marine plastics encounters and from reduced or contaminated catches (Takehama, 1990; McIlgrom et al., 2009; Newman et al., 2015).

The impact of macroplastics on the fisheries from Grenada was estimated with the help of what is referred to as ‘value transfer method’ (VTM), which is often used in impact analyses (Johnston et al., 2018). VTM is applied by assigning existing economic estimates of a current study/region/ecosystem to a similar problem

[5] No estimates were available on how much plastics end up on the coastline versus on the seafloor. It is assumed that the maximum amount of plastics that can end up on the coastline is 33.7% of the annual amount leaked into Grenada’s marine environment (from both Grenada and outside sources).

elsewhere. Following Arcadis (2013) and UNEP (2014a), who estimated the impact of marine plastics on European Union (EU) and global fisheries respectively, in this study Mouat et al (2010) is used as the reference study. Mouat et al. (2010) estimated the impact of marine plastics on Scottish net fisheries specifically. Here, a VTM was applied based on values from Mouat et al., (2010), and separating impact on net fisheries, from the impact on trap and line fisheries.

Mouat et al., (2010) conducted a survey study of Scottish net fisheries to investigate the extent by which this sector is impacted by marine litter, concluding that marine litter negatively impacted Scottish fisheries' 2008 revenue by 5%. Globally, an average of 80% of all marine litter is composed of plastics (Dunlop et al., 2020). Therefore, it can be considered that the impact of marine plastics on Scottish fisheries' revenue was 4%, i.e., 80% of 5%. This impact is broken down into four cost categories: dumped catch, net repairs, fouling incidents, and time lost clearing nets (Mouat et al., 2010).

Mouat et al., (2010) impact estimates are then transferred to the fisheries of Grenada. Although there is a relation between the amount of plastics present in Scottish waters versus what is present in the waters of Grenada, and how it impacts both countries' fisheries, fisheries from Scotland and Grenada are different in terms of the number and type of fishing vessels, the size of the fishing area, the volume and value of the fish catch and type of fisheries, among other factors. Thus, the value (or impact) transfer is not merely based on the amount of marine plastics present to transfer the size of the impact, but it also adjusts for a series of other variables or proxies that needs to be considered, for example: types of fishing gear used. The detailed methodology which presents the adjustment of fisheries size and impact estimation is presented in **Annex A1.3**.

***Estimates of impact on tourism***

As with fisheries, tourism is another sector that is a source of mismanaged plastics but is also impacted by the presence of marine plastics. One of the main impacts on tourism from marine litter comes from the pollution of beaches and coastal areas. These can have a negative impact on tourists' willingness to visit (WTV) beaches, leading to a loss in revenue (Jang et al., 2014; Kosaka and Steinback, 2018). Ballance et al., (2000) state that tourist behaviour, including WTV, can change according to different numbers of plastic items present on beaches. Two studies estimating tourists' WTV in other countries as related to the presence of marine plastics on the beaches are used to evaluate the potential risks to Grenada's tourism industry. These studies generated their WTV impact by taking surveys of how tourists' WTV varied according to the number of plastic items present on beaches.

A study conducted by Krelling et al., (2017) used a contingent valuation to assess the WTV of a beach under different littering scenarios on two beaches in Brazil. Ballance et al., (2000) used a travel cost method to assess the impact of plastics on tourism in Cape Town, South Africa. These different studies constitute options to estimate the risk of marine plastic pollution to the tourism sector and were applied to Grenada. **Annex A1.4** provides more details on the results of these studies.

*Prickly Bay Marina (APWC).*

In this study, the focus is solely on international tourism. Although domestic tourism does exist in Grenada, the impact of marine plastics on beach visits from the local population is not as clear as the potential reduction in international arrivals due to pollution. Furthermore, no distinction of behaviour has been made between land-based tourism, which includes air travellers as well and sea-based tourism (yachting and cruise ships). This means that the impact is considered the same regardless of the tourist category. However, it could be argued that sea-based tourism may be more impacted by marine plastic pollution since plastics floating around can also cause damages to vessels.

Applying the VTM using results from the Ballance et al. (2000) and Krelling et al. (2017) studies can result in a negative impact estimate on the tourism sector that has not yet occurred in Grenada. Despite increasing amounts of plastics in the Caribbean Sea, the Caribbean tourism industry has continued to grow in recent decades (Diez et al., 2019). Thus, the potential impact on tourism is a risk that has not (yet) fully materialised.

For the purposes of this study, this potential negative impact on tourism revenue is described as a risk (potential losses in tourism revenue). It is an avoided cost for the tourism sector as large accumulations of plastics on beaches, deterring tourism visits, is not yet occurring. This is due to two factors: First, actions are undertaken to reduce the potential impact of plastic pollution of beaches on the tourism industry, including, but not limited to: voluntary beach clean-ups (Hidalgo-Ruz and Thiel, 2015), and actions undertaken by the waste management authorities to keep beaches clean (Newman et al., 2015), among others.

Second, plastics may also accumulate in less visible areas than on sandy beaches, such as in mangroves or between rocks or underneath the sand, get buried in other parts of the shoreline, both above and below water, are taken out to the open ocean to accumulate elsewhere, or degrade into smaller, less visible particles. It is challenging to account for the costs of the different actions and how much plastics end up in each accumulation area. Thus, instead of only estimating the risk to the tourism sector if beaches are left uncleaned – and as a proxy for the minimum costs incurred by plastic pollution on Grenada's coastline – this study estimates the costs of cleaning up all plastic items that could at one point in time (during a given year) accumulate on the coast-or shoreline. This should be understood as the cost estimate of a continuous effort throughout the year, not a one-time clean-up.

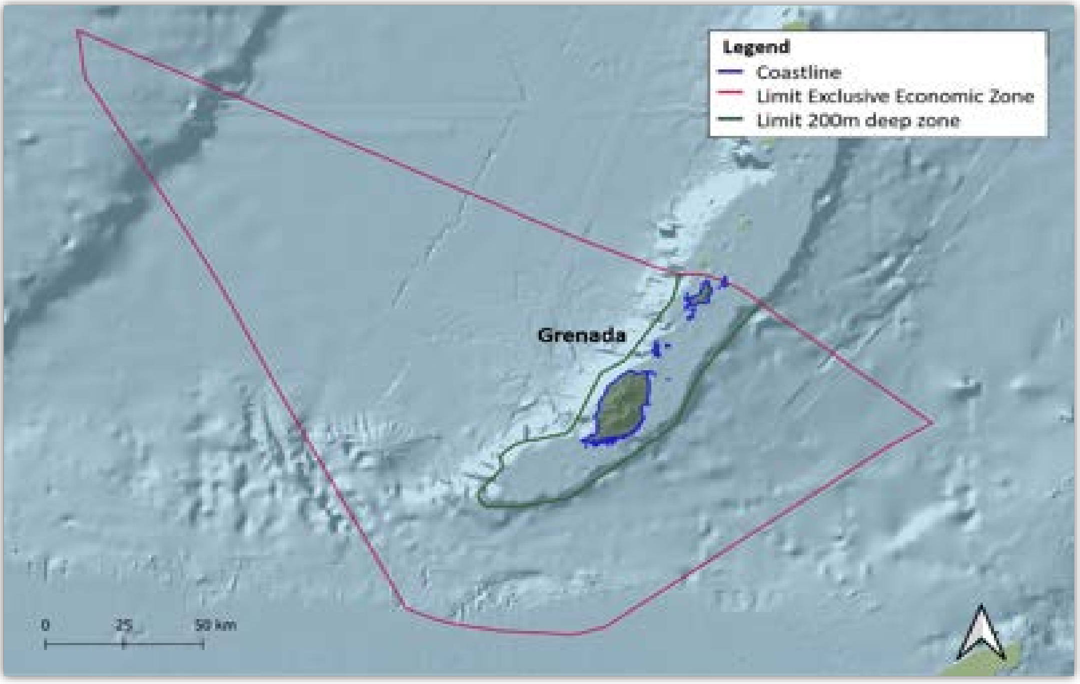
Since no clear budget allocation on the different beach clean-up efforts could be estimated (considering the combined cleaning efforts of municipalities, non-profit organisations (NGOs), hotels, etc.), and considering that no studies were available on where on the shore-or coastline plastics end up exactly during a specific time period, a proxy for this cost was developed. The costs of cleaning the entire coastal area of Grenada were calculated using the estimated amount of plastics that could end up on the coastline in one year (here 2019), followed by estimating the labour costs of cleaning plastics from beaches, based on data available through the Trash Information and Data for Education and Solutions (TIDES) database[6]. UNEP (2014a) used the opportunity cost of volunteered time to estimate the global clean-up costs imposed by plastic litter on beaches. This study considers that both volunteers and paid costs are potentially involved in cleaning efforts and assumes that the whole coastline is cleaned. This potentially creates an overestimation of this cost, but it is a proxy for the minimum effort needed to prevent further plastics from accumulating along Grenada's coastline, potentially impacting tourism in the future.

## 3.2. RESULTS (2019)

### 3.2.1. Plastic accumulation scenarios

The application of the previously described methodology requires not only estimating the stock of plastics, but also knowing where it is accumulating, as different accumulation areas will impact different sectors (fisheries or tourism in this study). **Map 2** presents the marine regions of Grenada where plastics could accumulate depending on the scenario considered (plastic accumulation scenario 1: **Table 7**, or plastic accumulation scenario 2: **Table 8**). More details on the construction of plastic stocks are provided in **Annex A1**.

[6] Available at: https://www.coastalcleanupdata.org/reports.




Sources: *Flanders Marine Institute, 2022; University of California Berkeley library geo data, GEBCO, 2012.*

***Map 2 – Marine regions of Grenada***

***Table 7 – Estimate of plastic accumulation (plastic accumulation scenario 1) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---|
| Sea surface | 286 |
| Coastline and seafloor | 13,914 |
| Coastal waters | 10,897 |
| Open ocean | 22,339 |

***Table 8 – Estimate of plastic accumulation (plastic accumulation scenario 2) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---|
| Shoreline | 40,717 |
| Coastal water (less than 200m) | 73 |
| Offshore (more than 200m) | 689 |

### *Marine plastics impacting fisheries*

For plastic accumulation scenario 1, the sum of plastics present on the sea surface, coastal waters, and open oceans within the EEZ is considered as marine plastics that will impact fisheries. The total amount of plastics impacting fisheries under this scenario is 33,552 tonnes.

For plastic accumulation scenario 2, the sum of plastics present in coastal waters and offshore is considered for the fisheries impact analysis. The total amount of plastics impacting fisheries under this scenario is 762 tonnes.

Additionally, the amount of plastics leaked in 2019 and impacting the fisheries sector is also estimated. Under plastic accumulation scenario 1, an average of 2,624 tonnes of plastics, and under plastic accumulation scenario 2, an average of 60 tonnes are estimated to have leaked into the EEZ in 2019 and accumulated in areas where plastics cause an impact on the fisheries of Grenada.

For estimating the results by transferring the impact calculations presented in the study by Mouat et al. (2009), plastic accumulation scenario 1 is used. The relative difference between the amount of plastics in Scotland and Grenada under both plastic accumulation scenarios remains more or less unchanged when the proposed methodology is applied; the results of the 'rule of three' under any individual plastic accumulation scenario are similar (see **Annex A1.3** for detailed explanations).

***Marine plastic risk to the tourism industry and coastal clean-up costs***

In this study, it is considered that, based on the plastic accumulation scenarios, a part of the 2019 annual plastic leakage, will end up on the coast or shoreline (see **Tables 5** and **6**) at a certain moment during the year. The assumption applied is that the percentage of plastic flow that accumulates on the coastline in that particular year is what could potentially impact tourism after being deposited. Although plastics could become degraded, buried in the shoreline, taken away by animals, etc., the largest potential accumulation during a one-year period is used to estimate the highest potential impact, or maximum risk, to the tourism industry. From the annual leakage estimate of the countries of the region, the amount of plastics considered to accumulate on the coastline (that could potentially impact tourism) is calculated based on plastic accumulation scenario 1. According to this scenario 33.7% of the plastics in the sea could end up on the coastline (or seafloor). Applying the second plastic accumulation scenario, 98.68% of the plastics in the sea ends up on the shoreline. We assume that during the year the plastics are leaked, it could accumulate on the coast or shoreline for some time.

Thus, according to plastic accumulation scenario 1, an estimated maximum amount of 1,024 tonnes of plastics could end up on the coastline of Grenada in 2019. According to plastic accumulation scenario 2, the total maximum amount is estimated to be 2,997 tonnes.

To transfer the studies from Krelling et al. (2017) and Ballance et al. (2000), who estimate impact based on plastic items present on beaches, to the potential impact estimates for this study, the amount (tonnes) of plastics needs to be translated to the number of items (see **Annex A1.4** for more details). To estimate how many items there could be per km of coastline, the number of items present in one tonne of plastics is estimated using the TIDES database[7]. Data from the last five (5) coastal clean-ups in Grenada (tonnes of plastics and items of plastics collected) were downloaded and compared to the maximum amount of plastics that could have ended up on the coastline under each plastic accumulation scenario in 2019 (see **Tables 9** and **10** for details). The number of items per tonne collected in 2018 were used for the analysis focusing on 2019 only. For the 2023-2040 period (see **Chapter 5**), the average from 2016-2020 was used. **Table A8** in the Annex gives a more detailed overview of the location (above or below water) from which the items were retrieved (land or sea).

[7] https://www.coastalcleanupdata.org/. Accessed on 15 October 2021.

*Table 9 – Number of items in one tonne of plastics (2019-2020)*

| Year | Plastics collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|
| 2020 | 1.09 | 17,003 | 15,669 |
| 2019 | 1.13 | 2,753 | 2,442 |
| 2018 | 0.45 | 13,466 | 29,956 |
| 2017 | 0.48 | 4,316 | 9,020 |
| 2016 | 0.95 | 434 | 456 |
| Average items per tonne collected | | | 9,278 |

*Source: Ocean Conservancy, 2021.*

*Table 10 – Number of plastic items per metre of coastline (2019)*

| Data on Grenada | Values |
|---|---|
| Coastline (km) | 121 |
| Plastics (in tonnes) (plastic accumulation scenario 1) | 1,024 |
| Plastics (no. of items) | 2,501,478 |
| Plastic items per km | 20,673 |
| Plastic items per m | 20 |
| Plastics (in tonnes) (plastic accumulation scenario 2) | 2,997 |
| Plastics (no. of items) | 7,320,125 |
| Plastic items per km | 60,497 |
| Plastic items per m | 60 |

*Figures might not add up due to rounding.*

According to plastic accumulation scenario 1, there could be a maximum of 20 plastic items per metre of coastline in Grenada, while according to plastic accumulation scenario 2, this could be up to 60 plastic items per metre.

By using the same methodology on Antigua and Barbuda, and Saint Lucia, the results spread between 52 plastic items per metre and 151 plastic items per metre for the former and between 35 plastic items per metre and 103 plastic items per metre for the latter (Mittempergher et al, 2022; Raes et al, 2022b). Given these results, Grenada seems to fit within the lower range for the region.

The results for Grenada are lower (half) to those found for Antigua and Barbuda (Mittempergher et al., 2022), and Saint Lucia (Raes et al., 2022), applying the same methodology. However, the above estimated accumulation frequency of plastic items for Grenada is large when compared to the average amount of plastic items collected during a single beach clean-up and reported in the TIDES database for the Lesser Antilles in 2019. According to this database, during coastal clean-ups an average of 1.5 plastic items per metre were recorded (see **Table A6** in annex for more details). Overall, these numbers are significantly lower than the estimates presented in this study, except for Saint Maarten, where a value of 162 items/metre was reported for 2021-2022[8].

There are a few explanations for these differences. First, the allocation of plastics following GRID-Arendal (2018) and Lebreton et al., (2019) may not only consider

[8] Retrieved from https://www.coastalcleanupdata.org/reports, for 54 clean-ups that took place between August 4, 2021 and August 4, 2022 in Saint Maarten.

plastics ending up in areas accessible for clean-ups (for example by ending up in coastal areas where the water is too deep). Second, this study uses the maximum potential number of items that could end up on the coastline in a given year. Plastics can get buried, degraded, etc. and thus no longer be visible for beach cleaners. Finally, research has shown that the more plastic items are surveyed on a beach in a given year, the higher the estimated annual number of plastic items (Smith and Markic, 2013; Schernewski et al., 2018).

### 3.2.2. Impact of marine plastics on fisheries (2019)

For the fisheries sector, this study only estimates the results using plastic accumulation scenario 1, since the methodology gives a similar result regardless of the scenario (see **Annex A1.3** for details). The impact on fisheries for 2019 is based on data on the types of vessels and fishing methods, (see **Annex A1.3** for more details). The results are presented in **Table 11**.

***Table 11 – Estimated Impact of plastic pollution on fisheries' revenue (2019)***

| Type of impact | Percentage of fisheries' revenue |
|---|---|
| Dumped catch | 1.2% |
| Net repairs | 0.6% |
| Fouling incidents | 0.1% |
| Time lost clearing nets | 1.9% |
| Total impact | 3.7% |

The total impact of 3.7% is slightly lower than the 4% revenue impact estimated by Mouat et al., 2010 for Scottish fisheries. The main reason behind the lower impact stems from the fact that only 29% of fish caught in Grenada is done using net gears (It is the only gear type that is impacted by net repairs and time lost clearing nets) while Mouat et al. (2010) focused on net fishing only for Scotland (i.e., 100% of the catches were done using that type of fishing gear). Should it be the same in Grenada, the impact on fishing revenues would also be much higher (see for example the estimates for Antigua and Barbuda presented in Mittempergher et al., 2022).

Other studies also used Mouat et al. (2010). For example, Arcadis (2014) estimated and adjusted the impact of marine litter on EU fisheries at 0.9% of the revenue. UNEP (2014a) and Trucost (2016) calculated that those marine plastics caused an annual global revenue loss of 2% in marine fisheries. Overall, the impact on Grenada's fishery sector is larger than what these studies found. However, the costs of fouling incidents, here estimated at 0.1 % for Grenada, is an impact also analysed by Takehama (1990), who estimated that the cost of damage on Japanese fishing vessels caused by marine debris, based on statistics from the insurance system, resulted in an estimated impact

*Abandoned fishing gear at Waltham Fishing Port Source (APWC).*

on fisheries' revenue at 0.3% of gross annual value.[9] This estimate was also used by McIlgorm et al. (2011, 2009) to estimate the economic cost of marine debris damage in the Asia-Pacific region. Based on the methodology used in this study, fishing boats in Grenada suffer slightly less from fouling incidents than what was found in Japan by Takehama (1990), although using a different methodology, even when adjusting for the amount of plastics (80%) in marine debris.

Abandoned fishing gear at Waltham Fishing Port Source (APWC)

Given Grenada's revenue during 2019[10], **the estimated 3.7% revenue impact of the plastic stock on fisheries' revenue was XCD 1,270,718** (USD 470,288).

Grenada's fisheries sector and others fishing in the Caribbean Sea, also contribute to marine plastics through abandoned, discarded, or lost fishing gear (ALDFG) (APWC, 2021b), which in return impacts the fishing industry (Lusher, 2017). ALDFG can perform "ghost fishing," which means it can continue to trap fish and crustaceans, as well as ensnaring and capturing other species, while this gear is no longer being controlled (Edyvane and Penny, 2017; National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program, 2015). Ghost fishing, despite not being addressed in this study, which looks only at the direct costs to the fishing sector, is an important aspect to consider when looking at fisheries and marine plastics. Fish ensnared in lost fishing gear can lead to increased fish mortality, reduced fish catch, reduced sustainability of the catch (Erzini, 1997; Butler et al. 2013; 1997) and revenue losses of 5% or even higher (Mathews et al., 1987, Nakashima and Matsuoka, 2004; Tschernij and Larsson, 2003). A Caribbean study reported that traps were the most common type of gear becoming ALDFG, 41%, followed by various types of nets (25%) (Matthews and Glazer, 2009). APWC, based on fisheries statistics and a study by Richardson et al. (2019a), estimated leakage of fishing gear in 2019 in Grenada as follows: (i) 78 nets, (ii) 103 traps and (iii) 2,172 lines. This quantity of gears corresponds to an estimated 17.6 tonnes of plastic leaked that year (APWC, 2021b). In a second estimate, using trade statistics, APWC (2021b) calculations suggest an average of around 3.41 tonnes of fishing gear could leak annually in Grenada's marine environment from its fisheries, providing two estimates of the potential size of ALDFG.

[9] McIlgrom et al. (2020) update this impact estimate to 1% in their more recent study on marine plastics impact in the APEC Region.
[10] **XCD 34,030,069** (USD 12,594,400).

In addition, to the rates at which fishing gear is lost, other factors that contribute to the likelihood of ghost fishing are the gear's degradation rate, which depends on different factors, including for example: water temperature, catch efficiency of the gear, susceptibility of species to ghost fishing, depth where the gear is lost, and/or the tidal and current conditions, which influence whether nets ball up faster or slower (Antonelis et al., 2011; Brown and Macfadyen, 2007; Erzini et al., 1997; Kaiser et al., 1996; Masompour et al., 2018). Thus, although ghost fishing is not included in this study as a direct cost to the fisheries sector, if included, ghost fishing would increase the cost estimates by increasing the estimated losses to the fisheries sector due to marine plastics.

### 3.2.3. Potential risk of marine plastics to tourism (2019)

**Table 12** presents the results on the maximum potential loss that Grenada could suffer if the estimated amount of coastline plastics were accumulating without being removed or ending up on the seafloor. For Grenada, results are the same for each impact transfer, regardless of the plastic accumulation scenario used.

***Table 12 – Estimated results of maximum potential impact on international coastal tourism Grenada (2019)***

| Result based on | Plastic accumulation scenario | Percentage of tourists not willing to visit | Number of tourists not willing to come | Potential loss in revenue (XCD) | Potential loss in revenue (USD) |
|---|---|---|---|---|---|
| Ballance et al., 2000 | Both accumulation scenarios give the same results | 97% | 510,220 | 459,120,065 | 97% |
| Krelling et al., 2017 | Plastic accumulation scenario 1 | 43% | 224,602 | 202,107,493 | 43% |
| | Plastic accumulation scenario 2 | 82.4% | 433,424 | 390,015,396 | 82.4% |

Relative to the contribution of the tourism sector to GDP, the potential risk (i.e., the potential loss in revenue from international tourists visiting Grenada) was estimated to be **XCD 1,240,542,415** (USD 459,120,065) based on Ballance et al. (2000), **XCD 546,094,446** (USD 202,107,493) under plastic accumulation scenario 1 and **XCD 1,053,821,599** (USD 390,015,396) under plastic accumulation scenario 2 both based on Krelling et al. (2017). Thus, the maximum risk to the tourism industry was estimated to be a potential loss equivalent to 37.9%, 16.7% and 32.2%, respectively of Grenada's GDP.

The estimate of the potential impact on tourism is very large. Although marine plastics can have a negative impact on tourism in the Caribbean (see for example Schuhmann, 2011), the actual impact may not be of the magnitude of the potential impact as presented above. For example, UNEP (2014a) and Trucost (2016), assumed that 3% of global marine tourism revenue was lost because of marine litter, including plastics, while McIlgrom et al., (2020) used a value of 1.5% of marine tourism GDP for their study on the economic costs of marine debris to the Asia-Pacific Economic

Cooperation (APEC) economies. These; however, are studies that focus on a global or regional impact, including many countries that are not as dependent on beach-going tourists as Grenada or other Caribbean SIDS. Conversely, Jang et al., (2014) found that visitor numbers at Geoje island's beaches, in the Republic of Korea, decreased by 63% after litter washed up on the beaches after a storm. This is an impact value closer to what was found by Ballance (2000) and Krelling et al. (2017) and is used here in this study to estimate the highest potential impact or overall risk to Grenada's tourism sector.

The potential revenue loss estimates for Grenada are based on the premise that all plastics that could end up on the shoreline accumulate sufficiently to have a visible impact on the aesthetic value of Grenada's marine environment, and particularly its beaches and coastal areas. It also assumes all plastic items have a size that relates to this visible impact. This illustrates the magnitude of risk for Grenada's economy. As a proxy for the actual cost of marine plastics on Grenada's tourism economy in 2019, the costs of cleaning up the entire amount of plastics estimated to end up on Grenada's shoreline is estimated.

### 3.2.4. Coastal clean-up costs (2019)

According to the data of the last five years of the International Coastal Clean-up (ICC), 671-person days were used to clean 4.8 tonnes of plastic from the coastline of Grenada (Ocean conservancy, 2019). This study considers that one person is working eight hours a day. Given that Grenada had an estimated 1,024 tonnes (plastic accumulation scenario 1) of plastics ending up on its coastline, it is estimated that approximately 141,019 person-days would have been needed to clean all the plastics from the coastline in the year 2019. Minimum daily wage for 2019 was at XCD 35.[11] Based on these data, the cost of coastal clean-ups in 2019 – so as not to have an impact on tourism – is estimated to **XCD 4,935,648** (USD 1,826,665) for plastic accumulation scenario 1. **Table 13** displays the details for both plastic accumulation scenarios.

***Table 13 – Estimated coastal clean-up costs according to the two plastic accumulation scenarios (2019)***

| | Plastics (in tonnes) | Coast cleaning cost (XCD) | Coast cleaning cost (USD) |
|---|---|---|---|
| Plastic accumulation scenario 1 | 1,024 | 4,935,648 | 1,826,665 |
| Plastic accumulation scenario 2 | 2,997 | 14,443,281 | 5,345,404 |

These estimated ICC costs will be used in the future scenarios presented in **Chapter 5** to obtain the gross benefit of reducing plastics in the marine environment.

Although these clean-up costs are potentially an overestimation, they should be understood as the minimum cost necessary to prevent plastic accumulation that could potentially impact the tourism industry in the future.

[11] Government of Grenada. 2011. Minimum Wages Order, 2011 (S.R.O. 30 of 2011). Available at GRD95177.pdf (ilo.org).

**Figure 5** presents the risks due to potential losses and the estimated clean-up costs, as well as the total revenue from tourism for 2019 under plastic accumulation scenarios.

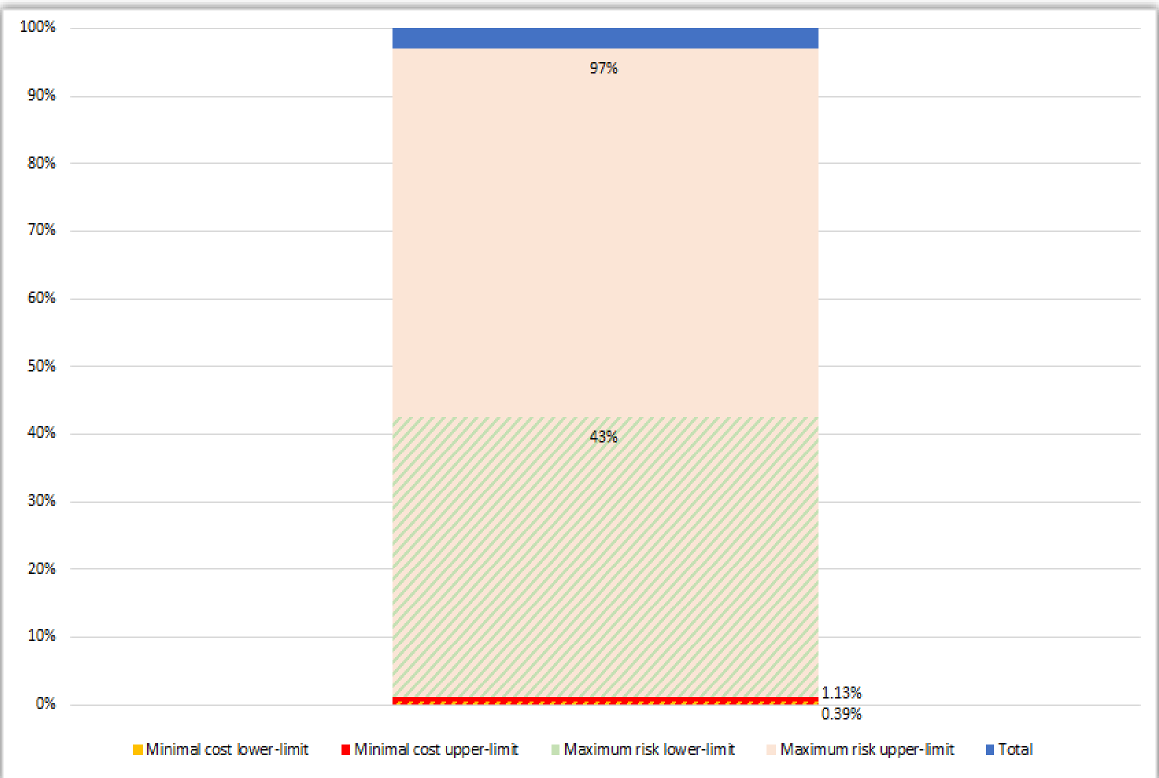



***Figure 5 – Actual and potential costs of plastic pollution to the tourism industry in 2019 and total tourism receipts under plastic accumulation scenarios***

### 3.2.5. Summarised impact (2019)

The impact of marine plastics can be divided into direct costs, which are the cost on fisheries, through loss of revenue, and coastal clean-up costs[12]; and the risk or potential impact (loss in tourism revenue, should plastic accumulation be left unchecked).

The estimated impact in Grenada in 2019 (looking at the direct costs) amounts to **XCD 6,206,366** (USD 2,296,952) under plastic accumulation scenario 1 and **XCD 15,713,999** (USD 5,815,691) under plastic accumulation scenario 2. This impact is equal to 0.19% and 0.48% respectively of Grenada's GDP.

The broader impact (costs to fisheries, and potential loss to tourism revenue) is estimated at between **XCD 552,300,812** (USD 204,404,445) or 16.9% of Grenada's GDP and **XCD 1,256,256,414** (USD 464,935,756) or 38.4% of Grenada's GDP.

[12] The proxy for the effort needed to keep the complete coastline clean by removing all plastic items.

# 4. PROPOSED SOLUTIONS

A broad range of instruments and policies have the potential to decrease the use of plastics and especially reduce plastic leakage into the marine environment, including bans of certain types of plastics, substitutions, or deposit-refund schemes, among others.

Among the recommendations for Grenada to improve its waste management system, APWC (2021b) and IUCN (2022) propose recycling. Including recycling as part of the waste management strategy is also acknowledged by the Grenada Tourism Association (GTA) and Grenada Hotel and Tourism Association (GHTA). Currently there is no systematic recycling or collection of recyclable materials in Grenada. There is only a small recycling facility on the island of Carriacou (IUCN, 2022). Most plastics are disposed of in general mixed waste at the landfill. In addition, APWC (2012b) proposes that the number of litter bins should be increased, as well as increasing the collection time of litter bins. Thus, in the next sections, the solution that will be analysed is establishing a system to collect, separate, and, following the proposed solution for Antigua and Barbuda (Mittempergher et al., 2022) and Saint Lucia (Raes et al., 2022) transport recyclable plastics, to a yet to be established regional recycling hub[13]. The latter focus is important, as according to APWC (2021b), the economies of scale in Grenada do not allow for a major impetus toward recycling because the volume of available material is limited. APWC (2021b) also proposes that recycling should be encouraged through sustainable financial mechanisms. This financing aspect is not considered in the study here.

Plastic segregated at Dumfries landfill (APWC).

In order to include a broader focus on economies of scale, in this study the impact of recycling will be considered first for Grenada alone, but then also from a regional cooperation point of view. The main focus, however, will be the costs and benefits of implementing a broader recycling system in Grenada.

[13] As such a hub does not yet exist, transport costs to Miami are used, which currently already has recycling infrastructure and a well-established container transport system to Grenada.

# 5. IMPACT OF MARINE PLASTICS IN GRENADA UNDER BUSINESS-AS-USUAL (BAU) AND PROPOSED SOLUTIONS (2023-2040)

## 5.1. METHODOLOGY 2 (RECYCLING SCENARIOS)

### 5.1.1. Forecasting of plastics, fisheries, avoided cost on tourism and coastal clean-ups

To estimate the impact of implementing a broader recycling system, two recycling scenarios are proposed, and compared to a business-as-usual (BaU) scenario. The two recycling scenarios are:

1. **National recycling scenario**: Only Grenada will implement strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC (2021b).
2. **Regional recycling scenario:** All the countries of the region will cooperate and start to better manage their mismanaged plastic waste (MPW) as their GDP per capita increases. This scenario is based on Lebreton and Andrady (2019). (See **Annex A3**, where **Table A10** provides the estimated growth rate for each country).

Future plastic flows under a BaU scenario have been estimated using the growth rate of mismanaged waste used by Lebreton and Andrady (2019) for the period 2020-2040 for the non-PWFI countries considered in this study, while estimates from APWC data have been used for data of Grenada (APWC, 2021b), as well as Antigua and Barbuda, and Saint Lucia, where needed (APWC, 2021c and d).

For the national recycling scenario, the potential amount of recycled plastics by Grenada has been obtained from APWC (2021b) data. It corresponds to 46% of the total plastic usage per year. The simulation assumes that Grenada would gradually implement the recycling system (25% implementation rate in 2023, which means that 11.5% of the plastics would be recycled – up to 100% in 2026 and thereafter). In this study it is assumed that a recycling rate of 100% will generate an estimated average reduction of leakage of approximately 60% (U.S. GAO, 1990; Iowa the Policy Project, 2008; Waste et al., 2013; DEC, 2020; COEX, 2020). Thus, a 46% recycling rate implies that, according to the national recycling scenario, Grenada's plastic leakage would be reduced by 27.6%.

In addition, for the fisheries sector, the analysis considers two different scenarios regarding fish stocks:

1. Constant fish catch during the period considered.
2. Fish catch decreases by 0.5% per year, because of climate change, whereby fish stock is estimated to decrease by 0.5% per year (FAO, 2018).

For tourism, to illustrate potential future risk of marine plastic pollution to revenue from the tourism sector, the expected number of tourists without any impact from marine plastic pollution is estimated for the coming decades. The expected growth from 2031 to 2040 in the tourism sector for Grenada is based on an extrapolation of the UNWTO (2011) estimates until 2030, combined with past data on annual growth in this sector (see **Annex A2.2.4** for more details on the extrapolation). This study assumes that tourism will be back to pre-Covid figures in 2025 (**Figure 6**) (McKinsey & Company, 2020).

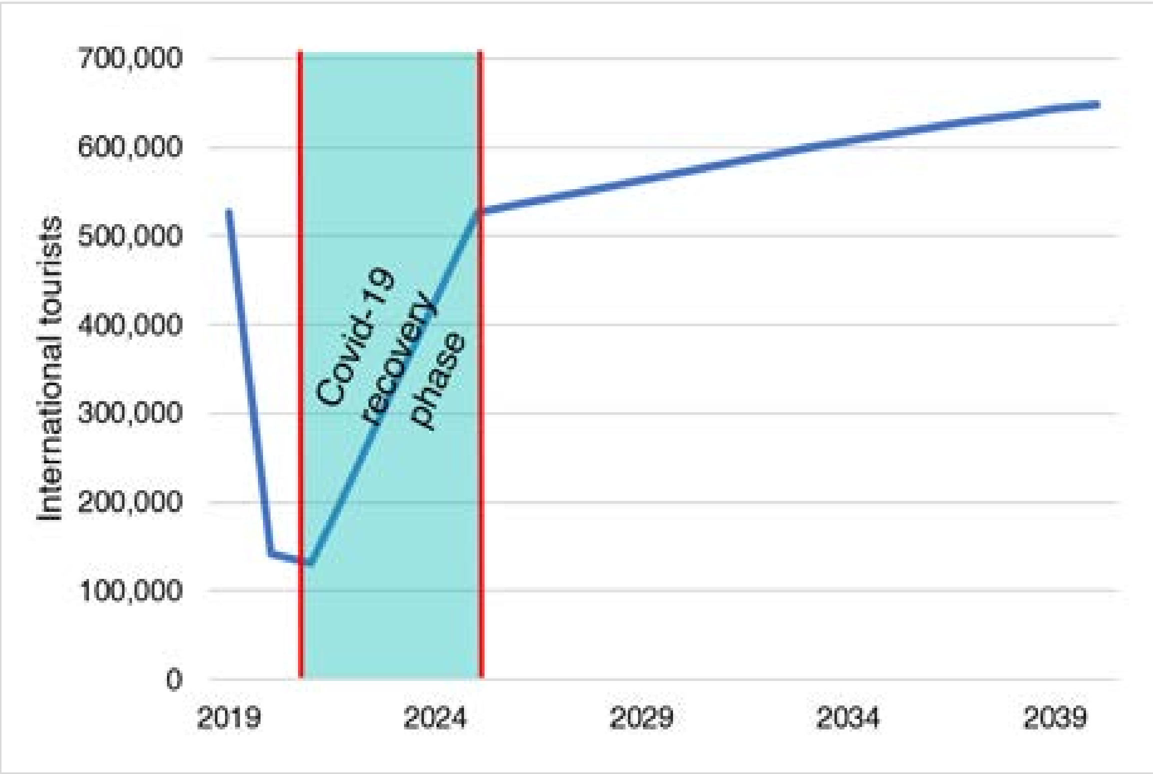



***Figure 6 – Estimated number of international tourists in Grenada (2020-2040)***

The expected continuous increase of tourists in the coming decades indicates that the potential loss of tourism revenue caused by the existence of polluted shorelines will increase, especially if plastic leakage remains the same or, even worse, increases[14]. In the next sections, this study only focuses on estimating the impact on fisheries and coastal clean-ups. However, given the importance of tourism for Grenada's economy, there is potentially a much higher cost related to marine plastics than what is presented here.

[14] Tourism is also an important source of marine plastics (APWC, 2021b).

Lebreton and Andrady's (2019) data on a future scenario of MPW[15] were first used to estimate the impact of marine plastic pollution for the period 2023-2040 under the BaU scenario following the steps shown in **Figure 7**.

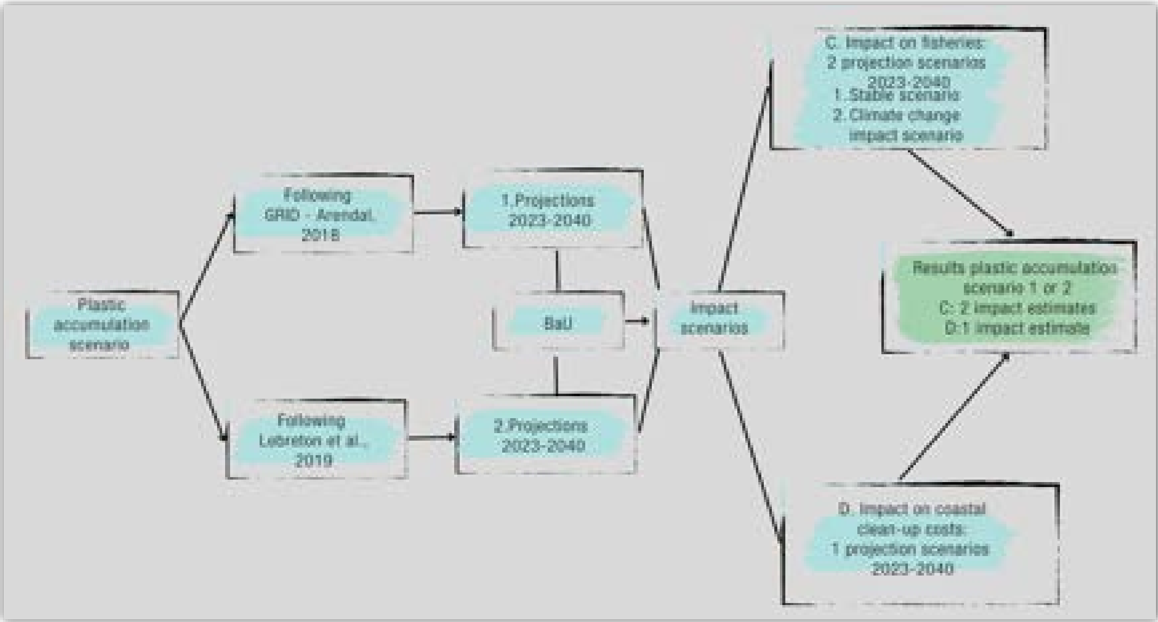



*Figure 7 – Schematic representation of the impact of marine plastic pollution under BaU*

The estimated impact for the two plastic recycling scenarios were then calculated as shown in **Figure 8**.

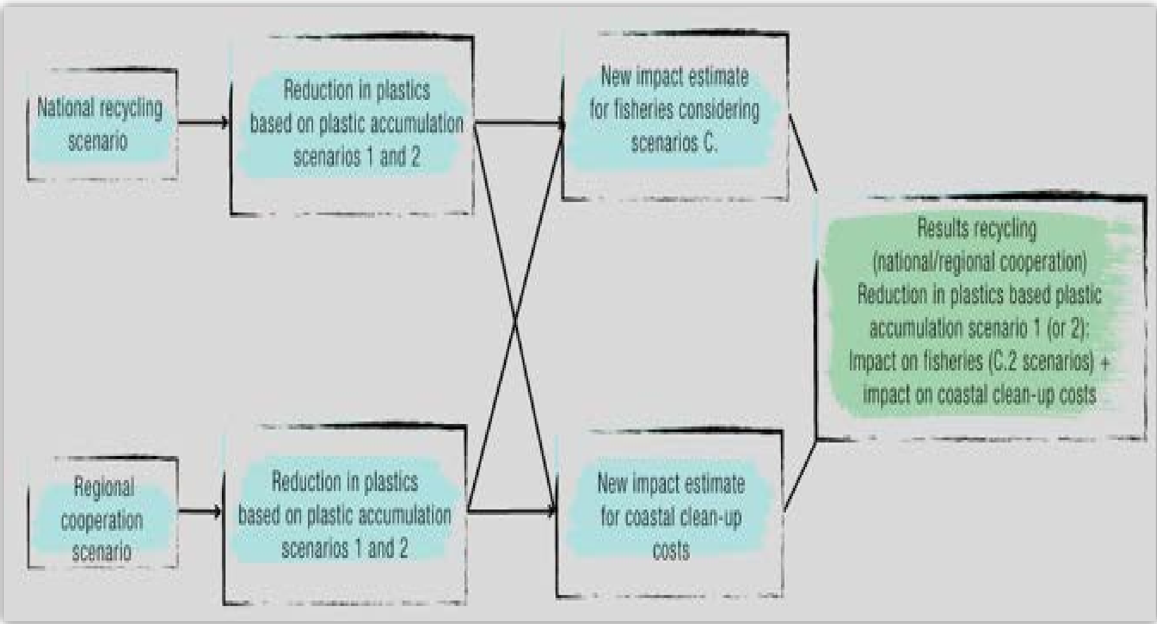



*Figure 8 – Schematic representation of the impact of both recycling scenarios (National recycling and regional cooperation scenario)*

[15] Lebreton and Andrady 2019 published scenarios called "Future emission scenarios". For the BaU scenario, the scenario called "MPW Scenario A" was applied. It assumes that countries will not implement any measures to mitigate plastic emissions.

### 5.1.2. Cost-benefit analysis of BaU versus recycling

To estimate the impact of recycling, and compare this to a BaU scenario, a cost-benefit analysis (CBA) is applied. CBA is an analytical tool used to judge the advantages and disadvantages of an investment or decision by assessing its costs and benefits to put the welfare change attributable to it in perspective. Therefore, it is often used to guide policy alternatives (European Commission, 2014). To conduct a CBA, key considerations are the period of analysis, the discount rate, the different alternatives to be considered and the estimated costs and benefits related to these alternatives.

***Period of analysis***

The period of analysis for all the CBA models was set to 17 years, from 2023 to 2040. The final year of the analysis was based on data available from Lebreton and Andrady (2019).

***Discount rate***

The discount rate is used in the CBA analysis to transform future monetary values to net present monetary values (NPV). By doing this, the cash flows of the system can be compared. There are two key reasons for applying a discount rate. First, individuals normally prefer benefits in the present compared to obtaining them in the future (Boardmand et al., 2011). This assumption is based on the uncertainty of obtaining future benefits compared to the certainty of obtaining the benefits in the present (Staehr, 2006). Second, there is an opportunity cost of forgoing the present benefits for future benefits. In this case, the discount rate represents the opportunity cost of forgoing the benefits of any other investments (Boardmand et al., 2011). Based on this, it is important to decide which discount rate is adequate to use; a higher discount rate represents a higher decrease of future values.

The process in which future values are converted and expressed in terms of present values is called discounting (Boardmand et al., 2011). The discounting process uses a discount rate to convert future values to present values. In this study, the discount rate was calculated as the average of multiple discount rates and is equal to 6.35% (see **Annex A2.1** and **Table A8** for details on its calculation).

***Net Present Value (NPV)***

CBA methodology allows the use of financial indicators to assess the performance of any investment and compare it with others. In this case, the recycling scenarios and the related BaU scenario are compared. To assess the performance of each scenario, the indicator used is the NPV of the BaU and of the two recycling scenarios.

The NPV is the difference between the benefits and cost using the discounting process to get the present net benefits. The result is the NPV of an investment. **Equation 2** shows how to calculate the NPV:

$$NPV = \sum_{t=0}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \qquad (\textbf{Equation 2})$$

Where:

*NPV* = Net Present Value of an investment
*Benefit* = gross benefits of the investment in year t
*Cost* = gross costs of the investment in year t
*T* = period of analysis
t = year; and
r = discount rate

The reference year of 2022 is used to present costs and benefits, and the resulting NPV for the analysis of the impact of recycling.

***Benefits***

The impact of marine plastics on fisheries and coastal clean-ups for the scenarios presented previously is done in the same manner as presented for the impact assessment in 2019. Benefits of implementing the recycling scenarios are based on the reduction of negative impact by implementing recycling on a national or regional basis. Thus, the benefits are calculated based on the difference between the impacts under BaU versus recycling. **Figure 9** illustrates the different steps taken to estimate the benefit of implementing recycling only on a national basis in Grenada under recycling scenario 1 (national recycling scenario):

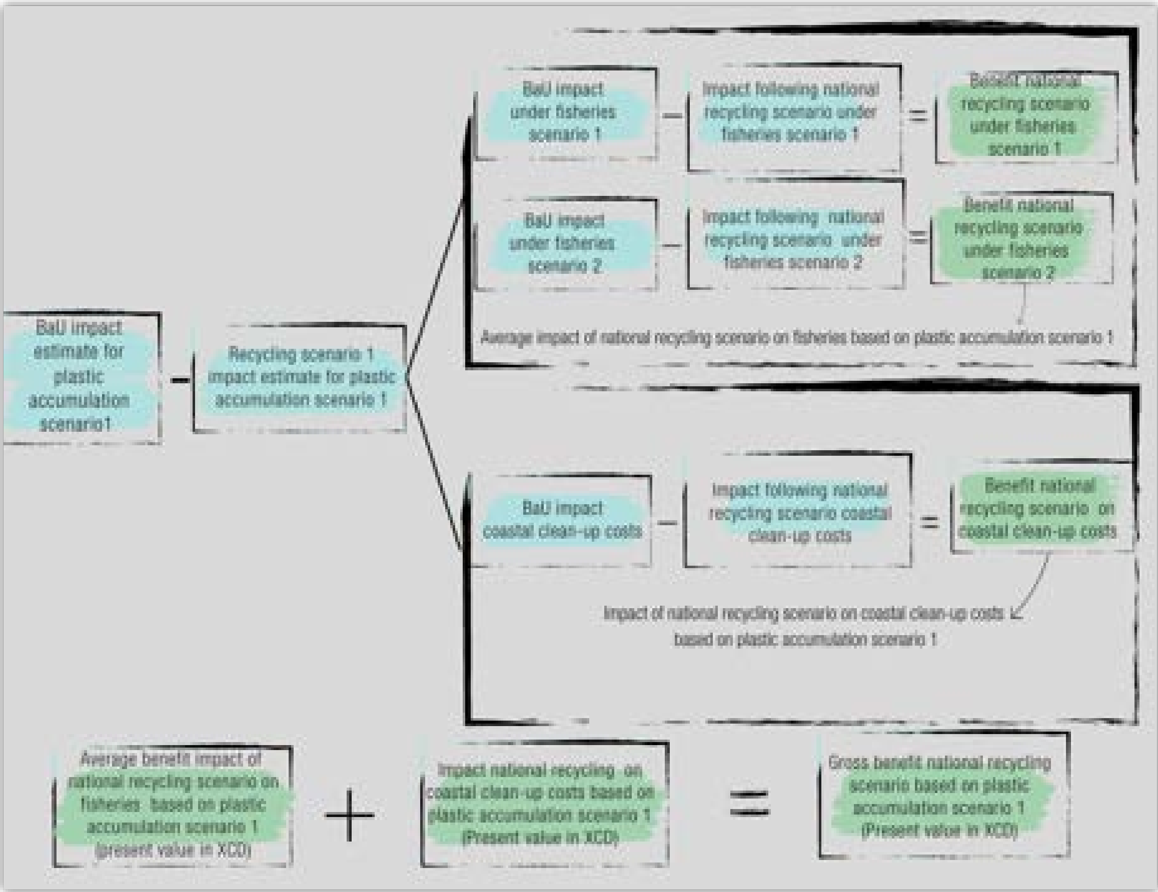



***Figure 9 – Schematic representation of the estimation of the gross benefit for a given recycling and plastic accumulation scenario***

***Costs***

Under BaU, costs were estimated using the total waste management budget (WMB) provided by APWC (2021b).

Under the national recycling and regional cooperation scenario, the final cost of recycling plastics was estimated as follows in **Equation 3**:

$$Final\ Cost_{recycling\ plastic} = (Cost^{WMB}_{recycling\ plastic} + Cost_{recycling\ plastic}) - Cost^{WMB}_{BaU} \quad (\textit{Equation 3})$$

Where,

$Cost_{recycling\ plastic}$ was estimated by including the cost of collection and sorting of plastics as well as its shipping to Miami for treatment (and potential sale afterwards). For collection cost, data from Searious Business (2021) on labour, investment, and fixed costs were used. Sorting costs were estimated using PEW (2020). Finally, Satney, M. (2022) provided data for the shipping costs. As a simplification, no impacts of scale (neither economy nor diseconomy) were considered for the cost of recycling plastics. This means that for any amount of plastics that needs to be recycled, the costs remain constant.

$Cost^{WMB}_{BaU}$ was estimated using the average cost per tonne during 2019 provided by APWC (2021b). An assumption applied was that general waste grows at the same rate as plastic waste.

$Cost^{WMB}_{recycling\ plastic}$ was estimated considering a simplified assumption of a linear relationship between cost and amount of waste collected (i.e., x tonnes of plastics recycled induce a decrease by y% of waste ($\frac{plastic\ recycled}{Total\ waste}$) leading to a savings of y% to the WMB). The same assumption as above was applied, namely that general waste grows at the same rate as plastic waste.

## 5.2. RESULTS RECYCLING SCENARIOS

### 5.2.1. Plastic accumulation scenarios under BaU (2023-2040)

To measure the benefits for the fisheries sector and of a reduction in coastal clean-up costs of increased recycling of plastics, a counterfactual BaU scenario is first constructed (see **Figure 10** for plastic accumulation scenario 1, and **Figure 11** for plastic accumulation scenario 2) (see **Annex A1** for the assumptions used to construct plastic stocks). These figures allow for **isolating which part of the plastic stock that is accumulating is impacting the sectors analysed in this study**; it can either be costs for the fisheries sector or coastal clean-ups. The impact that is not captured corresponds to the plastics that previously got buried into the seabed or shoreline according to the plastic accumulation scenarios[16].

[16] For 2019 and future scenarios, coastal clean-up costs are used as a proxy for overall costs, considering the minimum costs to not continue the increase in plastic accumulation on coast and shoreline, but does not consider

For instance, in 2023, following this study's methodology, 51,088 tonnes of plastics could be found within Grenada's jurisdiction. This study captures the impacts of plastics on the economy in two ways: loss of revenue for the fisheries sector and costs of coastal clean-ups. Fisheries will be impacted by 33,738 tonnes of that stock (shown by the blue part in **Figure 10**). Coastal clean-ups will be impacted depending on the amount of plastics that washes up on land; in this example, the plastics should amount to 1,094 tonnes (shown by the blue part in **Figure 10**). A certain amount of plastics (equal to 16,256 tonnes, shown by the grey hashed section in **Figure 10**) are already buried in the sea floor or shoreline, thus not impacting any of the two activities/sectors considered.

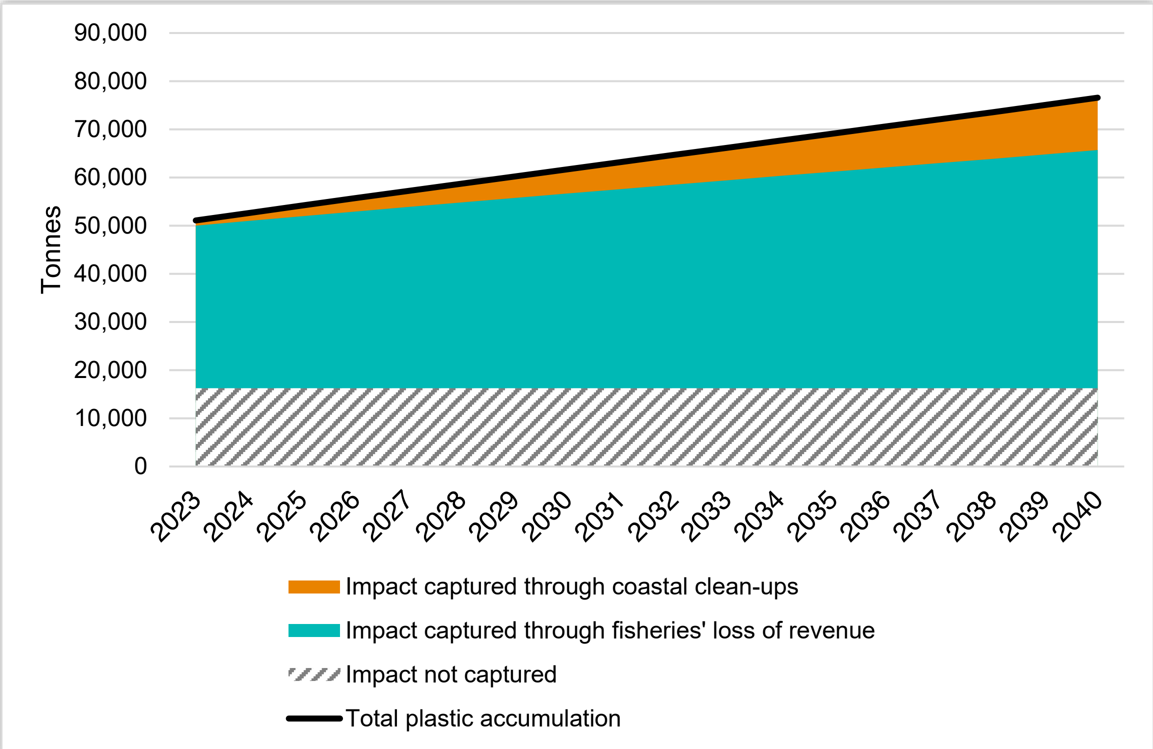



***Figure 10 – Future plastic accumulation under plastic accumulation scenario 1, BaU***

plastics that accumulated in the past. This does not imply it is considered this plastic does not create any impacts, it is just not captured here in this study.

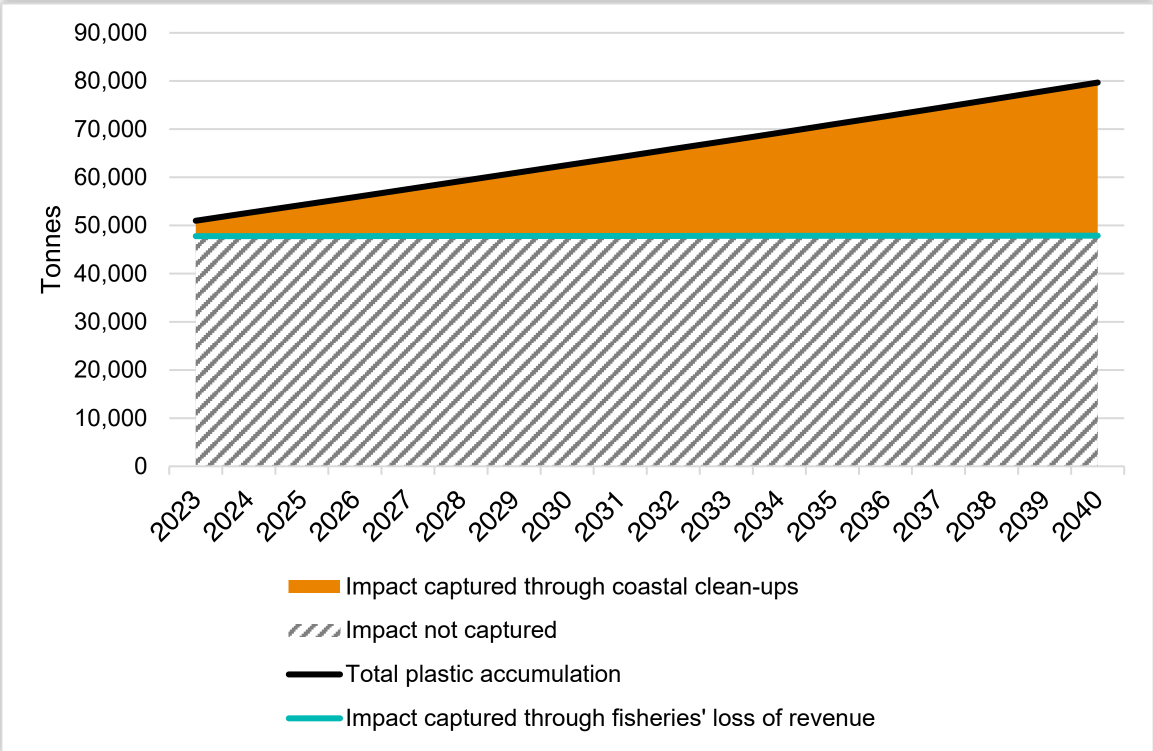



*Figure 11 – Plastic accumulation under plastic accumulation scenario 2*

According to Lebreton and Andrady (2019), leaked plastics in the Caribbean region could increase by an estimated 82% by 2040. Analysing the results for Grenada based on the two different plastic accumulation scenarios yields the results displayed in **Tables 14** and **15** (see **Annex A1.3** for more explanation on the construction of future plastic stocks).

*Table 14 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 1 (in tonnes)*

| Location | Plastics (tonnes) | Percentage increase compared to 2019 |
|---|---|---|
| Sea surface | 520 | 81.6% |
| Coastline and seafloor | 27,115 | 94.9% |
| Coastal waters | 19,790 | 81.6% |
| Open ocean | 40,568 | 81.6% |
| **Total** | 87,994 | 85.5% |

*Table 15 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 2 (in tonnes)*

| Location | Plastics in tonnes | Percentage increase compared to 2019 |
|---|---|---|
| Shoreline | 40,717 | 94.9% |
| Coastal water (less than 200m) | 73 | 81.2% |
| Offshore (more than 200m) | 689 | 81.2% |
| **Total** | 41,479 | 94.6% |

### 5.2.2. Impacts under BaU (2023-2040)

***Impacts fisheries BaU (2023-2040)***

Having estimated the future stock of plastics for each year between 2023 and 2040 (see **Annex A2, Annex A2.2.1, Annex A2.2.2** and **Annex A2.2.3** for details), the impacts, benefits, and costs of recycling for that period can also be estimated. In the following sections, these estimates will always be presented twice. First, by giving their future value, and second by presenting them in present value using a discount rate of 6.35%.

The total future value of the costs for the period (2023-2040) to the fisheries sector is estimated at **XCD 34,443,280** (USD 12,747,327). By using the average discount rate of 6.35%, the present value is estimated to amount to **XCD 18,873,083** (USD 6,984,856). This value is more or less the same for both plastic accumulation scenarios, so only one value is used for both.

***Coastal clean-up costs BaU (2023-2040)***

The total value of the **coastal clean-up costs is** estimated to amount to **XCD 109,240,610** (USD 40,429,537) in future value and **XCD 60,317,464** (USD 22,323,266) in present value under the **plastic accumulation scenario 1,** and to **XCD 319,682,759** (USD 118,313,382) in future value and **XCD 176,513,599** (USD 65,327,017) in present value under **plastic accumulation scenario 2**. **Annex A2.2.5** and **Annex A2.2.6** provides more details.

*Fishing vessels docked in Grenada (APWC).*

***Overall direct cost mismanaged plastics (2023-2040)***

The future and present values of the overall impact, direct cost to the fisheries sector and clean-up costs are displayed in **Table 16**. They depend on which plastic scenario is chosen; thus, four different values are presented.

***Table 16 – Future and present values of the overall direct costs to fisheries and coastal clean-ups (2023-2040) (discount rate: 6.35%)***

| Plastic Accumulation Scenarios | | |
|---|---|---|
| | **Scenario 1 (XCD)** | **Scenario 2 (XCD)** |
| Future value | 143,683,890 | 354,126,039 |
| Present value | 79,190,547 | 195,386,682 |

## 5.2.3. Cost of implementing the recycling scheme

The operating cost of the general waste management system is estimated to amount to XCD 267.2 per tonne of waste (details in **Annex A3.5**).

Establishing improved infrastructure to collect and store general waste, such as bins with lids for all households comes at a cost. This estimated cost per tonne of recycling plastics is presented in **Table 17** (details in **Annex A3.4**). **Figure 12** compares the WMB under the BaU scenario with the WMB under the recycling scenario, which is combined with the cost of recycling. The difference between the two waste management scenarios is presented in **Figure 13** and is equal to the actual cost of recycling.

***Table 17 – Estimated costs of recycling per tonne of plastics (2019)***

| Types of cost | | XCD per tonne | USD per tonne |
|---|---|---|---|
| Collecting cost | Labour cost | 149.8 | 55.4 |
| | Investment cost | 28.4 | 10.5 |
| | Fixed cost | 30.0 | 11.1 |
| Sorting cost | | 356.4 | 131.9 |
| Shipping cost | | 73.9 | 27.3 |
| **Total** | | **638.5** | **236.3** |

*Source: Searious Business, 2021; PEW, 2020.*

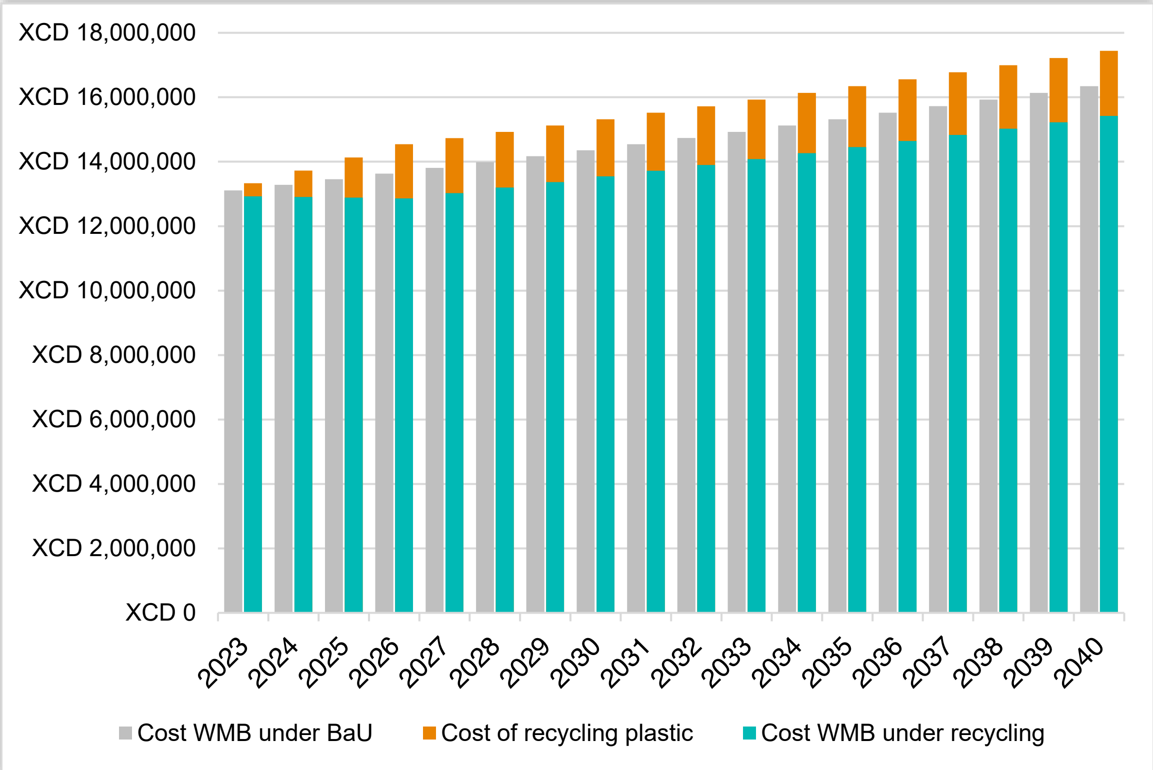



*Figure 12 – Estimated cost of recycling, and the waste management budget under BaU scenario and the national recycling scenario (XCD/year)*

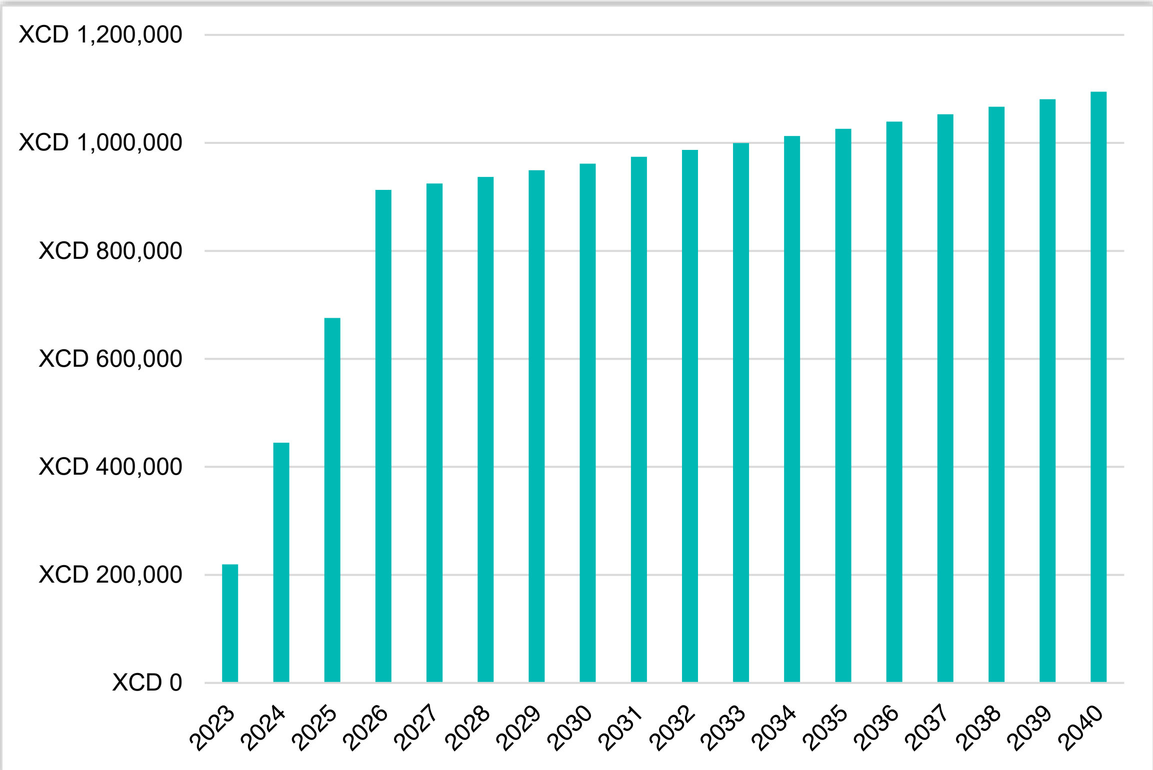



*Figure 13 – Actual cost of recycling (XCD/year)*

The future value of the overall cost is estimated to be **XDC 16,361,451** (USD 6,055,311). Applying the discount rate of 6.35% results in an estimated present value of **XCD 8,630,517** (USD 3,194,122).

### 5.2.4. Recycling scenarios – plastic stocks (2023– 2040)

The impact in terms of the amount of plastics under the two recycling scenarios (national recycling and regional cooperation) is displayed in **Figure 14** for the fisheries sector and in **Figure 15** for the coastal clean-ups.

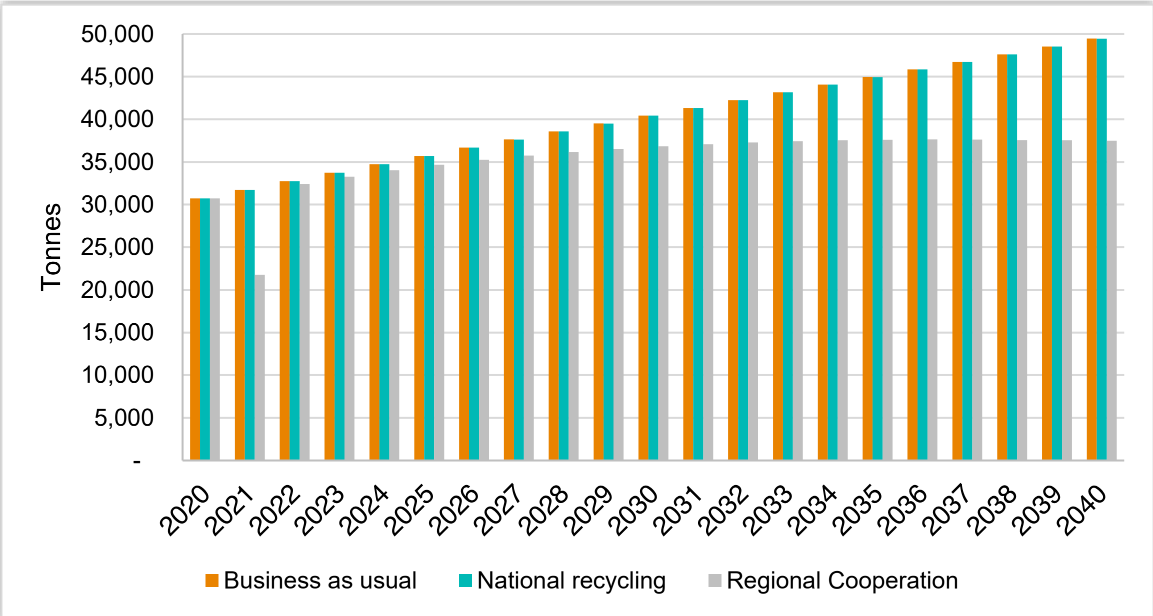



***Figure 14 – Estimated tonnes of plastics in Grenada's waters under the three future plastic management scenarios***

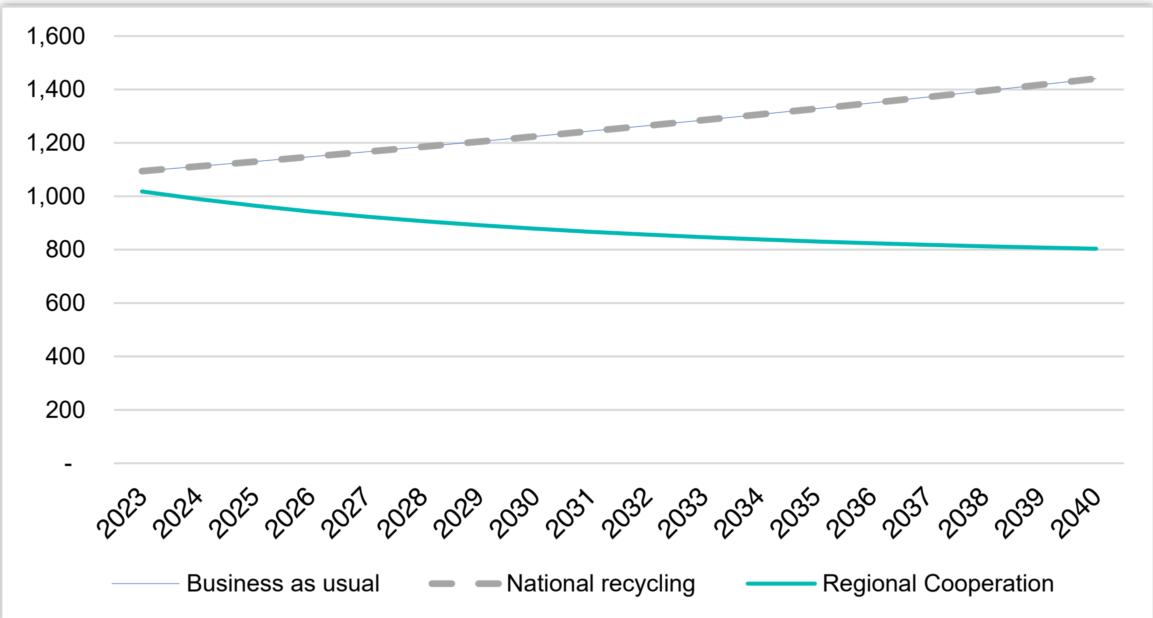



***Figure 15 – Estimated tonnes of plastics ending up on Grenada's shoreline each year under the three future plastic management scenarios***

### 5.2.5. National recycling scenario: costs and benefits of national recycling

The estimated future value of the reduction in loss of revenue for the fisheries sector is **XCD 4.039** (USD 1,494) while the present value is **XCD 1,918** (USD 709). **Table 18** presents the future values of the reduction of coastal clean-up costs under the two plastic accumulation scenarios compared to the BaU scenario while **Table 19** shows the present value of the same estimations (discount rate of 6.35%). Details are available in **Annex A3.1**, **Figure A6** for the fisheries sector and **Annex A3.2, Table A12** for the coastal clean-ups.

***Table 18 – Future value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 24,930 | USD 9,227 | XCD 72,956 | USD 27,001 |

***Table 19 – Present value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 13,236 | USD 4,899 | XCD 38,734 | USD 14,335 |

### 5.2.6. Regional recycling scenario: benefits of regional implementation of recycling

The future value of the reduction in loss of revenue for the fisheries sector is **XCD 4,110,460** (USD 1,521,265), while the present value is **XCD 1,788,593** (USD 661,951).

The future values of the reduction of the coastal clean-up costs are displayed in **Table 20**. **Table 21** shows the present value of the benefits of a reduction in coastal clean-up costs in Grenada. The calculations follow the same methodology used for the national recycling scenario, details of which are available in **Annex A3.3**, **Figure A7** for the fisheries sector and **Annex A3.2**, **Table A13** for the coastal clean-ups.

***Table 20 – Future value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 32,977,066 | USD 12,204,688 | XCD 96,504,399 | USD 35,715,914 |

***Table 21 – Present value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 15,955,538 | USD 16,418,181 | XCD 46,692,438 | USD 48,046,322 |

The benefits of the national recycling scenario alone for both sectors are relatively low. This result stems from the fact that the existing stock (impacting fisheries) and the additional plastics accumulating every year (impacting both fisheries and clean-up costs) – based on this study's assumptions – come mostly from elsewhere. The Lebreton and Andrady (2019) dataset on countries' MPW shows that Grenada occupies the 25th rank out of 35 counties of the Caribbean region in terms of MPW. Therefore, Grenada's efforts to reduce its plastic pollution will only contribute to decreasing the amount impacting the country by a small fraction; hence, the relatively low benefits displayed above. Contrasting the national recycling scenario results with the benefits from the regional cooperation scenario. Results also highlight the importance of nations working together to efficiently tackle marine plastic pollution.

### 5.2.7. Overall results national and regional recycling scenarios

**Figures 16** and **17** show the annual benefits of both recycling scenarios (national and regional cooperation) as well as the annual costs of implementing a national recycling system. **Figure 16** shows the results under plastic accumulation scenario 1, while **Figure 17** shows results under plastic accumulation scenario 2. Results are displayed both in discounted and non-discounted values. **Table 22** shows the net future and present values of the regional cooperation and national recycling scenario. Negative values are highlighted in light orange whereas positive values are highlighted in turquoise.

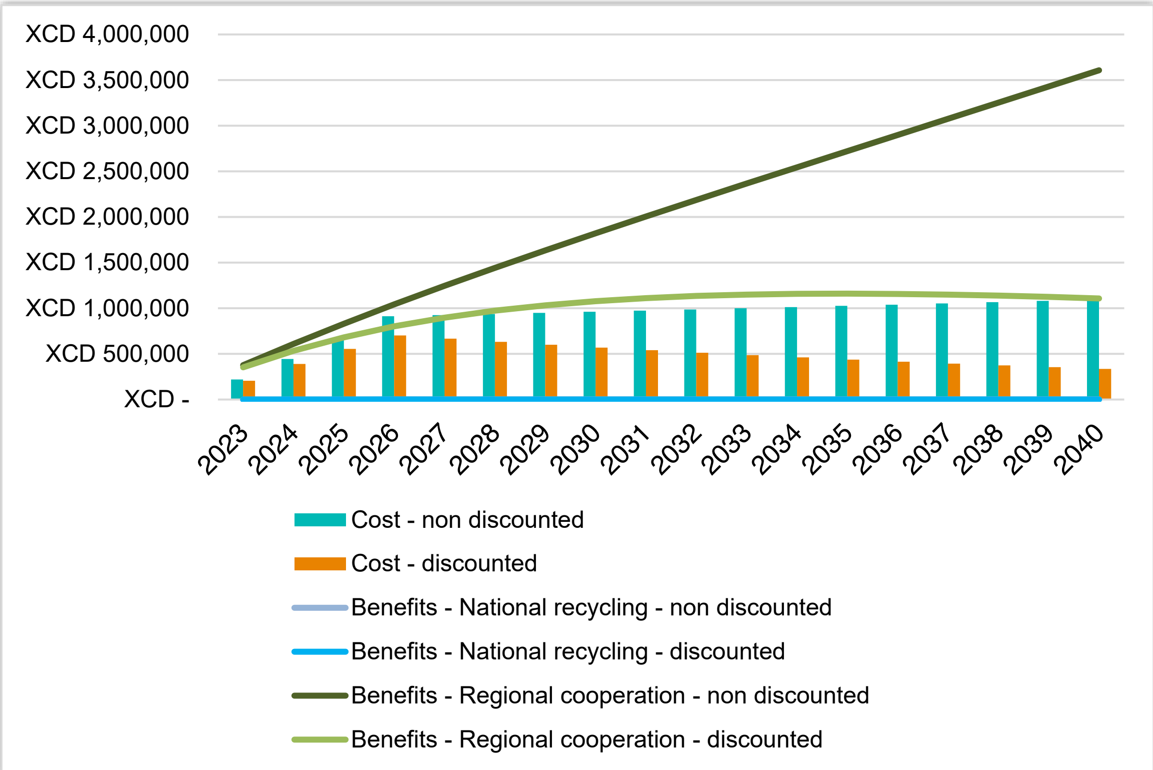



*Figure 16 – Cost of recycling plastics for Grenada (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 1 (future and present values) (discount rate: 6.35%)*

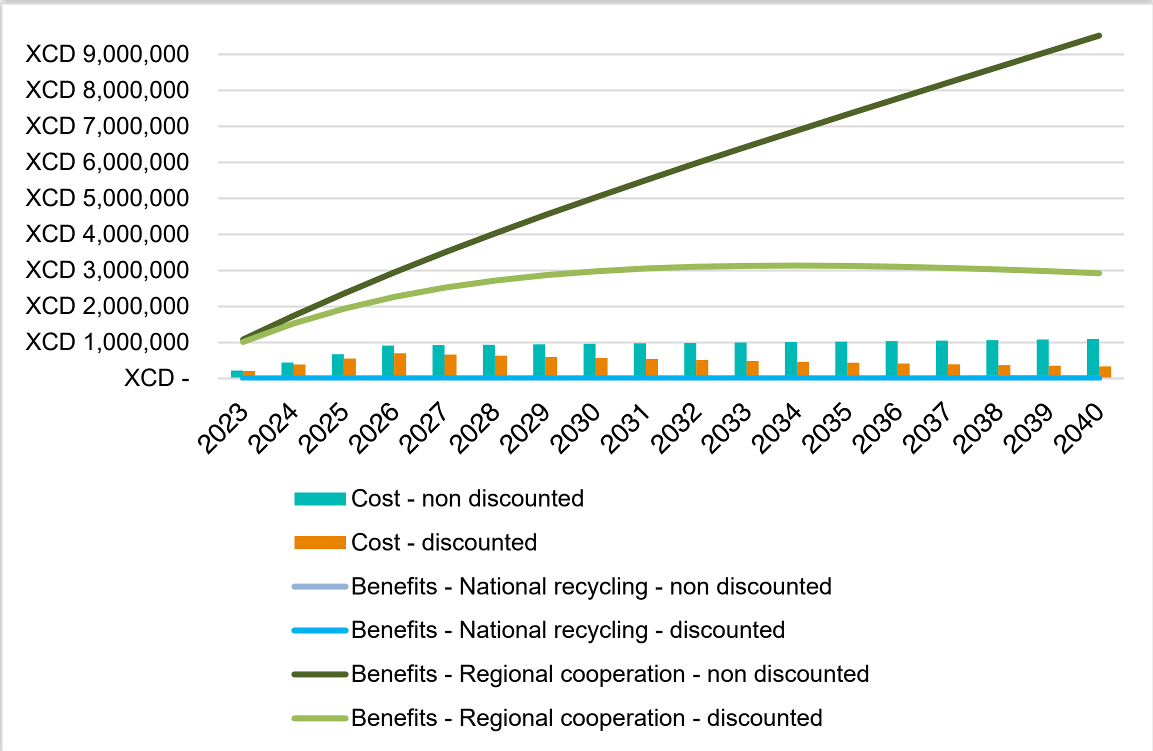



***Figure 17 – Cost of recycling plastics for Grenada (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 2 (future and present values) (discount rate: 6.35%)***

**Table 22** shows that none of the national recycling scenarios are profitable based on the benefits and costs considered, and without or with applying the discount rate used. However, under the regional cooperation scenario, for both plastic accumulation scenarios, the benefits of a regional reduction in MPW greatly overcome the costs of implementing recycling in Grenada.

***Table 22 – Net future and present values of the national and regional cooperation scenario under both plastic accumulation scenarios (discount rate used: 6.35%)***

| Recycling Scenario | Plastic Accumulation Scenarios | Net Future Value | | Net Present Value | |
|---|---|---|---|---|---|
| | | XCD | USD | XCD | USD |
| National recycling | 1 | -16,332,482 | -6,044,590 | -8,615,363 | -3,188,513 |
| | 2 | -16,320,799 | -6,040,266 | -8,589,865 | -3,179,077 |
| Regional Cooperation | 1 | 20,726,076 | 7,670,642 | 9,113,615 | 3,372,914 |
| | 2 | 84,253,409 | 31,181,869 | 39,850,514 | 14,748,525 |

This result diverges from the outcome of Saint Lucia (Raes et al., 2022) (where no scenario is profitable when looking at the net present value). This difference stems from the fact that the minimum wage of Grenada used here is higher (more than 2.6 times the Saint Lucian one); and that according to the data used, less plastics per person per day is collected (47% the amount collected in Saint Lucia). In Grenada – as compared with Saint Lucia – more people at a higher wage are required to collect the same amount of plastic during coastal clean-ups, making initiatives to reduce plastic pollution more cost efficient there.

However, not all benefits from recycling and reducing plastic leakage have been considered thus far. For instance, plastic scraps can be sold on the appropriate


*Prototype of bench made of recycled plastics (Searious Business).*

market, the price depending on various factors such as the country, the type of polymer, and/or the quality. Grenada could resell some or all its recycled plastics. For example, if the average price of USD 245.5[17] per tonne, observed in the EU is applied (Eurostat, 2021), then the present value of the recycled plastics for Grenada would amount to **XCD 18,120,539** (USD 6,706,343) for the period considered, creating additional benefits. This price is potentially higher than what could be obtained in a market accessible for Grenada's plastic scrap material. To breakeven in NPV over the 18-year period considered, Grenada would need to resell the plastics at least at a constant price of **XCD 314.5** (USD 116.4) per tonne under the least profitable scenario (national recycling under plastic accumulation scenario 1) and **XCD 315.4** (USD 116.7) per tonne under the best case (regional cooperation under plastic accumulation scenario 2).

Furthermore, sending containers with recyclable plastics back to the port of origin can potentially have a positive price effect. As many goods in Grenada are imported, sending back full containers (with plastics for recycling) could potentially reduce the costs of marine transport for imported goods within the country.

Additional benefits could also be generated not only through the sale of plastics as raw materials for recycling, but also by directly using collected plastics for the development of alternative value chains. For example, within the PWFI project, Searious Business (2021) has developed alternative value chains for recycled plastics. In Grenada a product concept to recycle plastics for the production of beams, planks, tiles and parts as semi-finished products; and outdoor public and private furniture as end products. An improved recycling system and especially the development of alternative value chains can also generate employment opportunities.

Finally, Grenada has two functioning landfills (the Perseverance and Dumfries landfills). Combined, they still have four years of remaining capacity (APWC, 2021b). By reducing the amount of waste that ends up at the landfill, this lifespan can be moderately extended, providing another financial benefit for the waste management system (Graham et al., 2022).

[17] Exchange rate of 1.0031 USD per EUR used to convert Eurostat (2021) data (Exchange rate retrieved on 15 July 2022).

*Dumfries Landfill, Carriacou Island (APWC).*

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influence costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example, to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Grenada.

# 6. OTHER ASPECTS OF THE IMPACT OF MARINE PLASTIC POLLUTION AND INSTRUMENTS TO REDUCE IT

## 6.1. ADDITIONAL ECONOMIC AND SOCIAL BENEFITS

***Employment***

Fisheries and agriculture contribute 4.9% of the country's GDP (Statista, 2022). More specifically, fisheries make up to 31% of the GDP of the agriculture sector (FAO, 2022).

If plastic pollution accumulating on the coastline decreases the number of visitors, this will not only reduce the revenue generated by the tourism sector but can also have a significant impact on the number of people employed in this sector. Tourism has become the economic base for Grenada, contributing to 44.4% of all jobs in 2019, 25,200 jobs in total (WTTC, 2022).

Marine plastic pollution has a negative impact on fisheries revenue, and consequently also on the number of people employed in the fisheries sector. In 2017, there were around 3,500 fishers in Grenada. Of these, 86 percent were employed full time. There were also 400 people indirectly employed in in fisheries through marketing, transport and boat building among others (FAO, 2022)[18]. In addition, according to FAO (2022), fisheries are an important security net for the population, especially in moments when other means of income vanish, for example after hurricanes, when fisheries recover quicker than other sectors, Finally, in Grenada most of the rural communities are fishing communities (FAO, 2022).

***Food security***

In the Caribbean, fisheries not only contribute to employment and household income, but also to food security (Bovarnick et al. 2010). In 2017, Grenada had a per capita consumption of around 27.9 kilograms, among the highest levels of consumption in the Caribbean and the American continent overall (FAO 2022). In addition, FAO (2022) mentions that The Grenada Food and Nutrition Security Policy and Action Plan 2013-2018 makes abundant reference to sustainable fisheries, emphasising the importance of fishery products for food security. Marine plastics can affect food security both

[18] CRFM (2021) reports for 2019 2,552 persons employed in direct production in the marine commercial capture fisheries, and 7,656 persons employed in other fisheries dependent activities. This constitutes 18.5% of the total labour force employed in fisheries 2019.

directly through reduced fish stock, but also by contaminating fish with macro- and microplastics.

### *Balance of trade*

Tourism is responsible for contributing to 43.6% of GDP in 2019 and is the primary source of foreign currency (WTTC, 2020). Although smaller in magnitude in terms of contribution to the GDP (between 1.28% in 2017 and 1.04% in 2019), a reduction in fish capture will also have an impact on the balance of trade, as reduced local production may increase fish imports (CRFM, 2021). In 2017, an estimated USD 5.2 million of fish and fish products were exported and USD 2.7 million imported. Fish is one of the few products for which the island is self-sufficient. Finally, there is also a link between fisheries and tourism, as Grenada has an active recreational fishery sector (FAO, 2022).

### *Other impacts*

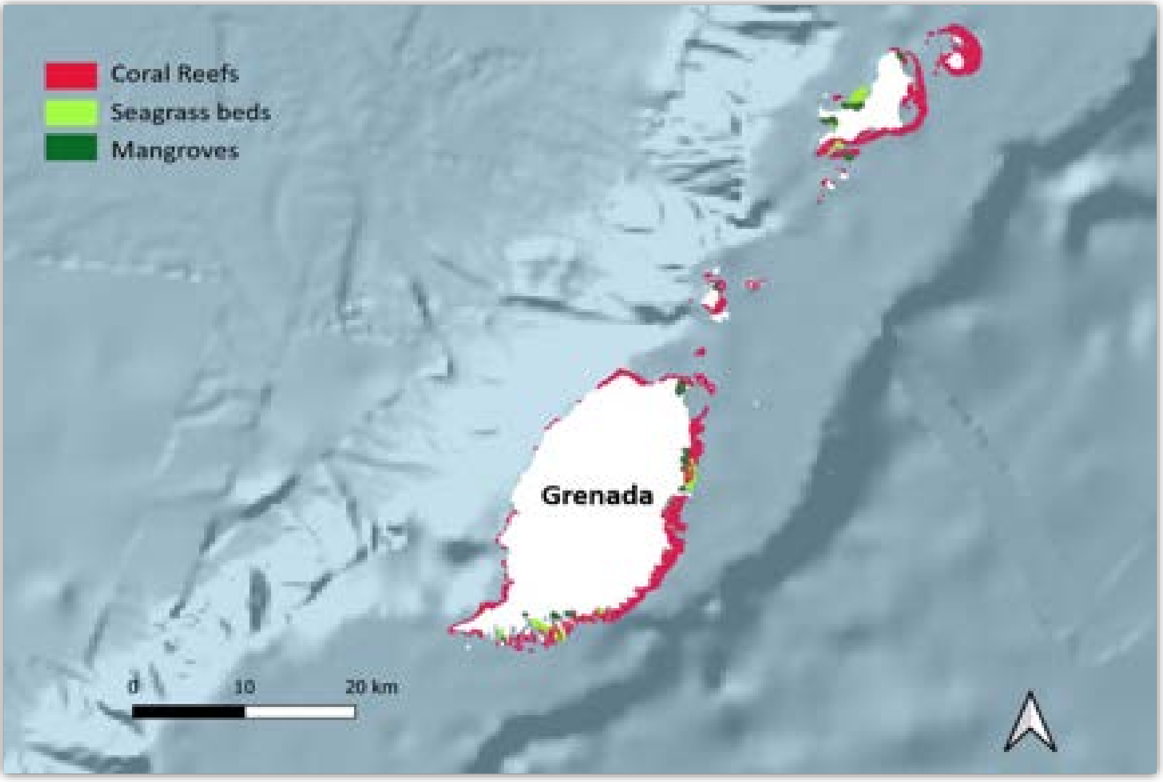
Although the aim of this study was to analyse the direct cost of marine plastics on the fisheries and tourism sectors, and the potential effects from activities to reduce this, marine plastics is not the only problem affecting these sectors and the economy of Grenada in general. the biggest impact on the tourism sector in Grenada have been hurricanes, such as Hurricane Ivan which in 2004 caused damages twice Grenada's GDP at that time, and the global travel restrictions following the outbreak of covid-19, creating the worst economic crisis in a century (UNDP, UNICEF, and UN Women, 2020; USAID, 2021). Although improving, the tourism sector has not yet fully recovered. In addition, the tourism sector is also vulnerable to the impact of climate change (Government of Grenada, 2017), manifested by: sea level rise, an increased frequency and intensity of storms, which can deter tourists from visiting the island, and coastal erosion, which can create a loss or degradation of tourism resources such as beaches (Government of Grenada, 2014; 2017).

While this study includes a climate change impact scenario in the future fisheries revenue estimates, the full extent of the impact of climate change – including for example: shifting fish migration and distribution patterns, changes in reproduction of certain fish species, or altered habitats of fish species, and impacts of more frequent extreme weather events on fishing efforts (Government of Grenada, 2017; CMEP, 2022; CANARI, 2019; Palacios-Abrantes et al., 2022) – has not been considered. Furthermore, in addition to the potential long-term impact of ghost fishing, Caribbean fishery resources are among the most overexploited in the world; regional production has declined by more than 40% over the last two decades (FAO, 2014). 54% of species or species groups in the Caribbean are considered overfished or over-to-fully fished (Western Central Atlantic Fishery Commission 2017). Overexploitation is the main threat to bony fishes in the Caribbean; it directly affects half the species in the greater Caribbean listed by IUCN as globally 'threatened' or 'near threatened' (Linardich et al., 2017).

## 6.2. IMPACT ON MARINE AND COASTAL ECOSYSTEMS

Beyond the direct impact of marine plastics on fish stocks, there are several challenges that could seriously impact the future of marine natural assets. Grenada's coastal zone and marine ecosystems are not only characterised by beaches, but also by mangroves (180 ha, FAO, 2020), seagrass beds (1,023 ha, UNEP-WCMC et al., 2021a) and coral reefs (8,700 ha, Sea Around Us, 2005; Spalding and Grenfell, 1997) (**Map 3**). These ecosystems not only play an increasingly vital role in tourism but are also an integral component in natural coastal defence and the ecology of the island. Coastal and marine resources also provide for livelihoods in several rural communities in the fisheries sector, as well as for recreation, sports, and enjoyment, and are an overall source of employment for many people (Government of Grenada, 2017; Reguero et al. 2018; Ruttenberg et al., 2018).

Coral reefs, mangroves and seagrass beds provide a range of key ecosystem services, such as protection of the shoreline from erosion and storm damage, breeding grounds for many species of fish and other marine species, water purification, disease control, carbon sequestration, nutrient cycling, sediment reduction, and recreation (Barbier et al., 2011; Luisetti et al., 2013; Ondiviela et al., 2014; Dudley et al., 2010, 2015; Mtwana Nordlund et al., 2016; Government of Grenada, 2017; Ruiz-Frau et al., 2017; Himes-Cornell et al., 2018; CANARI, 2019). These essential ecosystem services underline the importance of conserving and restoring these ecosystems. In addition, some species – specifically certain coral species – have a critical or vulnerable conservation status (Figure 18).




*Source: Giri et al., 2011; UNEP-WCMC, 2021a, UNEP-WCMC, 2021b.*

***Map 3 – Areas of coral reefs, seagrass beds, and mangroves in Grenada***

| RED LIST | Warm-water corals | Mangroves | Seagrasses | Coral-water corals |
|---|---|---|---|---|
| CR Critically Endagered | 2 | 0 | 0 | 0 |
| EN Endangered | 3 | 0 | 0 | 0 |
| VU Vulnerable | 6 | 0 | 0 | 1 |
| NT Near Threatened | 1 | 0 | 0 | 0 |
| LC Least Concern | 42 | 7 | 4 | 7 |
| DD Data Deficient | 4 | 0 | 0 | 0 |
| Total: | 57 | 7 | 4 | 8 |

*Source: https://habitats.oceanplus.org/grenada.*

***Figure 18 – IUCN Red List status of coral, mangrove and seagrass species in Grenada (2022)***

Coral reefs, seagrasses and mangroves are affected by marine plastics (NOAA Marine Debris Program, 2016; Tekman et al., 2022). For example, plastic debris interferes directly with the ecological role of mangrove forests (Ivar do Sul et al., 2014) and obstructs water flows in mangrove areas (Kantharajan et al., 2018). Coral populations can decrease significantly as the amount of litter increases (Richards and Beger, 2011; Yoshikawa and Asoh, 2004). Plastics can also increase the degree of disease contracted by corals (Lamb et al., 2018). Marine litter can also negatively affect seagrass ecosystems (Ganesapandian et al., 2011). Abandoned fishing gear damages seagrass beds by re-suspending sediments, disturbing rhizomes, and impacting the root structure of seagrasses (Barnette, 2001). In addition, mangrove forests and seagrass beds function as both traps and filters for marine plastics, including microplastics (Debrot et al., 2013; Sanchez-Vidal et al., 2021).

The impact of plastics should not be seen as an isolated effect. Plastic pollution is an additional stressor on marine ecosystems that are already dealing with multiple stressors (Lartaud et al., 2020; Tekman, 2022). Climate change causes coral bleaching (Petit and Prudent 2010; Siegel et al., 2019), ocean acidification (Bégin et al., 2016), and rising sea levels, accompanied by more frequent and severe storms (Sippo et al., 2018; Hughes et al., 2017). Further impacts occur through pollution from leakage of sediments, fertilisers and pesticides, and chemicals (Orth et al., 2006; Silbiger et al., 2018; van Dam et al., 2011), as well as due to overfishing (Burke et al., 2011; Zaneveld et al., 2016), unsustainable tourism (Burke et al., 2011; Lamb et al., 2014), algal blooms (Franks et al. 2016), sand mining (Government of Grenada, 2014), and invasive species (Biswas et al., 2018; Unsworth et al., 2019).

An ecosystem's degradation caused by plastic pollution in marine and coastal habitats impacts tourism, the fish stocks that depend on these habitats, as well as marine wildlife in general. Marine biodiversity that is not directly targeted by fisheries – such as seabirds and marine mammals – are not only impacted through habitat degradation, but also suffer directly from marine plastic pollution.

## 6.3. IMPACT ON MARINE WILDLIFE

There are 11 marine mammals that are found in the waters of Grenada, two of which are currently listed as "vulnerable" (Romero et al., 2002; IUCN, 2021). There are also five sea turtle species out of which four species are listed as "threatened" (CMS, 2020; CBD, 2014). There are at least 16 seabird species in Grenada, two of which are currently listed as "threatened" (BirdLife International, 2022; World Bank, 2018b) (**Table 23**).

***Table 23 – IUCN Red List status of threatened marine species in Grenada (2022)***

| | | |
|---|---|---|
| **Marine mammals** | | |
| Sperm Whale | *Physeter microcephalus* | Vulnerable |
| American Manatee | *Trichechus manatus* | Vulnerable |
| **Sea turtles** | | |
| Green Turtle | *Chelonia mydas* | Endangered |
| Loggerhead Turtle | *Caretta caretta* | Vulnerable |
| Leatherback | *Dermochelys coriacea* | Vulnerable |
| Hawksbill Turtle | *Eretmochelys imbricata* | Critically endangered |
| **Seabirds** | | |
| Black-capped Petrel | *Pterodroma hasitata* | Endangered |
| Leach's Storm-petrel | *Hydrobates leucorhous* | Vulnerable |

*Sources: Taylor et al., 2019; Deutsch et al., 2008; Seminoff et al., 2004; Casale et al., 2017; Wallace et al., 2013; Mortimer et al., 2008; BirdLife International, 2018a ; BirdLife International, 2018b.*

Marine plastics can also be a danger to marine fauna. Kanhai et al., 2022, classify the impact of marine plastics on biodiversity as follows: (1) Biological effects (e.g., plastic ingestion); (2) Physical effects (e.g., entanglement); (3) Ecological effects (e.g., introduction of invasive alien species); and (4) Chemical effects (e.g., transporter of pollutants). Tekman et al. (2022), in their extensive literature review on the effects of plastic debris and hazardous substances on marine species, classify these impacts on marine fauna as: (i) Physical interactions, specifically: entanglement, ingestion, colonisation, and contact or coverage; and (ii) Chemical interactions: additives and absorbed substances.

The interactions have impacts on marine species such as seabirds, sea turtles, marine mammals, sharks, rays, and sponges (Tekman et al., 2022). According to the Convention on Biodiversity (CBD) Report, 'Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity' (2016), the total number of species known to be affected globally by marine debris (mainly plastics) is around 800; of those, the proportion of cetacean and seabird species affected by marine debris ingestion is 40% and 44%, respectively (CBD, 2016).

**Ingestion:** A wide range of animals ingest plastics. Certain marine animal populations – especially those that feed exclusively at sea, such as seabirds and sea turtles - present plastic debris in their stomachs (Hammer et al., 2012; Wilcox et al., 2015). Sea turtles can, while feeding, ingest plastic debris at all stages of their lifecycle (Mascarenhas et al., 2004), which can potentially have lethal consequences (Schuyler et al., 2014). For example, Wilcox et al. (2018), found a 50% probability of mortality once the sea turtles they analysed had 14 pieces of plastics in their digestive system. Discarded and semi-inflated, floating bags are of particularly hazardous as they are often mistaken for jellyfish and can block the oesophagus once ingested (Gregory, 2009). Tekman et al. (2022), analysing the studies collected in the LITTERBASE database[19], found a total of 272 seabird species had encountered plastic debris by ingestion. Reinert et al. (2017), found that 11% of 6,561 examined manatees had ingested marine debris or had become entangled, 50 of which died as a direct result.

**Entanglement:** happens if a plastic item wraps itself around the body, for example abandoned or lost fishing gear (Macfadyen et al., 2009; Richardson et al., 2019b). Marine mammals are among the species most affected by entanglement (Hammer et al., 2012). Fishing gear poses special risks for large, air-breathing marine animals, such as whales, dolphins, seals, sea lions, manatees, and dugongs, drowning after they become entangled in the nets (Laist, 1997; Lusher et al., 2018). Other species that are affected through entanglements are sharks, rays, and chimaeras (Parton et al., 2019).

**Colonisation** by alien species can be facilitated by plastic debris, which can be a threat to marine biodiversity and ecosystems. Aggressive invasive species can be dispersed by free-floating marine plastics. Their introduction can endanger sensitive or at-risk coastal environments (García-Gómez et al., 2021). Plastic debris can function as vectors, transporting viral and bacterial pathogens (harmful to both humans and animals), potentially spreading them to new areas (Bowley et al., 2021).

**Contact** or **coverage** with plastics, also called smothering, is another type of interaction. For example, coverage of sponges with plastics can impair prey capture and growth rates (Mouchi et al., 2019).

*Green sea turtle in a reef in Grenada (Shutterstock, Eric Carlander).*

[19] https://litterbase.awi.de/.

**Chemical** impacts occur: (1) because of harmful substances associated with plastics, such as Bisphenol A (BPA) or flame retardants; and (2) through sorption and desorption of chemical pollutants (Hermabessiere et al., 2017, Tekman et al., 2022).

According to Tekman et al. (2022), plastic pollution should always be considered in the context of the many other stressors affecting the marine environment. At present, plastic pollution alone may, by itself, not drive critical decreases in populations; it may just push an individual, population or ecosystem into decline and possibly over a critical threshold. For example, habitat destruction impacts all marine wildlife in Grenada (Government of Grenada, 2014, 2017). Globally, seabirds are threatened by bycatch and overfishing, climate change, and invasive species (Croxall et al., 2012; Dias et al., 2019). Turtles are also threatened by climate change (Laloë et al., 2016), as well as by predation by pigs and dogs, human harvesting of turtles and their eggs, and beach erosion (Government of Grenada, 2017; Tekman et al., 2022). Other impacts on marine wildlife come from collisions with boats (Jägerbrand et al., 2019), chemical pollution (Arzaghi et al., 2020), noise pollution (Badino et al., 2016) and ocean deoxygenation (Laffoley and Baxter, 2019).

The impact analyses on fisheries and tourism sectors, as well as the presentation of the effects on marine ecosystems and wildlife discussed above, focus mainly on interactions with macroplastics. However, **microplastics** are also of concern. Marine plastics, specifically those with a lifetime of hundreds of years, tend to degrade into micro- and nano-plastics over time. The size of these plastic pieces facilitates their uptake, can block the digestive tract, and contribute to the chemical body burden eliciting toxicological effects (Carbery et al., 2018; Tekman et al., 2022). These plastics may contain chemical additives and contaminants, some of them with suspected endocrine disrupting effects that when ingested may be harmful for marine animals (Gallo et al., 2018; Prokić et al., 2019). In addition to the direct ingestion of plastic debris, larger animals, higher in the food chain also ingest plastics. Microplastics are easily ingested by small organisms, such as plankton; contaminants leach from plastics tend to bioaccumulate in those organisms that ingest them – the higher the trophic level, the higher the chemical concentrations (Hammer et al., 2012). Morrall et al. (2018), found microplastics in fish, and in intertidal snails, demonstrating that microplastics are present in coastal and marine environments in Grenada.

## 6.4. MARINE PLASTICS IN MARINE PROTECTED AREAS

Marine protected areas (MPAs) are an essential tool in the recovery and protection of marine ecosystems and the vital services they provide (Reuchlin-Hugenholtz, 2015). MPAs protect marine biodiversity and ecosystems by limiting the economic activities in the area (IUCN, 2013). Currently, less than 1% of the marine area of Grenada is protected and all of the MPAs lie within 200m zones (Marine conservation Institute, 2022). Around 80% of Grenada’s coastline is covered by MPAs, which provide protection to the coastal ecosystem and habitats (CBD, 2022) (see **Map 4**, below). The area coverage of MPAs for Grenada is estimated to be 236 km² (UNEP-WCMC, 2022c).


*Source: Marine Conservation Institute, 2021 ; UNEP-WCMC, 2021c.*

***Map 4 – Marine protected areas in Grenada***

MPAs in Grenada are impacted by several factors, including poor demarcation and non-enforced management practices (Homer, 2016). However, in addition, the global pervasiveness and high abundance of plastic debris in the marine environment are growing threats for MPAs (OECD, 2016). The delineated boundaries for MPAs cannot stop plastics from entering and posing risks to vulnerable habitats and species (Giuseppe, 2022).

The estimated amount of plastics present in 2019 in Grenada's MPAs (**Map 4**) is presented in **Tables 24** and **25**.

***Table 24 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 1***

| Accumulation areas | Plastics in MPA (tonnes) |
|---|---:|
| Sea surface | 0.0045 |
| Coastline and seafloor | 11,269 |
| Coastal waters | 21,164 |
| Open ocean | 0.349 |

***Table 25 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 2***

| Accumulation Areas | Plastics In MPA (Tonnes) |
|---|---:|
| Offshore – deeper water | 151,823 |
| Shallow water | 9,418 |
| Shoreline – dry land | 1,768 |

# 7. SUMMARY AND CONCLUSIONS

The results of this study show the estimated impact of marine plastics on fisheries in 2019 to be 3.7% of revenue, excluding the impact of ghost fishing. The estimated losses due to plastic leakage in the marine environment for the Grenadian fisheries sector is **XCD 1,270,718** (USD 470,288).

For tourism, the potential percentage of tourists who would no longer be willing to visit the country if all plastics accumulated on beaches is estimated to be between 43% and 97%. To avoid this loss, the cleaning of beaches and coastline is estimated to cost between **XCD 4,935,648** and **14,443,281** (USD 1,826,665 and 5,345,404), which is equal to between 39% and 115% of the 2019 waste management budget.

The total direct cost of mismanaged waste in Grenada in 2019, looking at fisheries and coastal clean-ups, is estimated to be between **XCD 6,206,366** (USD 2,296,952) under plastic accumulation scenario 1 and **XCD 15,713,999** (USD 5,815,691) under plastic accumulation scenario 2.

From 2023 to 2040 and under a BaU scenario, the estimated direct impact -which is the sum of the revenue loss for the fisheries sector and the estimated coastal clean-up costs in present value is **XCD 79,190,547** (USD 29,308,122) under plastic accumulation scenario 1 and **XCD 195,386,682** (USD 72,311,873) under plastic accumulation scenario 2.

The present value of the overall cost of recycling is estimated to be **XCD 20,455,156** (USD 7,570,376). The present value of the benefits under plastic accumulation scenario 1 of the national recycling scenario alone is estimated to be **XCD 15,154** (USD 5,608) compared to **XCD 40,652** (USD 15,045) as estimated under plastic accumulation scenario 2. The present value of the benefits of the regional cooperation scenario, is estimated to be **XCD 17,744,131** (USD 6,567,035) under plastic accumulation scenario 1 and **XCD 48,481,031** (USD 17,942,646) under plastic accumulation scenario 2.

The cost-benefit analysis resulted in an estimated net present value that varies between **XCD -8,615,363** (USD -3,188,513) (national recycling and plastic accumulation scenario 1) and **XCD 39,850,514** (USD 14,748,525) (regional cooperation and plastic accumulation scenario 2) for the period 2023-2040. The results of the cost-benefit analysis highlights the importance of regional collaboration, due to the transboundary nature of the marine litter. This is consistent with what was found by Macias et al., 2022 for the Mediterranean.

This study mainly focused on estimating direct costs for the economy of Grenada, looking at costs for the fisheries and tourism sectors. Some costs, such as the impact of ghost fishing, and benefits, such as the potential of selling plastics on the market for recyclables, were not included. In addition, mismanaged plastics also have broader impacts on blue natural capital assets and marine biodiversity, which can generate additional impacts to the economy. With this said, it is difficult to quantify the impact on marine ecosystems and biodiversity (Tekman et al., 2022). The impact of marine plastics must be seen in light of the multiple stressors, which impact the marine environment and the blue economy that depends on it.

While the results demonstrate that the implementation of a national recycling scenario in Grenada can, in and of itself, generate a positive environmental impact in terms of reducing marine plastic pollution over the current BaU practices, although potentially with a negative NPV, the implementation of a regional recycling collaboration can have an even greater positive impact in terms of reducing MPW. Notwithstanding, in both cases, additional social, economic and environmental benefits can be derived from the simultaneous implementation of a range of policy solutions and tools to address the problem and generate a larger reduction in mismanaged plastic and potentially also in plastic stocks. These include, for example: reducing and substituting plastic use to systems such as extended producer responsibility, market-based instruments such as deposit refund schemes or landfill taxes, and the improvement of waste collection systems and infrastructure, including fishing systems and gear (Newman et al., 2015). It should also not be forgotten that recycling potential does exist in Grenada, e.g., two active metal aggregators exist in Grenada and Carriacou (APWC, 2021b). Further cost-effectiveness and cost-benefit analyses will be needed to continue supporting the decision-making process, including further work around the cost-and benefits of establishing a regional recycling hub in the Caribbean Region. In addition, it is key to link these results with sustainable financial mechanisms, to encourage recycling and other measures to reduce MPW.

In addition to recycling, a range of instruments and initiatives have been proposed globally to reduce MPW, and beyond the scope of this study, such as, product taxes, to include the externalities caused by plastic leakage into the environment and to generate revenue. This; however, comes with additional challenges, including, for example, where to tax the products (during production, export, import, usage). If plastics are taxed at the production source, it may not be collected where the main impact is caused. For example, according to APWC (2021a), the costs of plastic pollution on SIDS are hugely disproportionate to their contributions. These global and distributional issues highlight the importance of not only developing national legislation and regional collaboration, but also a global treaty on plastics.

There is also a need for further data on mismanaged plastics and leakage, and where it accumulates in the marine environment. Additional work is also needed to understand the real cost of plastics, including microplastics. Although efforts have been undertaken, such as the studies conducted by Trucost (2016) and WWF (2021), more empirical evidence is needed on the costs of marine plastics to fisheries, tourism, and the blue economy as a whole.

Finally, a broader accounting framework is needed to provide a more comprehensive picture of how marine plastics, together with multiple stressors, impact the national economy. Ocean Accounting[20] seems particularly suited for this. Future national assessments should aim to include this accounting system as part of economic impact estimates and scenario analyses.

[20] https://www.oceanaccounts.org/.

***Remarks***

This study uses survey-based data available on the plastic leakage for Grenada, Antigua and Barbuda, and Saint Lucia (APWC, 2021b, 2021c and 2021d), and is complemented by data on global estimates (Lebreton and Andrady, 2019), which can potentially be less accurate. The more local and national data are available, the stronger the understanding of plastic leakage into the marine environment.

Different models exist on global plastic accumulation (e.g., Lebreton et al., 2012 and Eriksen, 2014) and where these plastics accumulate within the marine environment (e.g., GRID-Arendal, 2018 and Lebreton et al., 2019 as used in this study). More evidence is needed on what types of plastics are accumulating in which location to improve the understanding of the impacts of marine plastics on the economy and the blue natural capital on which it depends.

Within the limitations of this study, it was not possible to estimate the amount of plastics that enter the Caribbean Sea and accumulate. Instead, only exchanges among countries bordering the Caribbean Sea were considered, while equating inflow with outflow was assumed for the rest. Given that the focus of this study was to estimate the benefits of a national and a regional recycling system, and not a broader Atlantic Ocean wide system, this assumption should not affect these impact estimates. However, it may create an underestimation of the current impact caused by marine plastics. However, the highest plastic accumulations in the Atlantic take place in the North Atlantic gyre, in an area located around the Yucatan Peninsula and North of Cuba, outside of the research area (Eriksen, et al, 2013).

The allocation of plastics among the different countries limiting the Caribbean Sea was done based on the size of the EEZ and coastline. However, for the Lesser Antilles, the complete area of the EEZs was considered, including both areas within the Caribbean Sea, and those in the Atlantic Ocean. This provides these relatively smaller countries, with a comparatively larger share of EEZs and coastline, and thus of plastics allocated to each of them, as compared to countries where only the area within the Caribbean Sea was considered. This was necessary, given the focus on the complete EEZs and coastlines for the PWFI project countries in this study. Although this could cause a potential overestimation of the percentage of plastics allocated to these countries as compared to other countries bordering the Caribbean Sea, for the actual impact estimates, this additional allocation may somewhat offset the no consideration of plastics accumulating from outside the Caribbean Sea in the EEZs and on the coastlines of the countries that are the focus of this study.

The impact of marine plastics on fisheries of Grenada was done transferring the impact estimates of a study conducted elsewhere. The study of Mouat et al. (2010) was also used by others (Arcadis, 2013; UNEP, 2014a). There is a clear need for more field survey data on the impact on fisheries to strengthen an understanding of this issue.

Estimates of the amounts of plastics potentially affecting tourism through beach pollution differed from field data reported in the TIDES database. More data on marine plastic accumulation on beaches and coastal areas will improve the accuracy of the potential impact on tourism.

The potential impact on tourism was illustrated with studies from South Africa and Brazil, not based on empirical evidence on how plastic pollution affects the behaviour of international tourists visiting the Caribbean.

No actual impact on the tourism sector was included in the assessment of the recycling scenarios, only a maximum impact scenario to illustrate the potential risk to the tourism industry if plastics accumulate on beaches. Even a 3% impact (see UNEP 2014a) would have increased the positive impact of recycling as compared to the BaU scenario. However, as this impact estimate could not be accurately transferred to the beach-oriented tourism industry in Grenada, this study only considers impacts that could be explained based on plastic stock estimates.

This study focused on the impact of marine plastics on two sectors of the economy, versus a broader range, which would include the impact on property values, or the impact caused by greenhouse gas emissions from plastic production (see for example UNEP, 2014a and Graham et al., 2022).

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influenced costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example: to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Grenada).

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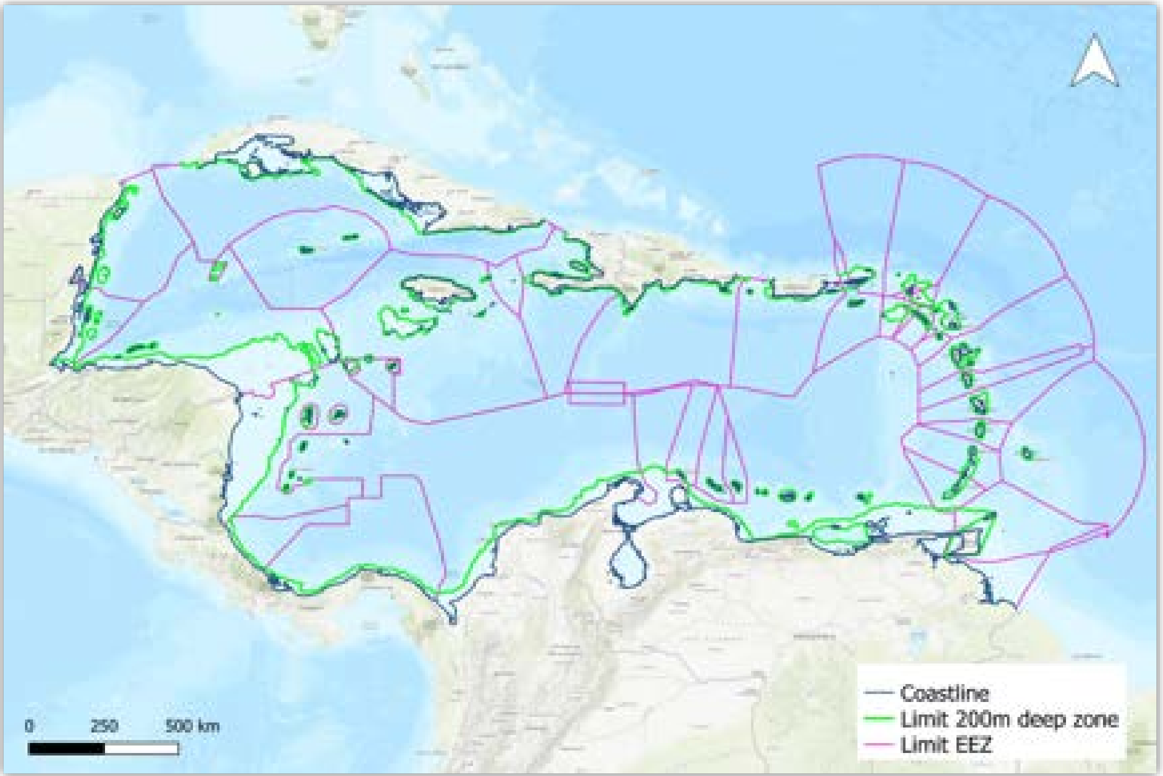
# Annexes

## ANNEX A1. METHODOLOGY USED FOR IMPACT ESTIMATIONS

### Annex A1.1. PLASTIC STOCK ESTIMATION

As a starting point, a semi-closed marine system is defined to estimate plastic stocks. This definition is used since plastics present in a country's EEZ or shoreline, often does not only come from a country's own terrestrial and marine mismanaged plastic waste but can from other countries as well. In addition, plastics will also flow out, accumulating in one of the oceanic accumulation zones (see for e.g., Lebreton et al., 2012[21], Eriksen et al., 2014[22]). For Grenada, the interactions between countries bordering with the Caribbean Sea (**Map A1**), based on a shared marine area, proximity, currents (Gyory et al., 2008[23]), as well as additional impacts of hurricanes in the region were mainly considered.




***Map A1 – Presentation of the Caribbean Region as used in this study***

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To estimate the amount of plastics, present in 2019, the following steps were taken, and assumptions made:

- Use of data on MPW floating into the Caribbean Sea for non-PWFI countries provided by Lebreton et al. (2019)[24] and estimates by APWC for PWFI countries.
- Regressive analysis going back to 1950 (**Figure A1**):
- Consider annual growth rate of plastic production based on data from Geyer et al. (2017) (1950-2015)[25]
- Average annual growth rate of plastic production from 2015 to 2020 of 4% as predicted by Ryan (2015)[26]

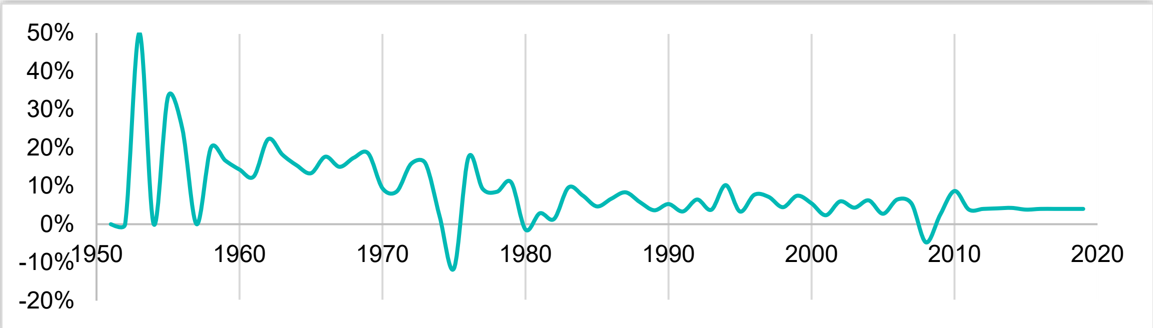


***Figure A1 – Plastic growth used for each year (1950-2019)***

- Two assumptions:
  - After 30 years, plastics either move to accumulation zones or get buried in the seafloor (Eriksen et al. (2014)[27].
  - Macroplastics deteriorate into microplastics at an annual rate of 3% (Lebreton et al. (2019); Lebreton et al. (2018))[28,29].
- Finally, once the total amount of plastics is estimated, it is distributed among countries according to the relative area of their EEZ, area of their coastal waters (i.e., less than 200 metres deep), and length of their coastline compared to the total areas of the region analysed in the report. In the case of Grenada, these values are respectively equal to 0.78%, 0.55%, and 0.51% of the total area/length of the Caribbean region. Each parameter used to distribute plastics is related to one of these figures.

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[25]Geyer, R., Jambeck, J.R., Law, K.L., (2017). Production, use, and fate of all plastics ever made. *Science Advances* 3, e1700782. Available at: https://doi.org/10.1126/sciadv.1700782.
[26] Ryan, P.G., (2015). *A Brief History of Marine Litter Research*, in: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 1–25. Available at: https://doi.org/10.1007/978-3-319-16510-3_1.
[27] Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., (2014). Plastic Pollution in the World's Oceans: More than 5 trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLOS ONE* 9, e111913. Available at: https://doi.org/10.1371/journal.pone.0111913.
[28] Lebreton, L., Egger, M., Slat, B., (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. *Sci Rep* 9, 12922. Available at: https://doi.org/10.1038/s41598-019-49413-5.
[29] Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., Debeljak, P., Maral, H., Schoeneich-Argent, R., Brambini, R., Reisser, J., (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Sci Rep* 8, 4666. Available at: https://doi.org/10.1038/s41598-018-22939-w.

- For GRID-Arendal (2018)[30]:
  - The amount of plastics on the coastline and seafloor is dependent on the relative length of the coastline (Grenada has 0.51% of the Region's total);
  - The amount of plastics in the coastal ocean waters is dependent on the relative size of the coastal water (Grenada has 0.55% of the Region's total); and
  - The amount of plastics in the open ocean waters and floating on sea surface is dependent on the relative size of the EEZ (Grenada has 0.78% of the Region's total).
- For Lebreton and Andrady (2019):
  - The amount of plastics on the shoreline – dry land depends on the relative length of the coastline (Grenada has 0.51% of the Region's total);
  - The amount of plastics in the coastal – shallow water depends on the relative size of the coastal water (Grenada has 0.55% of the Region's total); and
  - The amount of plastics in the offshore – deeper water depends on the relative size of the EEZ (Grenada has 0.78% of the Region's total).

## Annex A1.2. PLASTIC ACCUMULATION ESTIMATES

**Table A1** displays the amount of plastics that has accumulated in Grenada's jurisdiction until 2019 for both plastic accumulation scenarios.

***Table A1 – Plastic waste accumulated within Grenada's jurisdiction for both plastic accumulation scenarios (2019) (tonnes)***

| Plastic accumulation scenario | MWP scenario | Average | Low | Midpoint | High |
|---|---|---|---|---|---|
| Scenario 1 | Coastline and seafloor | 13,914 | 11,879 | 14,081 | 15,782 |
| | Coastal ocean waters | 10,897 | 9,303 | 11,028 | 12,360 |
| | Open ocean waters | 22,339 | 19,071 | 22,607 | 25,338 |
| | Floating on sea surface | 286 | 244 | 290 | 325 |
| | **Total** | **47,436** | **40,497** | **48,007** | **53,805** |
| Scenario 2 | Offshore – Deeper water | 689 | 588 | 697 | 781 |
| | Coastal – Shallow water | 73 | 63 | 74.23 | 83 |
| | Shoreline – Dry land | 40,717 | 34,761 | 41,206 | 46,184 |
| | **Total** | **41,479** | **35,411** | **41,978** | **47,048** |

## Annex A1.3. FISHERIES IMPACT ESTIMATES, METHODOLOGY

To estimate the impact of marine plastics on fisheries revenue from Grenada, results from Scotland presented by Mouat et al. (2010)[31] were transferred to Grenada. Value (or impact) transfer is done using the 'direct rule of three.' The 'direct rule of three' helps solving the problems based on proportionality. It states:

[30] GRID-Arendal, (2018). How much plastic is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907. Accessed on 10 June 2021.
[31] Mouat, T., Lopez-Lozano, R. and Bateson, H. (2010). Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).

$$If\ A \equiv B \qquad \&\ X \equiv Y \qquad Then\ X = \frac{A * Y}{B}$$

Where A, B, X and Y are random variables. If the values of A, B and Y are known, one can estimate the value of X. The 'direct rule of three' states that B is related to A in the same proportion as Y is related to X.

This proportional relation is key to understanding why only one plastic accumulation scenario has been used for the fisheries sector instead of the two scenarios used for the coastal clean-ups. Indeed, even though the amount of plastics impacting fisheries under plastic accumulation scenario 1 is more than 39 times greater than the amount under plastic accumulation scenario 2, the difference is reported on B and Y of the above equation. Thus, it cancels itself out, meaning that the impact is the same regardless of the plastic accumulation scenario.

Coming back to the current relation, revenue is the function of price of the fish catch in market and quantity of fish catch.

$$Revenue = Price\ * Quantity\ (or\ volume)$$

As revenue could not be assessed, due to price differences existing between the two countries, this study estimated revenue as being the price per volume multiplied by the volume (quantity in tonnes), using fisheries' volume as a proxy. Hence, the value or impact transfer is based on a four percent impact on fisheries volume in Scotland, and then the volume is translated to fisheries' revenue.

The aim is to translate the impact estimates obtained by Mouat et al. (2010), to the data of fisheries of Grenada, which is achieved by applying data derived from Scottish fisheries.

The relation is expressed as follows:

- Impact% on fisheries ⇐ Amount of plastics present in the sea (in tonnes)
- Impact% on fisheries ⇐ Quantity of fish catch (in tonnes)

The relation between amount of plastics and amount of fish catch, where both have an influence on the estimated impact, can also be written as:

$$Impact_1 = PL_x * FC_x$$

Where" $Impact_1$ is the impact % of marine plastics on fisheries;

$PL_x$ is the amount of plastics present in the fishing zone in tonnes; and

$FC_x$ is the amount of fish caught in tonnes.

Plastics' impact is not only related to the amount of catch, but also related to a number of other factors such as net size, existing fish stocks, time spent on sea by each vessel, etc. As a proxy for this range of factors, the number of vessels and the total size of the fishing area are used. Thus, the impact relation can be represented by the equation below:

$$Impact_1 = \frac{Pl_x}{V_x * EEZ_x} * \frac{FC_x}{V_x * EEZ_x}$$

Where, $V_x$ is the number of vessels in Grenada's fishing zone, and $EEZ_x$ is the size of the fishing zone in km².

Given that both countries have a different amount of plastics present in their fishing zones, and each country catches different amounts of fish, the relation of two countries can be stated as follows:

$$Impact_1 = \frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}$$

$$Impact_2 = \frac{PL_{Grenada}}{V_{Grenada} * EEZ_{Grenada}} * \frac{FC_{Grenada}}{V_{Grenada} * EEZ_{Grenada}}$$

Applying the 'direct rule of three,' and solving for 'PI impact 2' (i.e., impact on fisheries' volume in Grenada in percentage), it can be represented as follows:

$$\%Impact_2 = \%Impact_1 * \frac{\frac{PL_{Grenada}}{V_{Grenada} * EEZ_{Grenada}} * \frac{FC_{Grenada}}{V_{Grenada} * EEZ_{Grenada}}}{\frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}}$$

***Input data from Scotland: Scotland fisheries overview***

Mouat et al., 2010[32] conducted a study through a survey on the Scottish fisheries that use net gears, to understand the extent by which this sector is impacted by marine litter. The study estimated that the impact on fisheries' revenue losses from marine litter was 5% in 2008, or 4% of the revenue if only considering marine plastics (Dunlop et al., 2020)[33].

**Table A2** provides the information that is needed to perform the impact transfer.

***Table A2 – Overview of data from Scottish net fisheries (2008)[34]***

| Vessels | Annual catch (tonnes) | Fishing area (km²) |
|---|---|---|
| 653 | 331,440 | 462,263 |

***Input data from Scotland: amount of plastics present in Scottish fishing area***

Every year, a certain amount of plastics are leaked into the oceans due to factors such as inadequate waste management system, illegal waste disposal, littering, urbanisation, etc. These leaked plastics impact many economic activities, including

[32] Mouat, T., Lopez-Lozano, R. and Bateson, H. 2010. Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).
[33] Dunlop, B.J. Dunlop, M. Brown, (2020) plastics pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles, Marine Pollution Bulletin, Volume 151, 110803, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2019.110803.
[34] Scottish Government statistics, 2008. A National Statistics Publication for Scotland: Scottish Sea Fisheries Statistics 2008.

fisheries (Boucher et al., 2019[35]). The estimated amount of plastics present in Scotland's fishing zone was 24,161 tonnes in 2008, based on the estimates from Lebreton and Andrady (2019)[36], and the plastic allocation from GRID-Arendal (2018)[37]. Thus, the assumption is that in 2008 the impact on Scottish fisheries of a 4% decrease in revenue was due to the presence of an estimated 24,161 tonnes of plastics in their fishing area.

***Input data for refined analysis on fishing gear and types of boat***

**Tables A3** and **A4** shows the details used to refine the data for the fisheries based on the context of Grenada. As a reminder, the direct application of the rule of three in this study implies that fisherfolks are only using net gear. The following correction allows a better restitution of the context of Grenada.

***Table A3 – Detailed data on the use of fish nets for refined impact on fisheries (2019)[38]***

| Species | Fishing gears used (YES = Nets or similar, NO = others) | Tonnes considered | Dumped catch | Net repairs | Fouling incidents | Time lost |
|---|---|---|---|---|---|---|
| Abalones, winkles, conchs | No | 26 | | | From the data on the types of boats (**Table A4**) | |
| Lobsters, spiny-rock lobsters | No | 30 | | | | |
| Marine fishes not identified | Yes | 34 | X | X | | X |
| Miscellaneous coastal fishes | Yes | 333 | X | X | | X |
| Miscellaneous pelagic fishes | Yes | 363 | X | X | | X |
| Sharks, rays, chimaeras | Yes | 15 | X | X | | X |
| Tunas, bonitos, billfishes | No | 1,747 | | | | |
| Turtles | Yes | 2 | X | X | | X |
| | | | 100% | 29% | 96% | 29% |

[35] Boucher J. and Billard G., (2019). « The challenges of measuring plastic pollution », Field Actions. Science Reports Special Issue 19 October 2019. URL: http://journals.openedition.org/factsreports/53.

[36] Lebreton, L., Andrady, A., (2019). Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.

[37] GRID-Arendal (2018) How much plastics is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907. Accessed on 10 June 2021.

[38] APWC. 2021. Plastic Waste-Free Islands Project: Plastic Waste National Level Quantification and Sectorial Material Flow Analysis in Grenada.

*Table A4 – Type of boats and their number (2019)* [39]

| Type of boats | # | Motor |
|---|---|---|
| Launch 10-15 m | 75 | Yes |
| Pirogue 7-9 m | 120 | Yes |
| Open 5-7 m | 210 | Yes |
| Open pirogue | 130 | Yes |
| Double ender | 25 | No |
| Percentage of boat that might suffer from fouling incidents | | 96% |

## Annex A1.4. Tourism impact estimates, methodology

The studies from Ballance et al. (2000)[40] and Krelling et al. (2017)[41] are used for Grenada. Balance et al. (2000) studied the impact of marine plastics on tourism in Cape Town, South Africa. Krelling et al. (2017) studied the impact in Brazil.

Cape Town is one of the most visited cities in South Africa. Out of all the tourists visiting the country, 49% are international tourists (City of Cape Town report, 2019).[42] A study conducted on Cape Town's beaches by Ballance et al., 2000 found that a number of tourists were not willing to come to beaches if they were littered (**Table A5**).

*Table A5 – Willingness to visit (WTV) a beach under different littering scenarios in Cape Town*

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.8 items | No change |
| 1.8-8 items | 85% |
| 8 items and more | 97% |

*Source: Ballance et al. 2000.*

The different littering scenarios have been adjusted to reflect the fact that plastic items make up 80% of the litter found on the beach. Therefore, eight plastic items found per linear metre of beach shoreline imply that there are two non-plastic items along with them. This increased amount of marine litter on a given beach would make that beach fall under the last situation of Ballance et al. (2000) A 97% drop of WTV.

Krelling et al. (2017), used a contingent valuation to assess the WTV on two beaches of Brazil under different littering scenarios, as represented in **Table A6**. The same adjustment regarding the composition of littering on beaches has been made, e.g., 24 plastic items imply 30 items overall.

[39] FAO 2022. Fishery and Aquaculture Country Profiles. Grenada. Country Profile Fact Sheets. Fisheries and Aquaculture Division [online]. Rome. Accessed on 27 October 2022.
[40] Ballance, A., Ryan, P., Turpie, J. 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science 96, 210–213.
[41] Krelling, A.P., Williams, A.T., Turra, A. 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Marine Policy 85, 87–99. https://doi.org/10.1016/j.marpol.2017.08.021.
[42] City of Cape Town report. 2019. Annual report. Available at 2019_20_Integrated_Annual_Report.pdf (capetown.gov.za).

*Table A6 – Willingness to visit (WTV) a beach under different littering scenarios in Brazil*

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.2 items | No change |
| 1.2-9.6 items | 19.9% |
| 9.6-24 items | 42.7% |
| More than 24 items | 82.4% |

*Source: Krelling et al., 2017.*

The goal is to estimate the WTV of international tourists due to plastic beach pollution in Grenada. For this study, it is assumed that the behaviour of international tourists in Grenada will be similar to tourists in Cape Town and Brazil.

**Table A7** shows an overview of the number of items per metre in the Lesser Antilles according to the TIDES database.[43] **Table A8** shows the result of the beach clean-ups by giving details for the location of where the items were retrieved from.

*Table A7 – Marine litter collected in Lesser Antilles (2019)[44]*

| Country | Kilometres | Items | Items per metre |
|---|---|---|---|
| Antigua and Barbuda | 13.47 | 8,712 | 0.65 |
| Barbados | 12.87 | 47,355 | 3.68 |
| British Virgin Islands | 0.48 | 1,794 | 3.72 |
| Caribbean Netherlands | 15.92 | 8,050 | 0.51 |
| Cayman Islands | 0.40 | 900 | 2.24 |
| Dominica | 28.61 | 17,822 | 0.62 |
| Grenada | 1.85 | 2,753 | 1.49 |
| Guadeloupe | 1.21 | 338 | 0.28 |
| Sint Maarten | 3.40 | 1,869 | 0.55 |
| St Kitts & Nevis | 33.10 | 24,478 | 0.74 |
| Saint Lucia | 8.05 | 7,853 | 0.98 |
| St Vincent and the Grenadines | 12.47 | 5,515 | 0.44 |
| Trinidad and Tobago | 63.94 | 206,845 | 3.24 |
| US Virgin Islands | 65.45 | 46,964 | 0.72 |
| **Total** | **261.23** | **381,248.00** | **1.46** |

[43] https://www.coastalcleanupdata.org/reports. Accessed on 15 October 2021.
[44] Reports (coastalcleanupdata.org). Accessed on 15 October 2021.

*Table A8 – Marine litter collected per location for Grenada*

| Year | Location | Plastic collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|---|
| 2020 | Land (beach, shoreline and inland) | 1.09 | 17,003 | 15,669 |
| | Underwater | 0.03 | 191 | 6,903 |
| 2019 | Land (beach, shoreline and inland) | 1.13 | 2,753 | 2,442 |
| | Underwater | 0.26 | 1,480 | 5,748 |
| 2018 | Land (beach, shoreline and inland) | 0.45 | 13,466 | 29,956 |
| | Underwater | 0.36 | 6,857 | 19,178 |
| 2017 | Land (beach, shoreline and inland) | 0.48 | 4,316 | 9,020 |
| | Underwater | 0.14 | 1,017 | 7,377 |
| 2016 | Land (beach, shoreline and inland) | 0.95 | 434 | 456 |
| | Underwater | - | - | - |

# ANNEX A2. FUTURE SCENARIOS

## Annex A2.1. Discount rate for net present value

To obtain a discount rate for this study, an average of different discount rates is used. **Table A9** presents the discount rates used.

*Table A9 – Series of discount rates used to estimate Grenada's discount rate*

| Country | Discount Rate |
|---|---|
| European Union | 4 |
| Norway | 4 |
| UK | 3.5 |
| France | 4.5 |
| USA (CBO) | 2 |
| USA (OMB) | 5 |
| USA (EPA) | 5 |
| USA (GAO) | 0.1 |
| IDB | 12 |
| World Bank | 11 |
| Colombia | 12 |
| Costa Rica | 12 |
| Mexico | 10 |
| Calculated LA | 3.77 |

*Source: Moore et al. (2020)*[45].

[45] Moore MA, Boardman AE, Vining AR. Social Discount Rates for Seventeen Latin American Countries: Theory and Parameter Estimation. Public Finance Review. 2020;48(1):43-71. doi:10.1177/1091142119890369.

## Annex A2.2. BUSINESS-AS-USUAL (BAU) SCENARIOS (2023-2040)

### Annex A2.2.1. Plastics impacting fisheries (2023-2040)

**Figure A2** displays the amount of plastics impacting fisheries for each year.

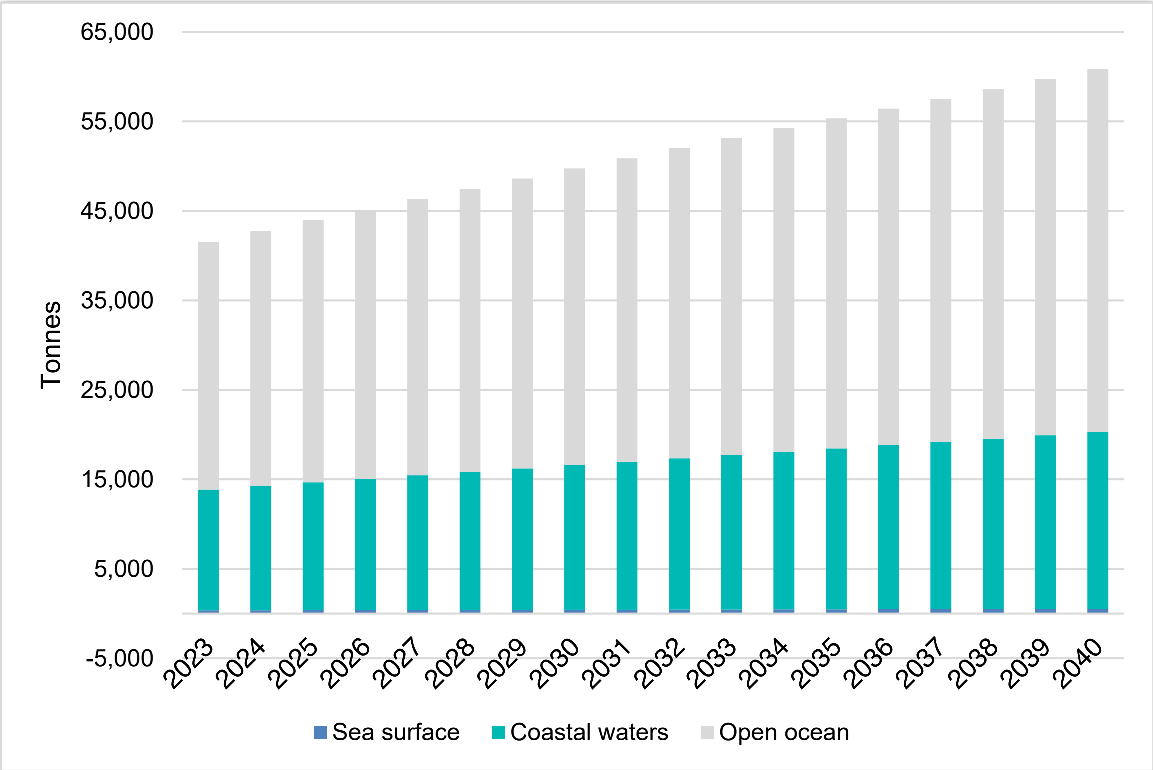


***Figure A2 – Plastics impacting fisheries under BaU scenarios for each year***

### Annex A2.2.2. Fisheries sector (2023-2040)

To predict the impact on fisheries in Grenada in the period 2020-2040, two different potential scenarios of how the fisheries sector will evolve are considered. **Fish scenario 1** corresponds to a BaU case where the **fish catch is stable** for the whole period considered. **Fish scenario 2** reflects a reduction in the fish catch due to climate change impacts by 2040. Therefore, **an annual decrease of 0.25% of fish catch potential** for Grenada's fisheries has been considered until 2040 (FAO, 2018[46]). Prices are considered constant. Both results are displayed in **Figure A3**.

**Figure A3** shows the estimated fish catch under the different "fish scenarios".

[46] https://www.fao.org/3/i9705en/i9705en.pdf.

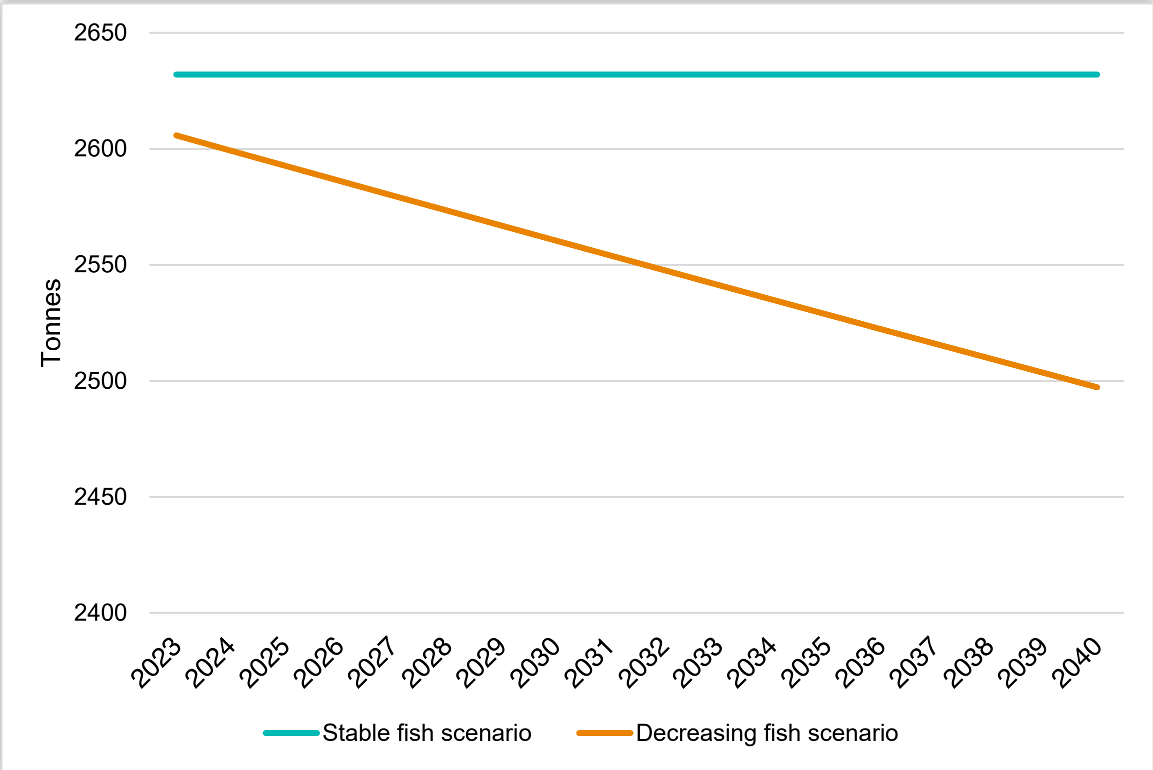


*Figure A3 – Evolution of fish catch for different fish scenarios (tonnes/year)*

### Annex A2.2.3. Impact on fisheries under BaU scenario (2023-2030)

The combination of the different plastic accumulation scenarios and fish scenarios allows for the generation of two impact scenarios (Presented in **Figure A4**):

- Fish scenario 1: Stable fish catch, no change over the period
- Fish scenario 2: Decrease in fish catch due to climate change

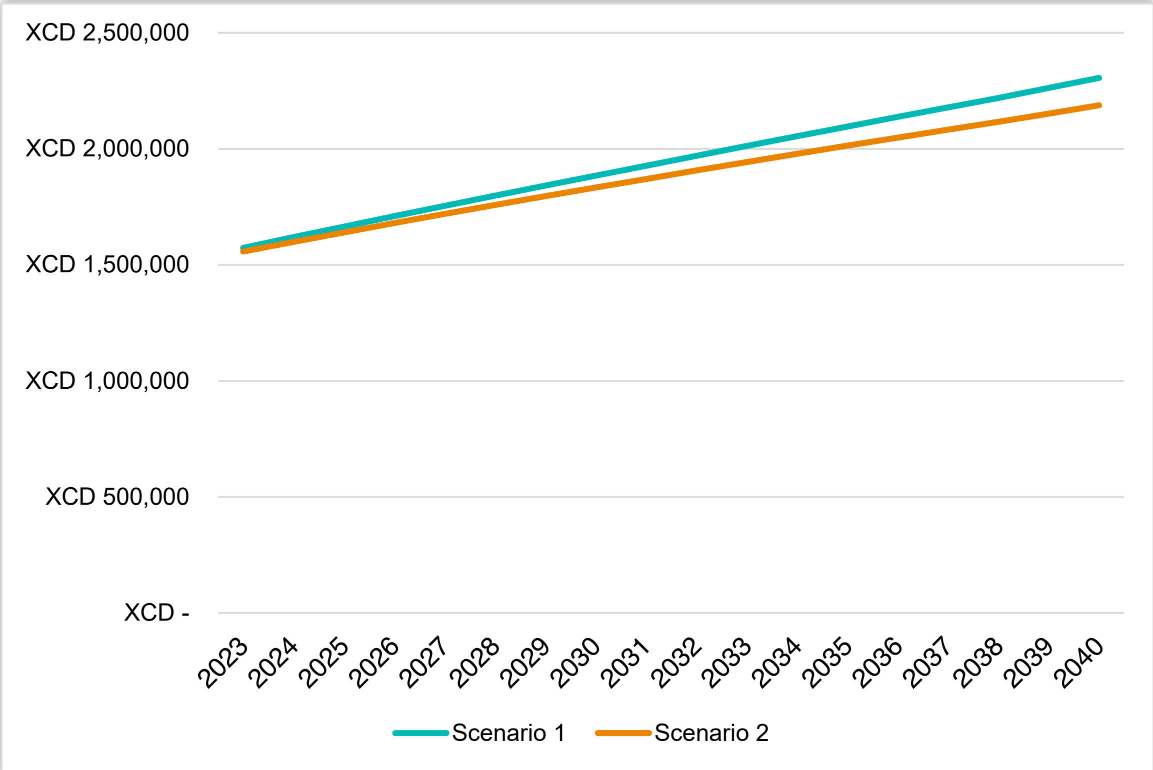


*Figure A4 – The estimated losses to the fisheries sector according to both fish scenarios (non-discounted values)*

### Annex A2.2.4. Tourism sector (2023-2040)

**Table A10** and **Figure A5** present the data used to estimate the future growth rate of the tourism sector in Grenada[47].

*Table A10 – Data used for the forecast of the growth rate of tourism sector*

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 1980 | 5.0% | | | |
| 1981 | 5.0% | | | |
| 1982 | 5.0% | | | |
| 1983 | 5.0% | | | |
| 1984 | 5.0% | | | |
| 1985 | 5.0% | | | |
| 1986 | 5.0% | | | |
| 1987 | 5.0% | | | |
| 1988 | 5.0% | | | |
| 1989 | 5.0% | | | |
| 1990 | 5.0% | | | |
| 1991 | 5.0% | | | |
| 1992 | 5.0% | | | |

[47] UNWTO. 2011. Tourism Towards 2030 Global Overview.

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 1993 | 5.0% | | | |
| 1994 | 5.0% | | | |
| 1995 | 5.0% | | | |
| 1996 | 2.4% | | | |
| 1997 | 2.4% | | | |
| 1998 | 2.4% | | | |
| 1999 | 2.4% | | | |
| 2000 | 2.4% | | | |
| 2001 | 2.4% | | | |
| 2002 | 2.4% | | | |
| 2003 | 2.4% | | | |
| 2004 | 2.4% | | | |
| 2005 | 2.4% | | | |
| 2006 | 2.4% | | | |
| 2007 | 2.4% | | | |
| 2008 | 2.4% | | | |
| 2009 | 2.4% | | | |
| 2010 | 2.4% | | | |
| 2011 | 2.4% | | | |
| 2012 | 2.4% | | | |
| 2013 | 2.4% | | | |
| 2014 | 2.4% | | | |
| 2015 | 2.4% | | | |
| 2016 | 2.4% | | | |
| 2017 | 2.4% | | | |
| 2018 | 2.4% | | | |
| 2019 | 2.4% | | | |
| 2020 | 2.4% | | | |
| 2021 | 1.7% | | | |
| 2022 | 1.7% | | | |
| 2023 | 1.7% | | | |
| 2024 | 1.7% | | | |
| 2025 | 1.7% | | | |
| 2026 | 1.7% | | | |
| 2027 | 1.7% | | | |
| 2028 | 1.7% | | | |
| 2029 | 1.7% | | | |
| 2030 | 1.7% | 1.7% | 1.7% | 1.7% |
| 2031 | | 1.6% | 0.9% | 2.3% |
| 2032 | | 1.5% | 0.6% | 2.5% |
| 2033 | | 1.5% | 0.3% | 2.6% |

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 2034 | | 1.4% | 0.0% | 2.7% |
| 2035 | | 1.3% | -0.2% | 2.8% |
| 2036 | | 1.2% | -0.4% | 2.9% |
| 2037 | | 1.1% | -0.6% | 2.9% |
| 2038 | | 1.1% | -0.8% | 3.0% |
| 2039 | | 1.0% | -1.0% | 3.0% |
| 2040 | | 0.9% | -1.2% | 3.0% |

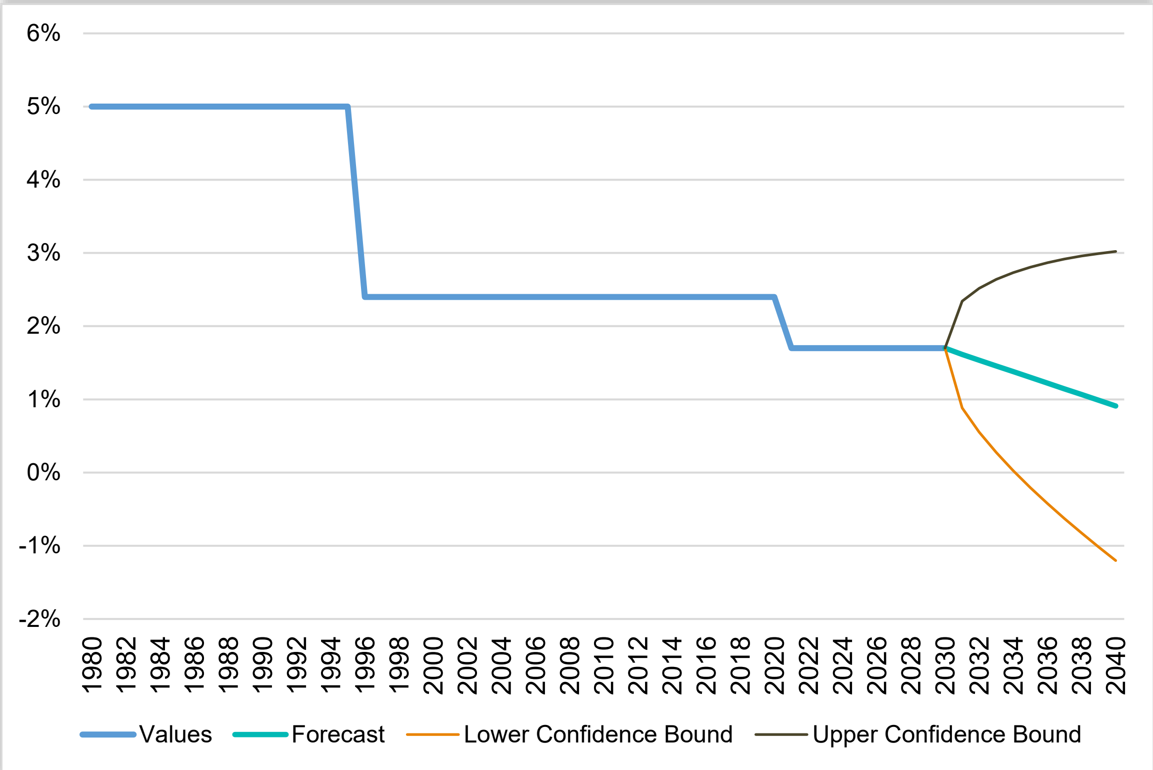


*Figure A5 – Estimated annual growth rate of the tourism sector and forecast for the years 2031 to 2040, 95% CI*

### Annex A2.2.5. Plastics impacting tourism (2023-2030)

To estimate the future impact of mismanaged plastics on tourism, only the impact on coastal clean-ups is considered. It is presented in **Figure A6**.

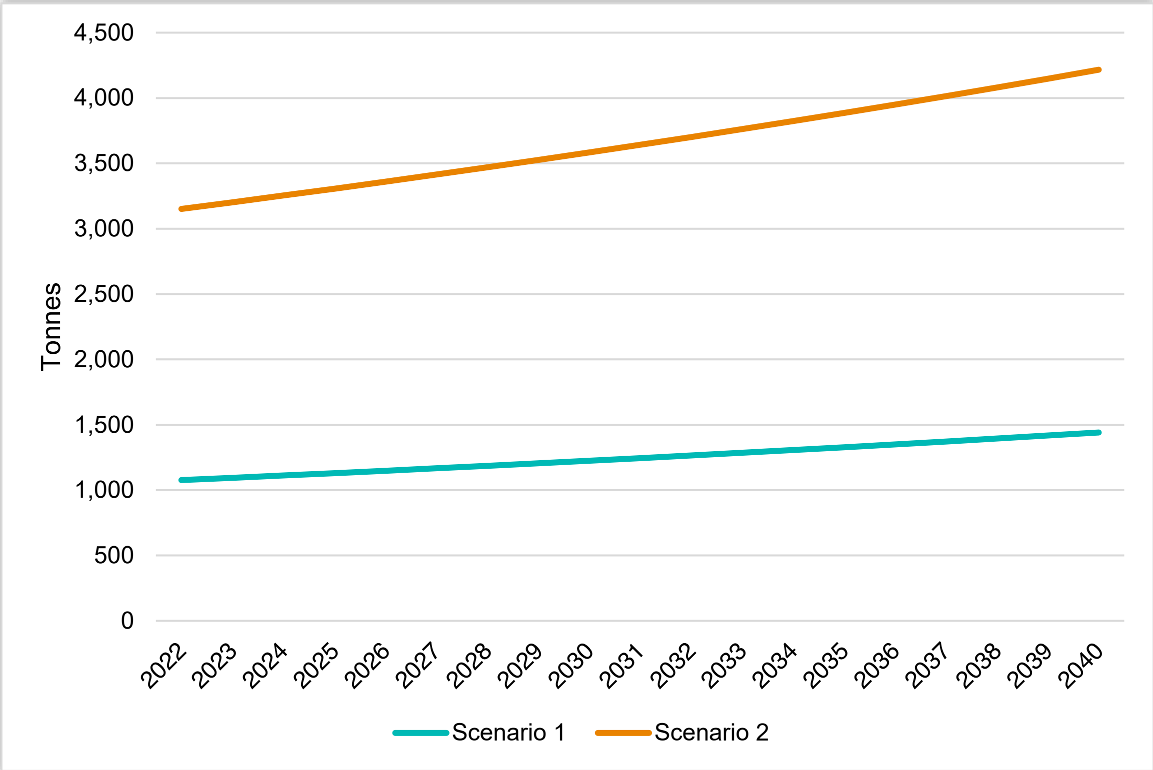


***Figure A6 – Estimated amount of plastics ending up on Grenada's coastline under BaU scenario (tonnes/year)***

Based on these estimates, the total amount of plastic items per metre can be calculated to obtain the coastal clean-up costs to avoid any impact on the tourism sector and is presented in **Table A11**.

***Table A11 – Estimated amount of plastics ending up on Grenada's coastline under BaU scenario under both plastic accumulation scenarios (items/metre)***

| Year | Items per metre according to | |
|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2020 | 80 | 234 |
| 2021 | 81 | 238 |
| 2022 | 83 | 242 |
| 2023 | 84 | 246 |
| 2024 | 85 | 249 |
| 2025 | 87 | 254 |
| 2026 | 88 | 258 |
| 2027 | 89 | 262 |
| 2028 | 91 | 266 |
| 2029 | 92 | 270 |
| 2030 | 94 | 275 |
| 2031 | 95 | 279 |

| Year | Items per metre according to | |
|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2032 | 97 | 284 |
| 2033 | 99 | 288 |
| 2034 | 100 | 293 |
| 2035 | 102 | 298 |
| 2036 | 103 | 303 |
| 2037 | 105 | 308 |
| 2038 | 107 | 313 |
| 2039 | 109 | 318 |
| 2040 | 110 | 323 |

### Annex A2.2.6. Impact on tourism and coastal clean-up costs under BaU scenario (2023-2030)

To maximise the probability that the predicted growth in tourism holds, coastal clean-ups will be necessary to avoid costs as presented earlier in this study. The same methodology as used for the 2019 impact is applied here for the different plastic accumulation scenarios. **Table A12** and **Table A13** present how an increase in plastic flow throughout the years will change the cost of coastal clean-ups, avoiding costs in the form of loss of tourism revenue. It is presented as the non-discounted value.

*Table A12 – Coastal clean-up costs for plastic accumulation scenario 1 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 5,273,127 | 2032 | 6,094,682 |
| 2024 | 5,358,125 | 2033 | 6,194,292 |
| 2025 | 5,444,624 | 2034 | 6,295,689 |
| 2026 | 5,532,654 | 2035 | 6,398,907 |
| 2027 | 5,622,244 | 2036 | 6,503,982 |
| 2028 | 5,713,425 | 2037 | 6,610,952 |
| 2029 | 5,806,227 | 2038 | 6,719,852 |
| 2030 | 5,900,682 | 2039 | 6,830,722 |
| 2031 | 5,996,823 | 2040 | 6,943,601 |

*Table A13 – Coastal clean-up costs for plastic accumulation scenario 2 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 15,431,328 | 2032 | 17,835,534 |
| 2024 | 15,680,067 | 2033 | 18,127,035 |
| 2025 | 15,933,199 | 2034 | 18,423,764 |
| 2026 | 16,190,811 | 2035 | 18,725,822 |
| 2027 | 16,452,989 | 2036 | 19,033,316 |
| 2028 | 16,719,821 | 2037 | 19,346,352 |
| 2029 | 16,991,398 | 2038 | 19,665,039 |
| 2030 | 17,267,813 | 2039 | 19,989,490 |
| 2031 | 17,549,159 | 2040 | 20,319,819 |

# ANNEX A3. RECYCLING SCENARIOS

1. National recycling scenario: Only Grenada will implement in-country strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC.
2. Regional recycling scenario: This scenario is based on Lebreton and Andrady (2019)[48] and implies that **all countries** in the region will cooperate and start to better manage their MPW when their GDP per capita increases.

**Table A14** provides the linear growth rate used for the projections.

*Table A14 – Annual growth rate used to estimate future MPW (2020-2040)*

| Country | Data in Lebreton and Andrady (2019) | Linear growth (2020-2040) |
|---|---|---|
| Anguilla | No data* | -4.8% |
| Antigua and Barbuda** | Yes | -8.3% |
| Aruba | No data* | -4.8% |
| Barbados | Yes | -5.1% |
| Belize | Yes | 0.7% |
| British Virgin Islands | No data* | -4.8% |
| Caribbean Netherlands (Bonaire, etc.) | No data* | -4.8% |
| Cayman Islands | No data* | -4.8% |
| Colombia | Yes | -4.5% |
| Costa Rica | Yes | -9.1% |
| Cuba | No data* | -4.8% |
| Curacao | No data* | -4.8% |
| Dominica | Yes | -5.3% |
| Dominican Republic | Yes | -13.5% |
| Grenada** | Yes | -13.7% |
| Guadeloupe | No data* | -4.8% |
| Guatemala | Yes | 0.5% |
| Haiti | Yes | 1.2% |
| Honduras | Yes | 0.9% |
| Jamaica | Yes | -1.5% |
| Martinique | No data* | -9.2% |
| Mexico/Yucatan (Nota 3) | Yes | 1.7% |
| Montserrat | No data* | -4.8% |
| Nicaragua | Yes | 0.4% |
| Panama | Yes | -9.3% |
| Puerto Rico | Yes | 1.0% |
| Saint Vincent | Yes | -5.1% |
| Saint Barthelemy | No data* | -4.8% |
| Saint Kitts and Nevis | Yes | -4.6% |
| Saint Lucia** | Yes | -10.7% |
| Saint Martin | No data* | -4.8% |

[48] Lebreton, L., Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.

| Country | Data in Lebreton and Andrady (2019) | Linear growth (2020-2040) |
|---|---|---|
| Sint Maarten | No data* | -4.8% |
| Trinidad and Tobago | Yes | -16.6% |
| Venezuela | Yes | -1.0% |
| Virgin Island of the US | No data* | -4.8% |

**When no data is available, the growth rate is assumed to be equal to the average of the region.*
*** For PWFI countries, APWC (2021)[49] data have been used (Antigua and Barbuda – 58% of plastics might be recycled each year, Grenada – 74%, and Saint Lucia – 46%). Lebreton and Andrady (2019) data for these three countries have only been used to estimate the region average.*

## Annex A3.1. Impact on fisheries by plastics, national recycling scenario

**Figure A7** presents the comparison for the fisheries between the BaU scenario and the national recycling scenario.

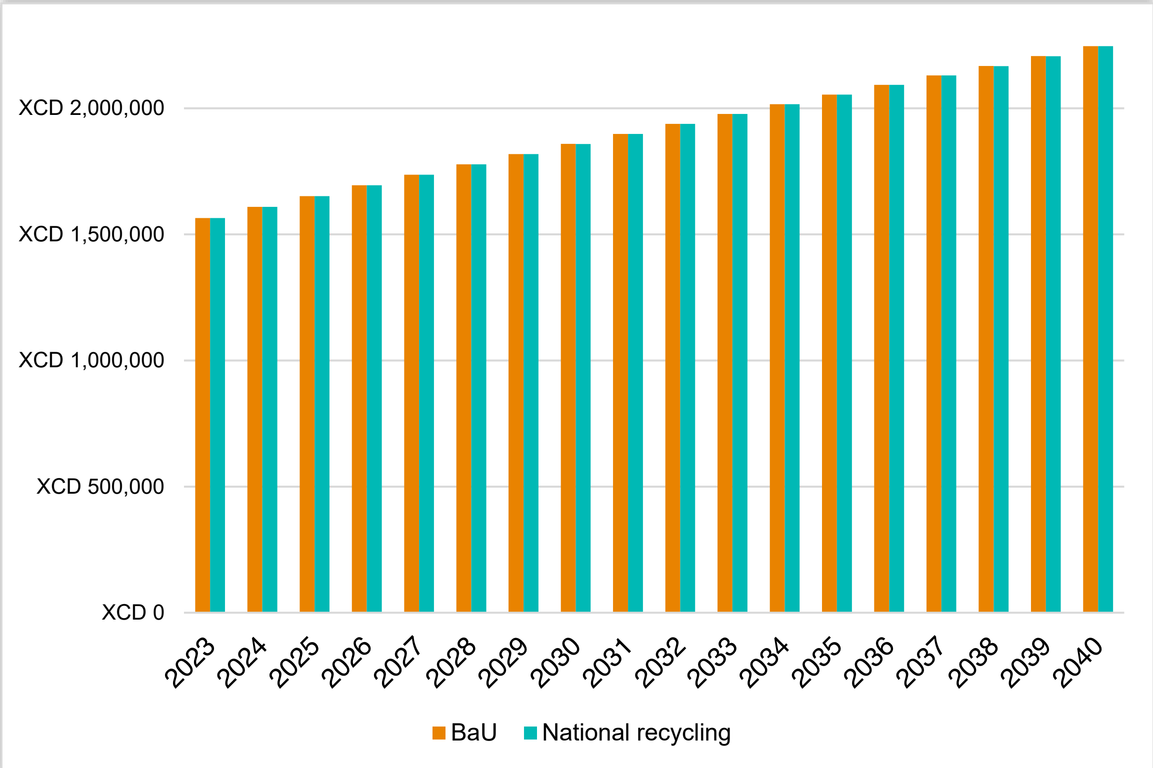


***Figure A7 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and national recycling scenarios***

## Annex A3.2. Impact on tourism (coastal clean-up costs), national recycling

**Table A15** presents the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), considering the national recycling scenario.

[49] APWC. 2021. Plastic Waste-Free Islands Project – Plastic Waste National Level Quantification and Sectorial Material Flow Analysis in Grenada.

*Table A15 – Annual plastic flow and items per metre (2023-2040) under national recycling scenario*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,094 | 3,202 | 84 | 246 |
| 2024 | 1,112 | 3,253 | 85 | 249 |
| 2025 | 1,130 | 3,306 | 87 | 253 |
| 2026 | 1,148 | 3,359 | 88 | 258 |
| 2027 | 1,166 | 3,413 | 89 | 262 |
| 2028 | 1,185 | 3,469 | 91 | 266 |
| 2029 | 1,205 | 3,525 | 92 | 270 |
| 2030 | 1,224 | 3,582 | 94 | 275 |
| 2031 | 1,244 | 3,641 | 95 | 279 |
| 2032 | 1,264 | 3,700 | 97 | 284 |
| 2033 | 1,285 | 3,761 | 99 | 288 |
| 2034 | 1,306 | 3,822 | 100 | 293 |
| 2035 | 1,328 | 3,885 | 102 | 298 |
| 2036 | 1,349 | 3,949 | 103 | 303 |
| 2037 | 1,372 | 4,014 | 105 | 308 |
| 2038 | 1,394 | 4,080 | 107 | 313 |
| 2039 | 1,417 | 4,147 | 109 | 318 |
| 2040 | 1,441 | 4,216 | 110 | 323 |

**Table A16** presents the coastal clean-up cost estimates for the national recycling scenarios.

*Table A16 – Impact on beach cleaning cost, national recycling scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 5,272,737 | 15,430,189 | 389 | 1,139 |
| 2024 | 5,357,404 | 15,677,957 | 721 | 2,109 |
| 2025 | 5,443,563 | 15,930,094 | 1,061 | 3,105 |
| 2026 | 5,531,244 | 16,186,684 | 1,410 | 4,127 |
| 2027 | 5,620,820 | 16,448,820 | 1,424 | 4,169 |
| 2028 | 5,711,986 | 16,715,610 | 1,439 | 4,211 |
| 2029 | 5,804,774 | 16,987,144 | 1,454 | 4,254 |
| 2030 | 5,899,214 | 17,263,515 | 1,469 | 4,298 |
| 2031 | 5,995,339 | 17,544,817 | 1,484 | 4,342 |
| 2032 | 6,093,182 | 17,831,147 | 1,499 | 4,387 |
| 2033 | 6,192,777 | 18,122,602 | 1,515 | 4,433 |
| 2034 | 6,294,158 | 18,419,284 | 1,531 | 4,480 |
| 2035 | 6,397,360 | 18,721,295 | 1,547 | 4,527 |
| 2036 | 6,502,419 | 19,028,741 | 1,564 | 4,575 |
| 2037 | 6,609,371 | 19,341,727 | 1,580 | 4,624 |
| 2038 | 6,718,255 | 19,660,365 | 1,597 | 4,674 |
| 2039 | 6,829,108 | 19,984,766 | 1,614 | 4,725 |
| 2040 | 6,941,969 | 20,315,044 | 1,632 | 4,776 |

## Annex A3.3. Impact on fisheries by plastics, national recycling

**Figure A8** presents the comparison for the fisheries between the BaU scenario and the regional cooperation scenario.

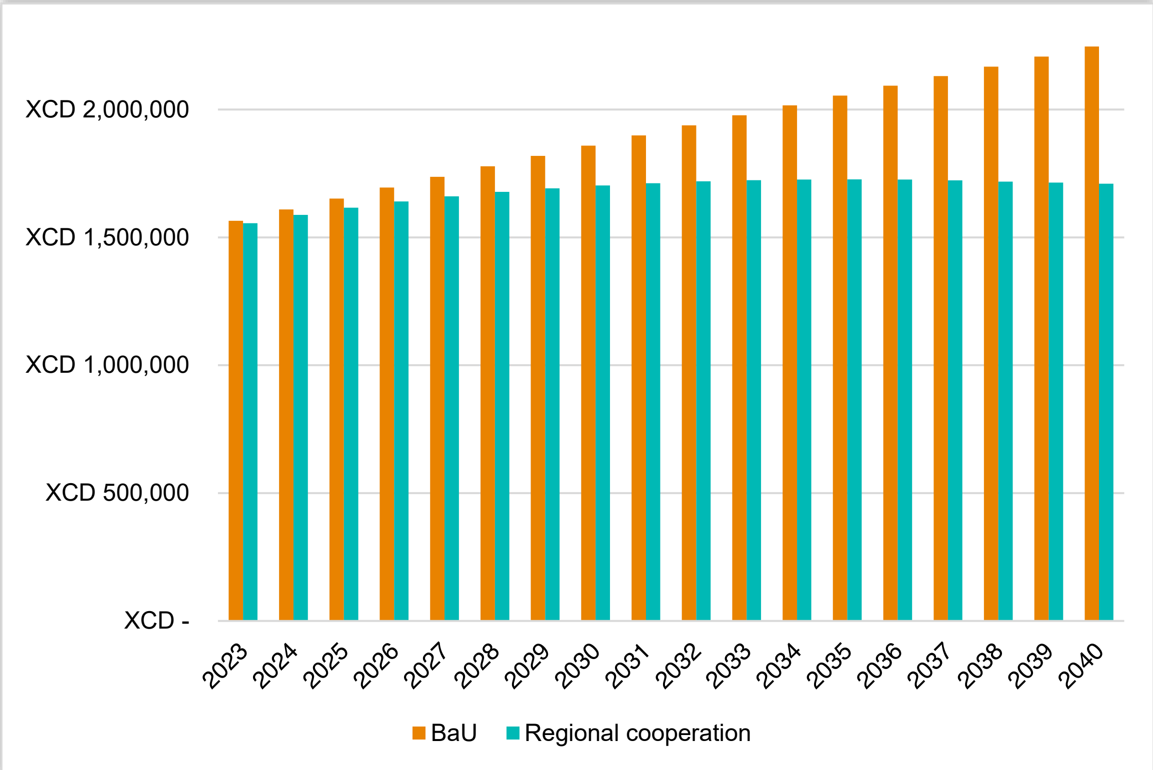


***Figure A8 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and regional cooperation scenarios***

### Annex A3.4. IMPACT ON TOURISM (COASTAL CLEAN-UP COSTS), REGIONAL COOPERATION SCENARIO

**Table A17** shows the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), under the regional cooperation scenario.

*Table A17 – Annual plastic flow and items per metre (2023-2040) under regional cooperation scenarios*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,018 | 2,979 | 78 | 228 |
| 2024 | 990 | 2,897 | 76 | 222 |
| 2025 | 965 | 2,824 | 74 | 217 |
| 2026 | 943 | 2,760 | 72 | 212 |
| 2027 | 924 | 2,704 | 71 | 207 |
| 2028 | 907 | 2,654 | 70 | 204 |
| 2029 | 892 | 2,611 | 68 | 200 |
| 2030 | 879 | 2,572 | 67 | 197 |
| 2031 | 867 | 2,537 | 66 | 195 |
| 2032 | 856 | 2,506 | 66 | 192 |
| 2033 | 847 | 2,479 | 65 | 190 |
| 2034 | 839 | 2,454 | 64 | 188 |
| 2035 | 831 | 2,432 | 64 | 186 |
| 2036 | 824 | 2,412 | 63 | 185 |
| 2037 | 818 | 2,395 | 63 | 184 |
| 2038 | 813 | 2,379 | 62 | 182 |
| 2039 | 808 | 2,365 | 62 | 181 |
| 2040 | 804 | 2,352 | 62 | 180 |

**Table A18** presents the coastal clean-up cost estimates, under the regional cooperation scenario (plastic accumulation scenarios 1 and 2).

*Table A18 – Impact on beach cleaning cost, regional cooperation scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 4,906,324 | 14,357,912 | 366,803 | 1,073,416 |
| 2024 | 4,770,349 | 13,959,994 | 587,776 | 1,720,073 |
| 2025 | 4,650,816 | 13,610,191 | 793,808 | 2,323,008 |
| 2026 | 4,545,508 | 13,302,017 | 987,146 | 2,888,794 |
| 2027 | 4,452,751 | 13,030,572 | 1,169,493 | 3,422,417 |
| 2028 | 4,371,150 | 12,791,774 | 1,342,275 | 3,928,047 |
| 2029 | 4,298,879 | 12,580,281 | 1,507,348 | 4,411,118 |
| 2030 | 4,234,746 | 12,392,601 | 1,665,936 | 4,875,212 |
| 2031 | 4,177,727 | 12,225,740 | 1,819,096 | 5,323,420 |
| 2032 | 4,126,943 | 12,077,124 | 1,967,739 | 5,758,410 |
| 2033 | 4,081,637 | 11,944,542 | 2,112,655 | 6,182,494 |
| 2034 | 4,041,160 | 11,826,089 | 2,254,529 | 6,597,675 |
| 2035 | 4,004,951 | 11,720,126 | 2,393,956 | 7,005,697 |
| 2036 | 3,972,526 | 11,625,238 | 2,531,456 | 7,408,078 |
| 2037 | 3,943,469 | 11,540,205 | 2,667,483 | 7,806,147 |
| 2038 | 3,917,418 | 11,463,970 | 2,802,434 | 8,201,070 |
| 2039 | 3,894,062 | 11,395,620 | 2,936,660 | 8,593,870 |
| 2040 | 3,873,130 | 11,334,364 | 3,070,471 | 8,985,455 |

## Annex A3.5. Cost of implementing the national recycling scheme

Satney M. (2022) (PWFI consultant and based in St. Lucia)[50] provided data on tonnes of waste collected and its attached cost. The annual average amount of waste collected between 2018 and 2021 amounts to 131,944 tonnes for an average annual cost of XCD 14,560,000. This leads to an average cost of XCD 110.3 per tonne. **Table A19** shows the base data needed to estimate the cost of the recycling of plastics.

*Table A19 – Additional data needed to perform the cost analysis (2019)*

| | |
|---|---|
| Maximum recyclable amount | 74.43% |
| Plastic waste (tonnes in 2019) | 2,640 |
| Growth rate from 2020-2040 | 1.31% |
| Discount rate | 6.35% |
| Hourly wage used (minimum wage times two) | XCD 9 |
| Waste management budget | XCD 12,610,069 |

[50] Satney, M., 2022. Personal communication – Data on shipping cost.

### *Collecting cost*

Given the cost/number of hours needed to collect 80 tonnes of plastics by Searious Business (2021), the following are the estimated costs corresponding to 2,640 tonnes of plastics (**Tables A20**, **A21**, and **A22**).

*Table A20 – Labour costs for 2,640 tonnes of plastics (2019)*

| Activity | Hours per week | Cost per week |
|---|---|---|
| Managing collection points and drop off sites | 660 | XCD 5,940 |
| Administration | 185 | XCD 1,663 |

*Table A21 – Investment costs for 2,640 tonnes of plastics (2019)*

| Items | Cost | |
|---|---|---|
| Van | XCD 75,000 | USD 27,757 |

*Table A22 – Fixed costs for 2,640 tonnes of plastics (2019)*

| Fixed cost | Cost per month | |
|---|---|---|
| Gas | XCD 3,960 | USD 1,466 |
| Car insurance / maintenance | XCD 2,640 | USD 977 |

### *Cost of sorting*

Based on data by PEW (2020)[51] and presented in **Table A23**.

*Table A23 – Estimated cost of sorting, based on PEW (2020)*

| Selected Countries and Economies | Year | GDP (PPP[52] USD) | Operating expenditure per tonne (USD) | Capital expenditure per tonne (USD) | Total (USD) |
|---|---|---|---|---|---|
| Average High income | 2020 | 18,073.10[53] | 117 | 39 | 156 |
| Grenada | 2020 | 18,241.9[54] | 99 | 33 | 132 |

### *Cost of shipping (to Miami)*

The cost of a 40-foot container to Miami is XCD 5,000 (data provided by Satney M., 2022). This type of container has a capacity of 67m$^3$. Based on data provided by APWC (2021b) (see **Table A24**). The average density of plastic waste in Grenada is equal to 1.032 tonnes per m$^3$.

---

[51] PEW. (2020). Breaking the Plastic Wave. Available at: https://www.systemiq.earth/wp-content/uploads/2020/07/BreakingThePlasticWave_MainReport.pdf.
[52] Product based on Purchasing Power Parity.
[53] GDP, PPP (current international USD) – Upper middle income | Data (worldbank.org).
[54] GDP per capita, PPP (current international $) – Grenada | Data (worldbank.org).

*Table A24 – Data to estimate average density of one tonne of plastics in Grenada (2019)*

| | Percentage of total recycled | Density |
|---|---|---|
| PET | 13% | 1.38 |
| HDPE | 15% | 0.95 |
| LDPE | 14% | 0.925 |
| PP | 14% | 0.905 |

The total cost of recycling plastics in Grenada is displayed in **Table A25**.

*Table A25 – Cost of implementing the recycling system for Grenada per year*

| Year | Implementation rate of the recycling policy | Amount recycled | Amount considered (tonnes) | Amount recycled (tonnes) | Cost (XCD) (non-discounted) | Cost (XCD) (Discounted at 6.35%) |
|---|---|---|---|---|---|---|
| 2021 | 0% | 0% | 3640 | - | - | - |
| 2022 | 0% | 0% | 3688 | - | - | - |
| 2023 | 25% | 19% | 3736 | 695 | 405,221 | 379,498 |
| 2024 | 50% | 37% | 3785 | 1408 | 821,027 | 720,100 |
| 2025 | 75% | 56% | 3834 | 2139 | 1,247,624 | 1,024,795 |
| 2026 | 100% | 74% | 3884 | 2890 | 1,685,224 | 1,296,369 |
| 2027 | 100% | 74% | 3935 | 2928 | 1,707,233 | 1,229,933 |
| 2028 | 100% | 74% | 3986 | 2966 | 1,729,530 | 1,166,902 |
| 2029 | 100% | 74% | 4038 | 3005 | 1,752,118 | 1,107,101 |
| 2030 | 100% | 74% | 4091 | 3044 | 1,775,001 | 1,050,365 |
| 2031 | 100% | 74% | 4145 | 3084 | 1,798,182 | 996,537 |
| 2032 | 100% | 74% | 4199 | 3124 | 1,821,667 | 945,467 |
| 2033 | 100% | 74% | 4254 | 3165 | 1,845,458 | 897,014 |
| 2034 | 100% | 74% | 4309 | 3206 | 1,869,560 | 851,044 |
| 2035 | 100% | 74% | 4365 | 3248 | 1,893,977 | 807,430 |
| 2036 | 100% | 74% | 4422 | 3290 | 1,918,712 | 766,051 |
| 2037 | 100% | 74% | 4480 | 3333 | 1,943,771 | 726,793 |
| 2038 | 100% | 74% | 4539 | 3377 | 1,969,157 | 689,547 |
| 2039 | 100% | 74% | 4598 | 3421 | 1,994,874 | 654,209 |
| 2040 | 100% | 74% | 4658 | 3466 | 2,020,927 | 620,683 |

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# The economic impact of marine plastic pollution

## in Saint Lucia

Impacts on the fisheries and tourism sectors, and the benefits of reducing mismanaged waste

Leander RAES, Damien MITTEMPERGHER and Aanchal JAIN

IUCN Economics Team and Ocean Team

Norad

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# Acronym List

| Acronym | Description |
|---|---|
| ALDFG | Abandoned, Lost, or Otherwise Discarded Fishing Gear |
| ABWREC | Antigua and Barbuda Waste Recycling Corporation |
| APEC | The Asia-Pacific Economic Cooperation |
| APWC | Asia Pacific Waste Consultants |
| BaU | Business-as-Usual |
| BPA | Bisphenol A |
| CBA | Cost-Benefit Analysis |
| CBD | Convention on Biodiversity |
| EEZ | Exclusive Economic Zone |
| EU | European Union |
| GDP | Gross Domestic Product |
| HDPE | High-Density Polyethylene |
| ICC | International Coastal Clean-Up |
| MEA | Multilateral Environmental Agreements |
| MPA | Marine Protected Areas |
| MPW | Mismanaged Plastic Waste |
| NGO | Non-Profit Organisation |
| NOAA | The National Oceanic and Atmospheric Administration |
| Norad | Norwegian Agency for Development Cooperation |
| NPV | Net Present Values |
| OECD | Organisation for Economic Co-Operation and Development |
| PET | Polyethylene Terephthalate |
| PWFI | Plastic Waste-Free Islands |
| SIDS | Small Island Developing States |
| TIDES | Trash Information and Data for Education and Solutions |
| UNWTO | United Nations World Tourism Organization |
| VTM | Value Transfer Method |
| WMB | Waste Management Budget |
| WTV | Willingness to Visit |

# 1. INTRODUCTION

In 2019, with support from the Norwegian Agency for Development Cooperation (Norad), IUCN launched the Plastic Waste-Free Islands (PWFI) project. The initiative's overarching goal is to drive the circular economy agenda forward and to reduce plastic waste generation and leakage from island states. The project consists in assisting several island nations in the Pacific and Caribbean region to reduce plastic waste generation and eliminate leakage to the ocean on which they depend. The PWFI was implemented in Fiji, Samoa, and Vanuatu in the Pacific, and in Antigua & Barbuda, Grenada and Saint Lucia in the Caribbean Region.

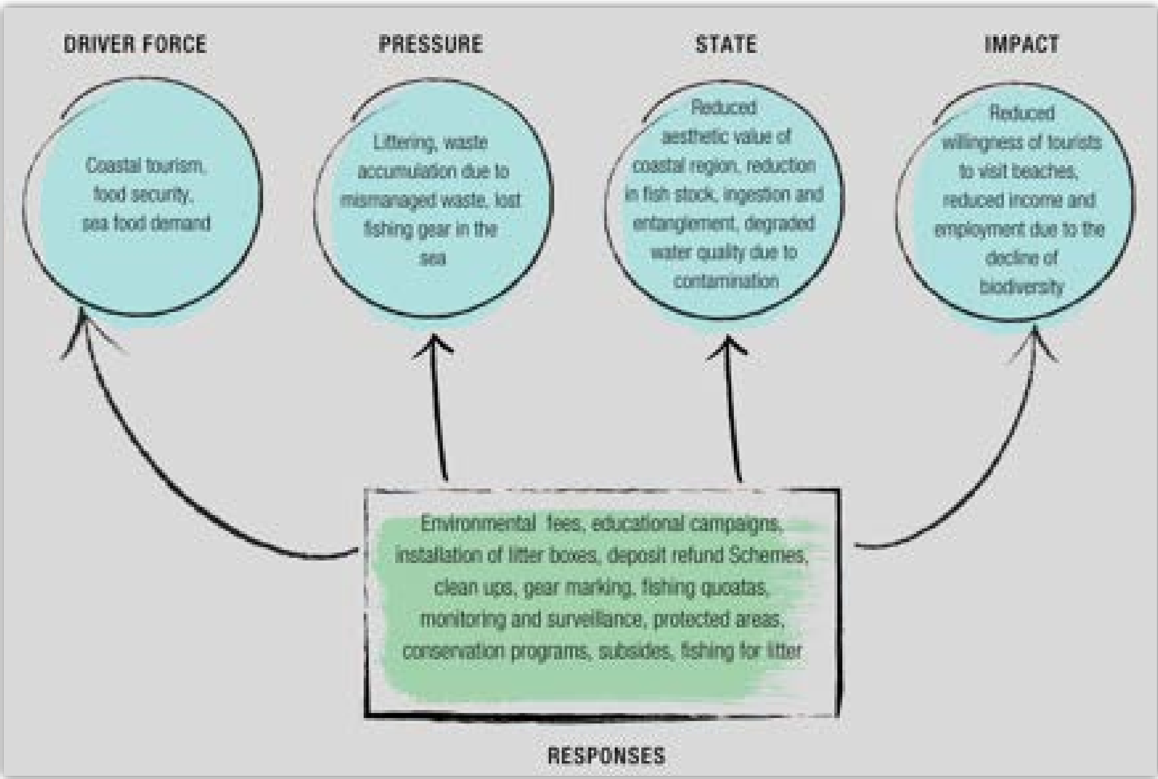
*Floating plastics in Saint Lucia's coastal waters. (Luis Eric Ecker).*

As part of the PWFI project, economic assessments were conducted. This report presents the findings of a study that aimed at estimating the impacts of marine plastics on the fisheries and tourism sectors in Saint Lucia, and the costs and benefits of implementing a solution (a national recycling system, with and without regional cooperation) to reduce mismanaged plastic waste and its leakage into the marine environment.

## 1.1. MARINE PLASTICS

Since the early 1950s, the use of plastics in everyday life has increased due to its durability, lightness, and low production cost (Filho et al., 2021). The amount of plastics produced between 2002 and 2015 was the same as the amount produced in the previous 52 years, between 1950 and 2002 (Geyer et al., 2017). At a global level, only 9% of plastics produced are recycled, and 22% of the plastic waste generated is mismanaged (Watkins et al., 2015; OECD, 2022a). According to a study by Thompson (2009), 10% of all mismanaged plastics leak into the oceans. Most of the mismanaged plastics are single-use plastics, mainly coming from food packaging, bottles, straws, and grocery bags. The main source of plastic waste flow in the oceans is land-based, contributing to approximately 80% of all marine plastics (Jambeck, 2015). Land-based litter load can come directly from the shoreline caused for example by tourism or it is transported from distant areas such as inland towns and industrial sites via watersheds and wastewater pipelines, mainly due to inefficient waste management practices (Veiga et al., 2016). The remaining 20% comes from sea-based activities (Hao wu, 2020), mainly from the fisheries sector (Andrady et al, 2012). Fisheries can add to marine plastic debris through discarded, lost, and abandoned fishing gear in the oceans and waterways (Oko-Institut, 2012). In addition to this, it is also responsible for throwing litter overboard from vessels (Hinojosa, 2011; Lusher, 2017).

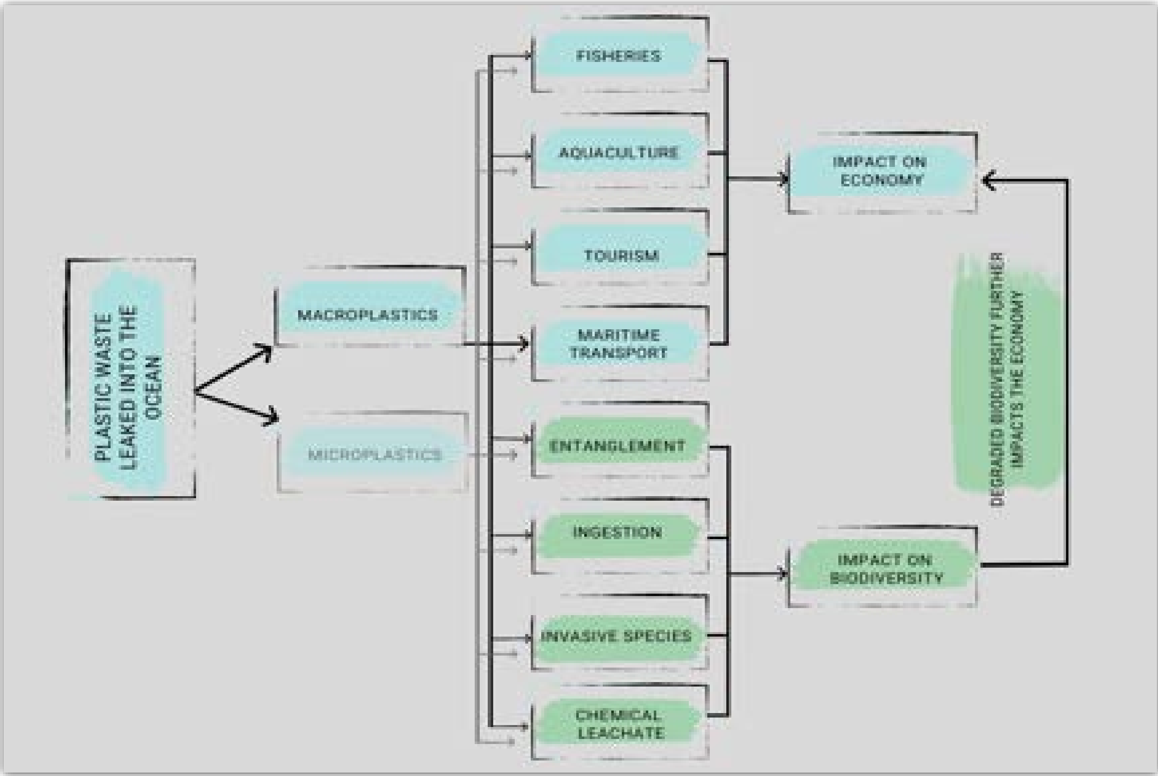
The marine plastic problem can be explained using the 'Driver, Pressures, States, Impacts and Responses' framework (Löhr et al., 2017; Miranda et al., 2019) (**Figure 1**). The drivers of plastic production originate from human needs such as food security, movement of goods and services, and shelter (Thevenon et al., 2014). These needs are fulfilled by the economic sectors where plastics are widely used (e.g., packaging of products, fishing nets for fisheries, construction, transportation, healthcare equipment, agriculture, and electronics, among others) (Abalansa et al., 2020). The use of plastics generates waste.




*Sources: Romagosa et al., 2014; Chassignet et al., 2021; Jahanishakib et al., 2021; Gebremedhin et al., 2018.*

***Figure 1 – Driver-Pressure-State-Impact-Responses framework for plastic pollution with examples***

Once plastics become waste, a part of this waste is mismanaged and leaks into the oceans. This generates negative impacts to the economy and biodiversity (**Figure 2**). The plastic pollution leaked generates four types of consequences. First, it impacts the physical ocean system through contamination (e.g., reduced health of marine habitats and water quality due to the presence of plastics), and sunlight blockage (Gallo et al., 2018). Second, the reduced environmental quality impacts marine biodiversity and ecosystems (e.g., increased fish mortality rates due to ingestion and entanglement, and reduced aesthetic value of beaches due to plastic litter) (Werner et al., 2016). Third, the degraded marine biodiversity and ecosystems has an impact on the provision of marine ecosystem services (e.g., supply of seafood and raw materials, transportation, storm protection) (Beaumont et al., 2019; Barbier, 2017). Finally, the economy is directly impacted (e.g., through lower fisheries and tourism revenues) (Bailly et al., 2017).




*Source: UNEP 2014a.*

***Figure 2 – Impact of plastics ending up in the oceans[1]***

Marine plastic pollution can generate significant economic costs in the form of gross domestic product (GDP) reductions, estimated at up to US$7 billion for 2018 alone (WWF, 2021). This is driven by the loss in revenue from tourism, fishing, aquaculture, transport, and other ocean-based activities (**Figure 2**) (McIlgorm et al., 2020). The costs associated with marine litter are divided between direct and indirect costs (Newman et al., 2015). Direct costs include the expenses for repair and replacement. For instance, fisheries revenues can be impacted due to damaged gears (Macfadyen, 2009) and expenses to the government to clean beaches where recreational activities are conducted (Mouat, et al., 2010). Additionally, the shipping industry can suffer losses due to marine debris entangling with propellers, potentially obstructing the engine (IMO, 2018). The indirect costs are related with impacts to biodiversity and habitats, including costs resulting from decreased ecosystem service provision (Rodríguez et al., 2020). For instance, the fisheries sector's revenue is further reduced due to the reduction in catches in the presence of marine plastics and lost or

[1] The study focuses on macroplastics.

abandoned gear (Richardson et al., 2021). Tourism industry's revenue could be impacted due to reduction in tourists' visits and spending in the presence of marine debris (McIlgorm et al., 2020).

Moreover, plastics at every stage of its life cycle (from production to consumption to waste treatment) emits a significant amount of greenhouse gases, which together with other sources, threaten the ability of the global community to keep global temperature rise below 1.5°C (Ford et al., 2022; Hamilton and Feit, 2019). It is estimated that by 2050, the plastic life cycle could contribute up to 15% of the entire carbon budget (Zheng and Suh, 2019).

These impacts will continue to increase if no action is taken to stop plastic production, consumption, and leakage. A report by the Organisation for Economic Co-operation and Development (OECD) states that the global plastic use and waste will triple by 2060 in the absence of plastic management policies. By 2060, plastic leakage to the environment is projected to double to 44 million tonnes a year, increasing the negative impacts on marine biodiversity and ecosystems, and further contributing to climate change (OECD, 2022b). To reduce the amount of plastics, efficient political responses and legal tools are required at the local, national, and international level (Nielsen et al, 2019; da Costa, 2020). The responses can be ex-ante (i.e., before plastic production and waste generation) or ex-post (i.e., once the plastic waste is dumped) (Lachmann et al., 2017; Schmaltz et al., 2020; Van Rensburg et al., 2020). Ex-ante measures include retention and reduction of waste at source (Wang, 2018). This can be achieved through changing producers' behaviour, e.g., extended producer responsibility (Raubenheimer et al., 2020; OECD, 2022a), or changing consumers' behaviour, (e.g., through bans and taxes) (Oosterhuis et al., 2014; BFFP, 2021). Consumer choices can also be altered through positive reinforcements such as educational campaigns (Willis et al., 2017) and incentives, such as deposit refund schemes for Polyethylene terephthalate (PET) bottles and plastic bags (Schuyler et al., 2018). In the case of ex-post responses, waste treatment and management techniques need to be addressed (Willis, 2018; Rajmohan et al., 2019). A report by PEW (2020) estimated that the amount of mismanaged plastics will more than double in the next 20 years if nothing is done. Jambeck et al. (2015) mention that to achieve a 75% reduction in the mass of mismanaged plastic waste, the 35 top-ranked countries with poor waste management practices would need to improve their waste management system by at least 85% by 2025. However, improving waste management infrastructure requires substantial investments (and time), especially in low and middle-income countries. The focus of these countries should first be on improving solid waste collection (UNEP, 2018) and then implementing local/coastal clean-ups (Rochman, 2016).

Some policies also aim at reducing plastics that have already escaped into the sea. For example, incentivising the fishing industry and rewarding fishers to bring back litter has proven to be successful in some cases (OSPAR, 2017; KIMO, 2010). This said, it might be more efficient to work on economic instruments that target land-based waste to reduce a significant amount of plastics, as most of the marine litter comes from land-based activities (Sheavly & Register, 2007; Jang et al., 2014; APEC, 2019). Nonetheless, there is no one straight solution to curb the plastic problem. The choice of a set of interventions for a country depends on the source of pollution being addressed, the country's institutional characteristics and infrastructure, consumer preferences and habitual behaviour, and the economy's overall sectoral composition (Oosterhuis et al., 2014).

## 1.2. THE CARIBBEAN

The Caribbean Sea, part of the Atlantic Ocean region, is one of the largest seas in the world and has an area of about 2,753,000 $km^2$ (Menzies et al., 2022). It has rich biodiversity and marine ecosystems that are crucial for the economic growth of tourism and fisheries, and as well for the health of the inhabitants (UNEP, 2019a). Within the Caribbean Sea there is a group of states and territories, including around 7,000 islands, islets, reefs, and cays, altogether called the Caribbean Region (Otieno, 2018).

*Saint Lucia Beach (IUCN).*

Caribbean economies depend highly on a healthy marine ecosystem, which is particularly valued for tourism (O'Brien et al., 2022). The climate and beaches help make the region one of the top tourist destinations in the world (Wong, 2015; Diez et al., 2019). The tourism sector accounts for 15% of the Caribbean Region's GDP (WTTC 2018). Aside from this, the Caribbean Sea is also a primary source of fish, providing different socio-economic opportunities for the inhabitants of the region (FAO, 2022; CANARI, 2020). The fisheries industry represents around 4.3% of the workforce in the region (CRFM, 2021).

However, the lucrative marine and coastal ecosystems are in danger, given that the Caribbean Sea is the second most plastic-contaminated sea in the world (UNEP, 2019b). According to a 2019 report by Forbes, 10 of the top 30 global polluters per capita are from the Caribbean region (Ewing-Chow, 2019). The plastic waste leakage in these territories is driven by illegal plastic waste disposal due to poor waste management systems along with limited recycling, and weak law enforcement (UNEP, 2018). Plastic pollution could cause damaging impacts on Caribbean islands' growing economies (Diez et al., 2019). According to APWC (2021a), around half of plastic waste generated in the Caribbean region is made up of by single-use plastics, mainly composed of PET bottles and plastic bags[2]. This plastic waste mainly comes from the household and commercial sectors within each territory (AWPC, 2021a).

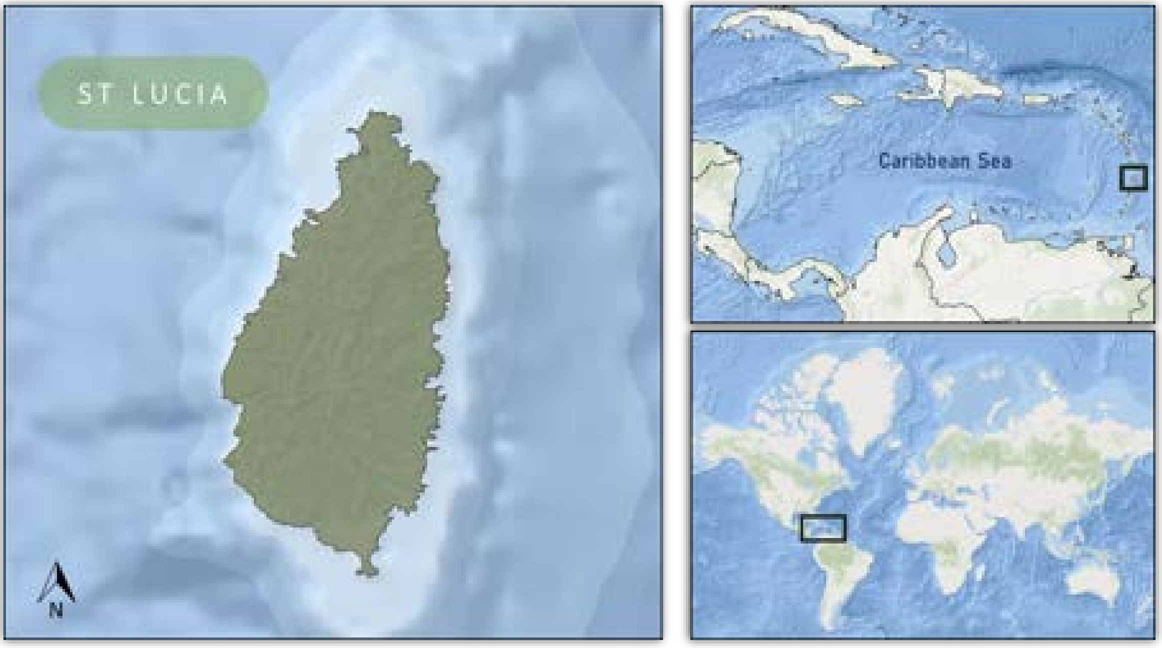
Small island developing states (SIDS) in the Caribbean region are particularly exposed and vulnerable to increased damage from plastic leakage, which poses a serious threat to ecosystems (Barrowclough et al., 2021; Lachmann et al., 2017). The thriving economies drive the demand for more consumer products, which exerts pressures on waste management facilities (UNEP, 2014b). Most of these islands have limited and small sized infrastructure, making the waste difficult to manage in terms of volume, composition, and recyclable potential (UNEP, 2019b).

Governments of these islands have started to recognise the impacts of this pollution on their social and economic well-being and have started to work on measures to curb plastic pollution (UNEP, 2018). Most measures focus on bans of single-use plastics and polystyrene, which comprise around 80% of Caribbean marine litter (Clayton et al., 2020). Considering the significant amount of PET and High-density polyethylene (HDPE) plastic leakage across the Caribbean islands, container deposit and transport schemes could prove effective (Schuyler, et al. 2018) to incentivise region-wide reverse logistics and to create recycling markets for countries without such availability (APWC, 2021a). However, there is little comparative analysis of policy responses to determine their efficacy (Chen, 2015; Rochman, 2016). To ensure sustainability of the Caribbean Sea's ecosystems, an integrated management approach with local stakeholders and government as well as with other nations is needed (Winther et al., 2020).

[2] This estimate is based on the estimation of single-used plastics in Antigua and Barbuda, Grenada, and Saint Lucia.

# 2. CASE STUDY INTRODUCTION

Saint Lucia is a small island developing state in the Eastern Caribbean inhabited by 183,629 people in 2020 (World Bank, 2021). It has a total land surface area of 616 km², with a maximum length and width of 43 and 23 km, respectively (**Map 1**) (Isaac and Bourque, 2001). **Table 1** provides an overview of some key data on Saint Lucia.




*Source: ESRI.*

***Map 1 – Location map of Saint Lucia***

***Table 1 – General data of Saint Lucia***

| Key Facts | |
|---|---|
| **Official name** | Saint Lucia |
| **Exclusive Economic zone** | 15,470 km$^2$ |
| **Coastline** | 158 km |
| **Capital** | Castries |
| **Climate** | Tropical |
| **Terrain** | Volcanic and mountainous with broad, fertile valleys; highest elevation 950 m |
| **Population age (2019)** | 47% under 30 years; 12% over 60 years |
| **Currency** | East Caribbean dollar (XCD) |
| **GDP (2019)** | USD 2.12 billion |
| **GDP per capita (2019)** | |

*Sources: Government of Saint Lucia, 2013a; Government of Saint Lucia, 2013b; Flanders Marine Institute, 2019; UNESCO, 2016; World Bank, 2019a; Kurup et al., 2010; Anthony et al., 2009; World Bank, 2022.*

Saint Lucia is rich in biodiversity and limited in physical and human resources, which makes its economy heavily dependent on its natural resources for food, shelter, medicines, water, sustainable livelihoods, agriculture, and tourism industries (Department of Sustainable Development, 2018). Since the 1990s, the economy has undergone a major transition from an agrarian-based economy to a service economy (Commonwealth Governance, 2015). Even though the agriculture sector is still important for social growth of the country, accounting for 20% of all jobs, the country's economy is mainly dependent on its tourism sector which is the largest foreign exchange earner (Jules, 2005). Tourism accounts for over 40% of the national GDP (Government of Saint Lucia, 2021; Knoema, 2022). The biological and geographical diversity helped Saint Lucia to attract a significant number of tourists worldwide (Mangal et al., 2019). In 2017, overnight visitors number were more than twice that of the year-round residents (Central Statistical Office of Saint Lucia, 2022a). When cruise ships are included, the total number of tourists is almost six times that of the resident population (World Bank, 2020). Saint Lucia provides a range of accommodations for its visitors. In 2019, it had 18 large hotels and 28 small hotels with around 5,078 rooms (APWC, 2021b). Additionally, the country has around 112 villas and cottages, and a growing rate of 'Airbnb' rooms (approximately 20% of the total room stock) (UNEP, 2019c, APWC, 2021b). Further details on tourism data can be found in **Table 2**, below.

*Table 2 – Overview of tourism data from Saint Lucia (2019)*

| Revenue (USD[3]) | International tourists (Number) | Expenditure per international tourist (USD) | Coastline (km) |
|---|---|---|---|
| 1,343,926,260 | 1,220,000 | 1,102 | 158 |

*Sources: WTTC, 2019 and World Bank, 2022.*

Over the last decade, Saint Lucia's fisheries sector has been growing as well (Government of Saint Lucia, 2018). Fisheries accounts for approximately 0.4% of the total GDP of the country in 2019 (at constant price), and for about 25% of the agricultural GDP in 2019 (Central Statistical Office of Saint Lucia, 2022b; FAO, 2022). This figure may not highlight the economic importance, but it is very crucial for Saint Lucia in terms of local livelihoods (World Bank, 2019b). Total capture production in Saint Lucia was estimated at 2 019 tonnes in 2019 (World Bank, 2019c). Over 50% of annual fish catches comprises offshore migratory pelagic fish (CRFM, 2020). Further details on fisheries data can be seen in **Table 3**, below.

*Table 3 – Overview of fisheries' data from Saint Lucia (2019)*

| Revenue (USD) | Catch volume (tonne) | Number of Vessels |
|---|---|---|
| 8,488,000 | 1,842 | 927 |

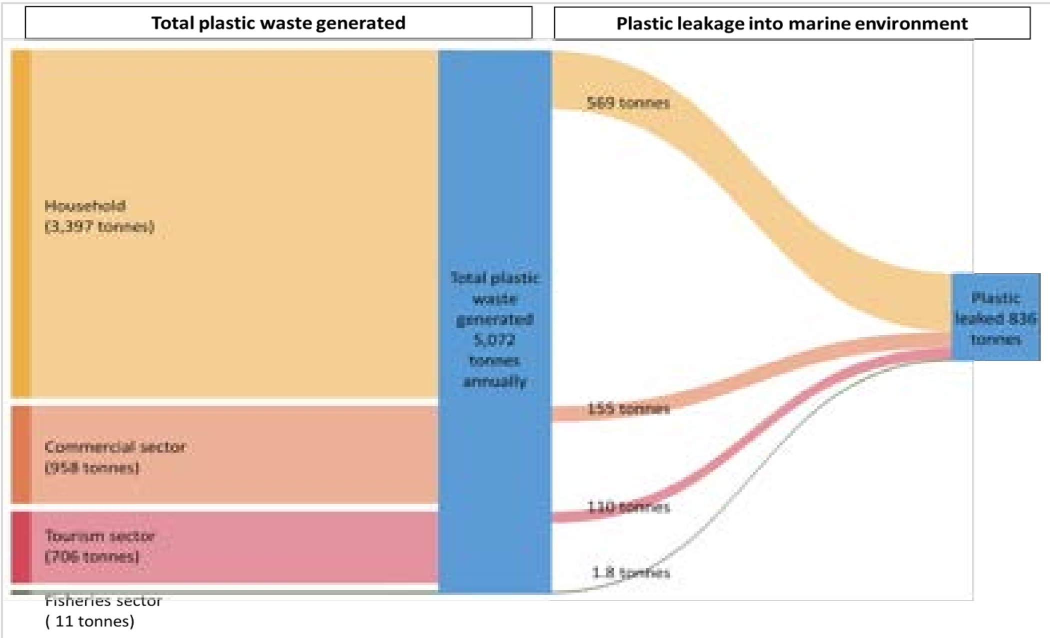
*Sources: Central Statistical Office Saint Lucia, 2022b; FAO 2022.*

Saint Lucia's dependence on its marine natural resources for economic activities such as tourism and fisheries, in combination with its exposed coastlines, makes it economically vulnerable to marine litter (Government of Saint Lucia, 2001).

[3] The exchange rate considered in this study is the average rate for 2019, USD 1 = XCD 2.702 (Source: https://www.exchangerates.org.uk/XCD-USD-spot-exchange-rates-history-2019.html). Accessed 25 July 2022.

## 2.1. Plastic leakage estimates in Saint Lucia

Plastic waste is a concern for the national government of Saint Lucia (Government of Saint Lucia, 2019a). According to Ewing-Chow (2019), Saint Lucia produces the sixth largest amount of plastic waste per capita in the Caribbean region, generating more than four times the amount of plastic waste per person as China. As per another report by APWC (2021b), 77,666 tonnes of waste were disposed of in Saint Lucia in 2019, out of which 6.5%, 5,072 tonnes were plastic waste. More than half of the disposed waste is disposed by households, followed by commercial and tourism sectors (**Figure 3**). Most of the plastic leakage is single-use plastics, predominantly PET bottles and HDPE containers (**Table 4**). Around 18.6% of all plastic waste disposed is leaked into the oceans each year, mainly due to poor waste management and limited landfill capacity (APWC, 2021b).




*Source: APWC, 2021b.*

***Figure 3 – Plastics disposed leaked from different sectors (2019)***

*Beach at Soufriere Bay, Saint Lucia (Simon Dannhauer, Shutterstock).*

*Table 4 – Plastic waste leakage rates (tonnes per year) per plastic polymer type and per sector in Saint Lucia (2019)*

| Plastic Polymer | Household leakage rates (tonne/year) | Commercial waste leakage rates (tonne/year) | Tourism leakage rates (tonne/year) | Fisheries leakage rates (tonne/year) |
|---|---|---|---|---|
| PET | 120.2 | 30.7 | 35.5 | 0.6 |
| HDPE | 45.0 | 18.1 | 7.1 | 0.2 |
| PVC | 28.4 | 13.7 | 10.3 | 0.0 |
| LDPE | 57.0 | 40.8 | 7.6 | 0.4 |
| PP | 33.4 | 0.5 | 2.4 | 0.2 |
| PS | 31.6 | 8.6 | 3.0 | 0.0 |
| Other | 253.4 | 42.8 | 44.3 | 0.5 |
| **Total** | **569.1** | **155.2** | **110.1** | **1.9** |

*Source: APWC, 2021b.*

To address the plastic litter problem, Saint Lucia has ratified and is responsible to enforce several conventions and protocols, or multilateral environmental agreements (MEAs) (Government of Saint Lucia, 2019b). Saint Lucia also has laws on a national level to reduce the plastic waste problem, including (Eunomia, 2021):

- Anti-litter legislation (1993), which makes provision for the abatement of nuisances caused by littering in public areas.
- Saint Lucia Solid Waste Management Authority Act (1996), which provides the framework for solid waste management in the country to develop a National Waste Management Strategy.
- National Waste Management Strategy – developed in 2003 but never submitted for the approval of the Cabinet of Ministers.
- Marine Pollution Management Act (2004), which establishes administrative and operational requirements for the management of ship-generated waste and places a ban on the disposal of waste into the territorial waters.
- Medical Waste and other Bio-hazardous Wastes Management Plan (2006), which sets minimum requirements for the safe handling, transportation, treatment, and disposal of biohazardous waste.
- Returnable Containers Act (2008), which can incentivise the return of plastic containers in exchange for the payment of a cash refund.

In recent years, the Government of Saint Lucia has substantially increased funding provided to the Saint Lucia Solid Waste Management Authority to efficiently address the plastic waste problem and reduce the load on landfills (UN, 2019). To reduce the load on landfills by controlling usage of single-use plastics, Saint Lucia has recently implemented a ban on single-use polystyrene products (Government of Saint Lucia, 2019c). However, the most common plastic items in household and commercial waste are beverage containers made from PET, accounting for roughly 23% of plastic disposal (APWC, 2021b). A recent initiative, RePLAST, has started to incentivise the collection of PET bottles (Unite Caribbean, 2020a, Unite Caribbean, 2020b). The only other complementary measures are environmental levies and fees imposed on visitors and ships arriving in Saint Lucia (Government of Saint Lucia, 2005).

# 3. IMPACT OF MARINE PLASTICS IN SAINT LUCIA (2019)

## 3.1. METHODOLOGY 1

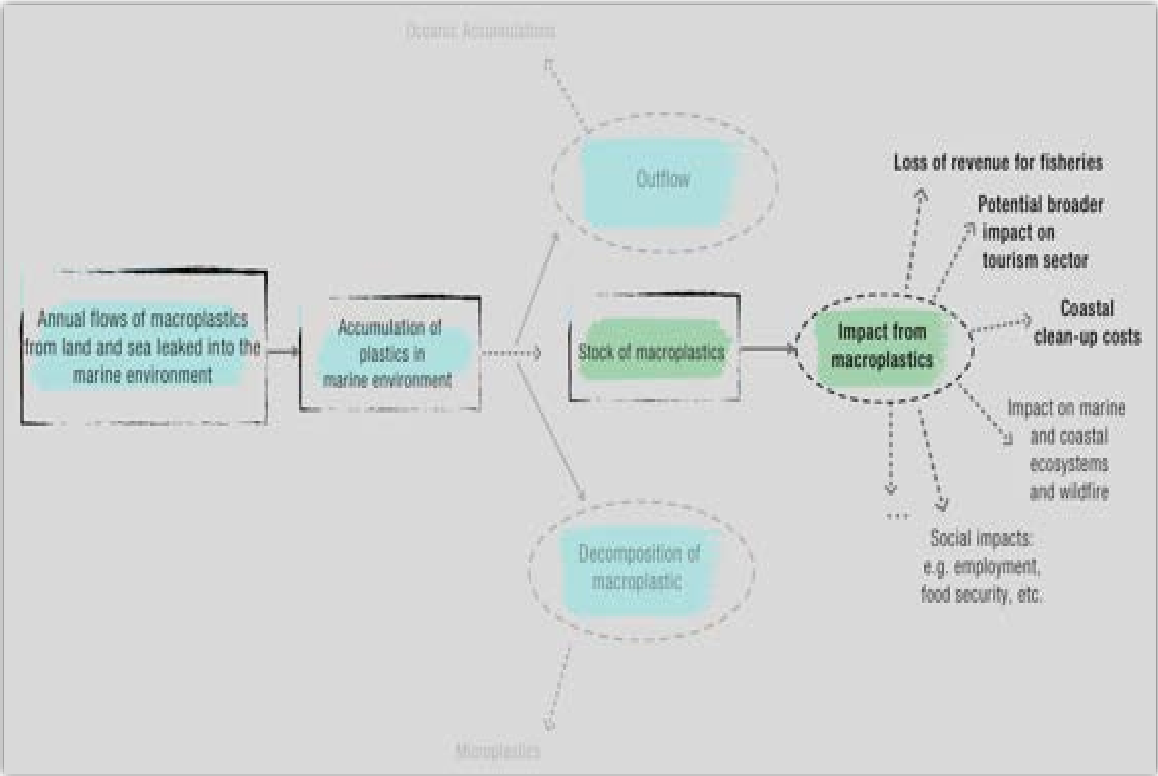
### 3.1.1. Data collection

Data collection was conducted through different means:

- Use of information developed through the PWFI project: plastic flow estimates (APWC, 2021a and b), policy analysis (APWC, 2021b; Eunomia, 2021) and business cases (Searious Business, 2021);
- National and international databases, including those providing spatial data; and
- Literature review.

### 3.1.2. Plastic stock estimates

Estimating the impact of marine plastics on the tourism and fisheries sectors requires a consideration of multiple steps and factors, taking into consideration that the impact of marine plastics is caused not only by its annual leakage (flow) into the marine environment, but by the stock of marine plastics already present (McIlgrom et al., 2009). For the purposes of this Report, the following steps were taken: (1) estimating plastic leakage; (2) estimating plastics flowing into the marine system considered (Caribbean Sea) from other sources or flowing out; (3) estimating a first stock of plastics; (4) considering decomposition and plastics floating out of the system and that accumulate in oceanic accumulation zones; and (5) estimating the stock of marine plastics accumulating in different parts of Saint Lucia's territory and impacting different sectors (**Figure 4**). In order to include inter-countries interactions, the focus is the Caribbean Sea, which is considered as a semi-closed system, whereas a simplification it is assumed the same amount of plastics that enters this system, floats out of it.




*Source: McIlgrom et al., 2009.*

***Figure 4 – A conceptualisation of the sources, stock, and fate of debris in the marine debris cycle***

The stock of marine plastics in the Caribbean Sea at time (t) can be represented by **Equation 1** (based on McIlgrom et al., 2009):

> *Stock (t) = Stock (t-1) + Volume of plastics entering the marine environment (t-1) – Volume cleaned up (t-1) – Volume decomposed (t-1) – Volume floating out of the system[4] (t-1) (**Equation 1**)*

This plastic stock is then divided among countries bordering the Caribbean Sea based on the size of their exclusive economic zone (EEZ), shallow waters, and coastlines (See **Map A1** in **Annex A1**).

Both the amount of plastics presents in Saint Lucian waters and its annual flow leaking into the marine environment are estimated based on (i) APWC estimates for Saint Lucia (2021b), and (ii) regional leakage into the Caribbean Sea based on Lebreton and Andrady (2019) and APWC (2021c and 2021d) (for Grenada, and Antigua and Barbuda). To estimate the current amount of plastics present, the following factors were considered: historical accumulation, degradation into microplastics, regional exchanges, and outflow towards oceanic plastic accumulation zones (Lebreton et al., 2019; Eriksen et al., 2014; Lebreton et al., 2018). **Annex A1** provides a more detailed overview of the different assumptions and calculations that were applied to estimate the amount of plastics present in Saint Lucian waters.

[4] This refers to plastics leaked into the system from sources bordering the Caribbean Sea (see **Annex A1**). For sources outside this system, we assume that the same amount of plastics enter, as leave the system.

Plastic accumulation in different parts of the marine environment was estimated based on two different plastic accumulation scenarios. These distributions of plastics in different areas are considered fixed over time.

1. **Plastic accumulation scenario 1**: Based on GRID-Arendal, (2018) and presented in **Table 5** (supporting papers: Jang et al., 2015; Lebreton et al., 2012; Jambeck et al., 2015; Cózar et al., 2014; Eriksen et al., 2014; van Sebille et al., 2015).

***Table 5 – Areas of plastic accumulation according to plastic accumulation scenario 1***

| Accumulation area | Percentage (%) |
|---|---|
| Sea surface | 0.50 |
| Coastline and seafloor[5] | 33.70 |
| Coastal waters | 26.80 |
| Open ocean | 39.00 |

2. **Plastic accumulation scenario 2**: Based on Lebreton et al., (2019) and presented in **Table 6**.

***Table 6 – Areas of plastic accumulation according to plastic accumulation scenario 2***

| Accumulation area | Percentage (%) |
|---|---|
| Shoreline | 98.62 |
| Coastal waters | 0.18 |
| Open ocean | 1.20 |

Throughout the text, the first accumulation scenario will be referred to as "plastic accumulation scenario 1"; the second as "plastic accumulation scenario 2".

### 3.1.3. Impact estimates

***Estimates of impact on fisheries***

Fisheries are not only a source of marine plastics, but also suffer from its impact. This impact can be directly and easily measurable through market values (McIlgrom et al., 2011), or indirectly, as related to the degradation of natural marine capital assets. Direct economic impacts can occur due to the costs to repair or replace damaged or lost gear due to encounters with marine plastics (e.g., repairing vessels with tangled propellers, clogged water intakes, etc.), as well as the loss of earnings due to lost productive time dealing with marine plastics encounters and from reduced or contaminated catches (Takehama, 1990; McIlgrom et al., 2009; Newman et al., 2015).

The impact of macroplastics on Saint Lucia's fisheries was estimated with the help of what is referred to as 'value transfer method' (VTM), which is often used in impact analyses (Johnston et al., 2018). VTM is applied by assigning existing economic estimates of a current study/region/ecosystem to a similar problem elsewhere.

[5] No estimates were available on how much plastics end up on the coastline versus on the seafloor. It is assumed that the maximum amount of plastics that can end up on the coastline is 33.7% of the annual amount leaked into Saint Lucia's marine environment (from both Saint Lucia and outside sources).

Following Arcadis (2013) and UNEP (2014a), who estimated the impact of marine plastics on European Union (EU) and global fisheries respectively, in this study Mouat et al (2010) is used as the reference study. Mouat et al. (2010) estimated the impact of marine plastics on Scottish net fisheries specifically. Here, a VTM was applied based on values from Mouat et al., (2010), and separating impact on net fisheries, from the impact on trap and line fisheries.

Mouat et al., (2010) conducted a survey study of Scottish net fisheries to investigate the extent by which this sector is impacted by marine litter, concluding that marine litter negatively impacted Scottish fisheries' 2008 revenue by 5%. Globally, an average of 80% of all marine litter is composed of plastics (Dunlop et al., 2020). Therefore, it can be considered that the impact of marine plastics on Scottish fisheries' revenue was 4%, i.e., 80% of 5%. This impact is broken down into four cost categories: dumped catch, net repairs, fouling incidents, and time lost clearing nets (Mouat et al., 2010).

Mouat et al., (2010) impact estimates are then transferred to the fisheries of Saint Lucia. Although there is a relation between the amount of plastics present in Scottish waters versus what is present in Saint Lucian waters, and how it impacts both countries' fisheries, fisheries from Scotland and Saint Lucia are different in terms of the number and type of fishing vessels, the size of the fishing area, the volume and value of the fish catch and type of fisheries, among other factors. Thus, the value (or impact) transfer is not merely based on the amount of marine plastics present to transfer the size of the impact, but it also adjusts for a series of other variables or proxies that needs to be considered, for example: types of fishing gear used. The detailed methodology which presents the adjustment of fisheries size and impact estimation is presented in **Annex A1.3**.

***Estimates of impact on tourism***

As with fisheries, tourism is another sector that is a source of mismanaged plastics but is also impacted by the presence of marine plastics. One of the main impacts on tourism from marine litter comes from the pollution of beaches and coastal areas. These can have a negative impact on tourists' willingness to visit (WTV) beaches, leading to a loss in revenue (Jang et al., 2014; Kosaka and Steinback, 2018). Ballance et al., (2000) state that tourist behaviour, including WTV, can change according to different numbers of plastic items present on beaches. Two studies estimating tourists' WTV in other countries as related to the presence of marine plastics on the beaches are used in order to evaluate the potential risks to Saint Lucia's tourism industry. These studies generated their WTV impact by taking surveys of how tourists' WTV varied according to the number of plastic items present on beaches.

A study conducted by Krelling et al., (2017) used a contingent valuation to assess the WTV of a beach under different littering scenarios on two beaches in Brazil. Ballance et al., (2000) used a travel cost method to assess the impact of plastics on tourism in Cape Town, South Africa. These different studies constitute options to estimate the risk of marine plastic pollution to the tourism sector and were applied to Saint Lucia. **Annex A1.4** provides more details on the results of these studies.

In this study, the focus is solely on international tourism. Although domestic tourism does exist in Saint Lucia, the impact of marine plastics on beach visits from the local population is not as clear as the potential reduction in international arrivals due to pollution. Furthermore, no distinction of behaviour has been made between land-based tourism, which includes air travellers as well and sea-based tourism (yachting and cruise ships). This means that the impact is considered the same regardless of the tourist category. However, it could be argued that sea-based tourism may be more impacted by marine plastic pollution since plastics floating around can also cause damages to vessels.

Applying the VTM using results from the Ballance et al. (2000) and Krelling et al. (2017) studies can result in a negative impact estimate on the tourism sector that has not yet occurred in Saint Lucia. Despite increasing amounts of plastics in the Caribbean Sea, the Caribbean tourism industry has continued to grow in recent decades (Diez et al., 2019). Thus, the potential impact on tourism is a risk that has not (yet) fully materialised.

For the purposes of this study, this potential negative impact on tourism revenue is described as a risk (potential losses in tourism revenue). It is an avoided cost for the tourism sector as large accumulations of plastics on beaches, deterring tourism visits, is not yet occurring. This is due to two factors: First, actions are undertaken to reduce the potential impact of plastic pollution of beaches on the tourism industry, including, but not limited to: voluntary beach clean-ups (Hidalgo-Ruz and Thiel, 2015), and actions undertaken by the waste management authorities to keep beaches clean (Newman et al., 2015), among others.

Second, plastics may also accumulate in less visible areas than on sandy beaches, such as in mangroves or between rocks or underneath the sand, get buried in other parts of the shoreline, both above and below water, are taken out to the open ocean to accumulate elsewhere, or degrade into smaller, less visible particles. It is challenging to account for the costs of the different actions and how much plastics end up in each accumulation area. Thus, instead of only estimating the risk to the tourism sector if beaches are left uncleaned – and as a proxy for the minimum costs incurred by plastic pollution on Saint Lucia’s coastline – this study estimates the costs of cleaning up all plastic items that could at one point in time (during a given year) accumulate on the coast-or shoreline. This should be understood as the cost estimate of a continuous effort throughout the year, not a one-time clean-up.

*Plastics at Saint Lucia's coastline (Luis Eric Ecker).*

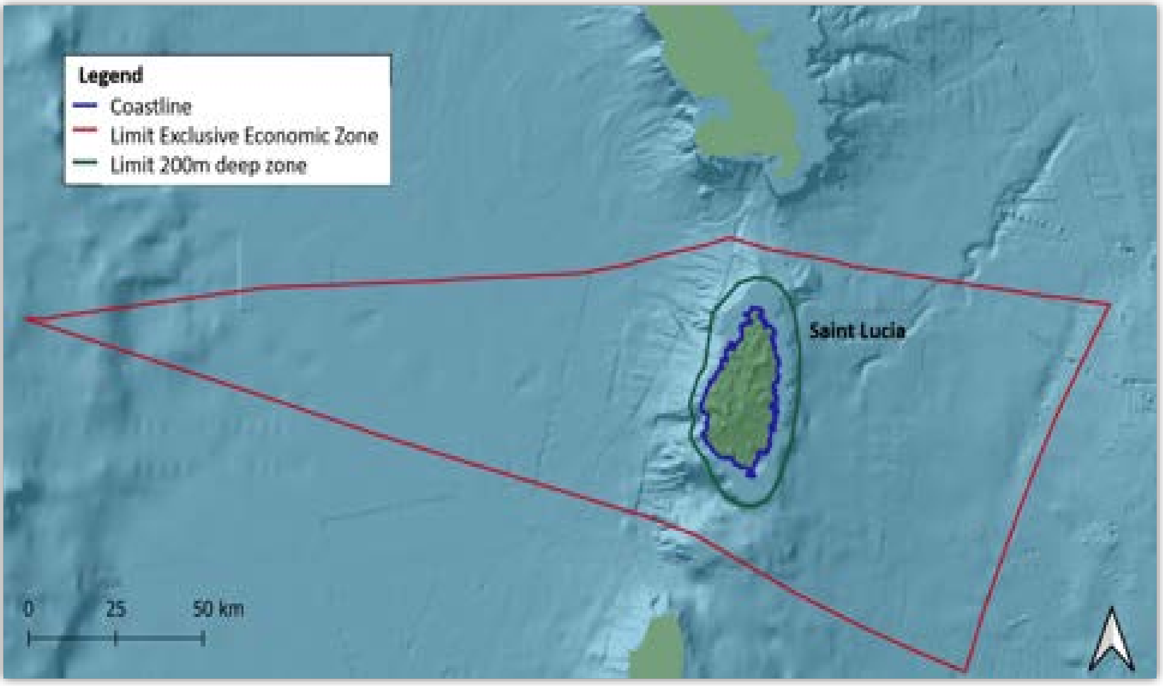
Since no clear budget allocation on the different beach clean-up efforts could be estimated (considering the combined cleaning efforts of municipalities, non-profit organisations (NGOs), hotels, etc.), and considering that no studies were available on where on the shore-or coastline plastics end up exactly during a specific time period, a proxy for this cost was developed. The costs of cleaning the entire coastal area of Saint Lucia were calculated using the estimated amount of plastics that could end up on the coastline in one year (here 2019), followed by estimating the labour costs of cleaning plastics from beaches, based on data available through the Trash Information and Data for Education and Solutions (TIDES) database[6]. UNEP (2014a) used the opportunity cost of volunteered time to estimate the global clean-up costs imposed by plastic litter on beaches. This study considers that both volunteers and paid costs are potentially involved in cleaning efforts and assumes that the whole coastline is cleaned. This potentially creates an overestimation of this cost, but it is a proxy for the minimum effort needed to prevent further plastics from accumulating along Saint Lucia's coastline, potentially impacting tourism in the future.

## 3.2. Results (2019)

### 3.2.1. Plastic accumulation scenarios

The application of the previously described methodology requires not only estimating the stock of plastics, but also knowing where it is accumulating, as different accumulation areas will impact different sectors (fisheries or tourism in this study). **Map 2** presents the marine regions of Saint Lucia where plastics could accumulate depending on the scenario considered (plastic accumulation scenario 1: **Table 7**, or plastic accumulation scenario 2: **Table 8**). More details on the construction of plastic stocks are provided in **Annex A1**.

[6] Available at: https://www.coastalcleanupdata.org/reports




*Sources: GEBCO, 2012; Flanders Marine Institute, 2022; University of California Berkeley library geo data.*

***Map 2 – Marine regions of Saint Lucia***

***Table 7 – Estimate of plastic accumulation (plastic accumulation scenario 1) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---|
| Sea surface | 186 |
| Coastline and seafloor | 18,169 |
| Coastal waters | 4,023 |
| Open ocean | 14,479 |

***Table 8 – Estimate of plastic accumulation (plastic accumulation scenario 2) (2019)***

| Accumulation area | Amount of plastics (tonnes) |
|---|---|
| Shoreline | 53,168 |
| Coastal water (less than 200m) | 27 |
| Offshore (more than 200m) | 446 |

### *Marine plastics impacting fisheries*

For plastic accumulation scenario 1, the sum of plastics present on the sea surface, coastal waters, and open oceans within the EEZ is considered as marine plastics that will impact fisheries. The total amount of plastics **impacting fisheries** under this scenario is: 18,688 tonnes.

For plastic accumulation scenario 2, the sum of plastics present in coastal waters and offshore is considered for the fisheries impact analysis. The total amount of plastics **impacting fisheries** under this scenario is: 473 tonnes.

Additionally, the amount of plastics leaked in 2019 and impacting the fisheries sector is also estimated. Under plastic accumulation scenario 1 an average of **1,463 tonnes** of plastics, and under plastic accumulation scenario 2 an average of **37 tonnes** are estimated to have leaked into the EEZ in 2019 and accumulated in areas where plastics cause an impact on Saint Lucian fisheries.

For estimating the results by transferring the impact calculations presented in the study by Mouat et al. (2009), plastic accumulation scenario 1 is used. The relative difference between the amount of plastics in Scotland and Saint Lucia under both plastic accumulation scenarios remains more or less unchanged when the proposed methodology is applied; the results of the 'rule of three' under any individual plastic accumulation scenario are similar (see **Annex A1.3** for detailed explanations).

***Marine plastic risk to the tourism industry and coastal clean-up costs***

In this study, it is considered that, based on the plastic accumulation scenarios, a part of the 2019 annual plastic leakage, will end up on the coast or shoreline (see **Tables 5** and **6**) at a certain moment during the year. The assumption applied is that the percentage of plastic flow that accumulates on the coastline in that particular year is what could potentially impact tourism after being deposited. Although plastics could become degraded, buried in the shoreline, taken away by animals, etc., the largest potential accumulation during a one-year period is used to estimate the highest potential impact, or maximum risk, to the tourism industry. From the annual leakage estimate of the countries of the region, the amount of plastics considered to accumulate on the coastline (that could potentially impact tourism) is calculated based on plastic accumulation scenario 1. According to this scenario 33.7% of the plastics in the sea could end up on the coastline (or seafloor). Applying the second plastic accumulation scenario, 98.68% of the plastics in the sea ends up on the shoreline. We assume that during the year the plastics are leaked, it could accumulate on the coast or shoreline for some time.

Thus, according to plastic accumulation scenario 1, an estimated maximum amount of 1,337 tonnes of plastics could end up on the coastline of Saint Lucia in 2019. According to plastic accumulation scenario 2, the total maximum amount is estimated to be 3,914 tonnes.

To transfer the studies from Krelling et al. (2017) and Ballance et al. (2000), who estimate impact based on plastic items present on beaches, to the potential impact estimates for this study, the amount (tonnes) of plastics needs to be translated to the number of items (see **Annex A1.4** for more details). To estimate how many items there could be per km of coastline, the number of items present in one tonne of plastics is estimated using the TIDES database[7]. Data from the last five (5) coastal clean-ups in Saint Lucia (tonnes of plastics and items of plastics collected) were downloaded and compared to the maximum amount of plastics that could have ended up on the coastline under each plastic accumulation scenario in 2019 (see **Tables 9** and **10** for details). The number of items per tonne collected in 2018 were used for the analysis focusing on 2019 only. For the 2023-2040 period (see **Chapter 5**), the average from

[7] https://www.coastalcleanupdata.org/ Accessed on 15 October 2021.

2016-2020 was used. **Table A8** in the Annex gives a more detailed overview of the location (above or below water) from which the items were retrieved (land or sea).

*Table 9 – Number of items in one tonne of plastics (2016-2020)*

| Year | Plastics collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|
| 2020 | - | - | - |
| 2019 | 1.51 | 7,853 | 5,199 |
| 2018 | 2.42 | 2,954 | 1,219 |
| 2017 | 2.62 | 23,806 | 9,083 |
| 2016 | - | - | - |
| | | Average items per tonne collected | 5,167 |

*Source: Ocean Conservancy, 2021.*

*Table 10 – Number of plastic items per metre of coastline (2019)*

| Data on Saint Lucia | Values |
|---|---|
| Coastline (km) | 158 |
| Plastics (in tonnes) (plastic accumulation scenario 1) | 1,337 |
| Plastics (no. of items) | 6,952,972 |
| Plastic items per km | 44,006 |
| Plastic items per m | 44 |
| Plastics (in tonnes) (plastic accumulation scenario 2) | 3,941 |
| Plastics (no. of items) | 16,277,292 |
| Plastic items per km | 128,776 |
| Plastic items per m | 128 |

According to plastic accumulation scenario 1, there could be a maximum of 44 plastic items per metre of coastline in Saint Lucia, while according to plastic accumulation scenario 2, this could be up to 128 plastic items per metre.

The results for Saint Lucia are similar to those found for Antigua and Barbuda (Mittempergher et al., 2022), applying the same methodology, but much higher (about double) as those found for Grenada (Raes et al., 2022). The above estimated accumulation frequency of plastic items for Saint Lucia is large when compared to the average amount of plastic items collected during a single beach clean-up and reported in the TIDES database for the Lesser Antilles in 2019. According to this database, during coastal clean-ups an average of 1.5 plastic items per metre were recorded (see **Table A6** in annex for more details). Overall, these numbers are significantly lower than the estimates presented in this study, except for Saint Maarten, where a value of 162 items/metre was reported for 2021-2022[8].

There are a few explanations for these differences. First, the allocation of plastics following GRID-Arendal (2018) and Lebreton et al., (2019) may not only consider plastics ending up in areas accessible for clean-ups (for example by ending up in coastal areas where the water is too deep). Second, this study uses the maximum potential number of items that could end up on the coastline in a given year. Plastics can get buried, degraded, etc. and thus no longer be visible for beach cleaners. Finally,

[8] Retrieved from https://www.coastalcleanupdata.org/reports, for 54 clean-ups that took place between 08/04/2021 and 08/04/2022 in Saint Maarten.

research has shown that the more plastic items are surveyed on a beach in a given year, the higher the estimated annual number of plastic items (Smith and Markic, 2013; Schernewski et al., 2018).

### 3.2.2. Impact of marine plastics on fisheries (2019)

For the fisheries sector, this study only estimates the results using plastic accumulation scenario 1, since the methodology gives a similar result regardless of the scenario (See **Annex A1.3** for details). The impact on fisheries for 2019 is based on data on the types of vessels and fishing methods, (see **Annex A1.3** for more details). The results are presented in **Table 11**.

***Table 11 – Estimated impact of plastic pollution on fisheries' revenue (2019)***

| Type of impact | Percentage of fisheries' revenue |
|---|---|
| Dumped catch | 1.2% |
| Net repairs | 0.6% |
| Fouling incidents | 0.1% |
| Time lost clearing nets | 1.8% |
| **Total impact** | **3.7%** |

The total impact of 3.7% is slightly lower than the 4% revenue impact estimated by Mouat et al. (2010) for Scottish fisheries. The main reason behind the lower impact stems from the fact that only 27% of fish caught in Saint Lucia is done using net gears (the only gear type that is impacted by net repairs and time lost clearing nets), while Mouat et al. (2010) focused only on net fishing for Scotland (i.e., 100% of the catches were done using that type of fishing gear). Should it be the same situation in Saint Lucia, based on the methodology used in this study, the impact on fishing revenues would also be much higher.

Other studies also used Mouat et al. (2010). For example, Arcadis (2014) estimated and adjusted the impact of marine litter on EU fisheries at 0.9% of the revenue. UNEP (2014a) and Trucost (2016) calculated that those marine plastics caused an annual global revenue loss of 2% in marine fisheries. Overall, the impact on Saint Lucia's fisheries sector is larger than what these studies found. However, the costs of fouling incidents, here estimated at 0.1 % for Saint Lucia, is an impact also analysed by Takehama (1990), who estimated that the cost of damage on Japanese fishing vessels caused by marine debris, based on statistics from the insurance system, resulted in an estimated impact on fisheries' revenue at 0.3% of gross annual value.[9] This estimate was also used by McIlgorm et al. (2011, 2009) to estimate the economic cost of marine debris damage in the Asia-Pacific region. Based on the methodology used in this study, fishing boats in Saint Lucia suffer slightly less from fouling incidents than what was found in Japan by Takehama (1990), although using a different methodology, even when adjusting for the amount of plastics (80%) in marine debris.

[9] McIlgrom et al. (2020) update this impact estimate to 1% in their more recent study on marine plastics impact in the APEC Region.

*Fishing nets at fishing port Bananes, Saint Lucia (APWC).*

Given Saint Lucia's fisheries' revenue during 2019[10], **the estimated 3.7% revenue impact of the plastic stock on fisheries' revenue was XCD 834,527** (USD 308,781).

Saint Lucia's fisheries sector and others fishing in the Caribbean Sea, also contribute to marine plastics through abandoned, discarded, or lost fishing gear (ALDFG) (APWC, 2021b), which in return impacts the fishing industry (Lusher, 2017). ALDFG can perform "ghost fishing," which means it can continue to trap fish and crustaceans, as well as ensnaring and capturing other species, while this gear is no longer being controlled (Edyvane and Penny, 2017; NOAA Marine Debris Program, 2015). Ghost fishing, despite not being addressed in this study, which looks only at the direct costs to the fishing sector, is an important aspect to consider when looking at fisheries and marine plastics. Fish ensnared in lost fishing gear can lead to increased fish mortality, reduced fish catch, reduced sustainability of the catch (Erzini, 1997; Butler et al. 2013; 1997) and revenue losses of 5% or even higher (Mathews et al., 1987, Nakashima and Matsuoka, 2004; Tschernij and Larsson, 2003). A Caribbean study reported that traps were the most common type of gear becoming ALDFG, 41%, followed by various types of nets (25%) (Matthews and Glazer, 2009). APWC, based on fisheries statistics and a study by Richardson et al. (2019a), estimated leakage of fishing gear in 2019 in Saint Lucia as follows: (i) 56 nets, (ii) 74 traps and (iii) 1,557 lines. This quantity of gears corresponds to an estimated 12.6 tonnes of plastic gear leaked that year (APWC, 2021b). In a second estimate, using trade statistics, APWC (2021b) calculations suggest an average of around 9 tonnes of fishing gear could leak annually in Saint Lucia's marine environment from its fisheries, providing two estimates of the potential size of ALDFG.

In addition to the rates at which fishing gear is lost, other factors that contribute to the likelihood of ghost fishing are the gear's degradation rate, which depends on different factors, including for example: water temperature, catch efficiency of the gear, susceptibility of species to ghost fishing, depth where the gear is lost, and/or the tidal

[10] **XCD 22,934,576** (USD 8,480,000).

and current conditions, which influence whether nets ball up faster or slower (Antonelis et al., 2011; Brown and Macfadyen, 2007; Erzini et al., 1997; Kaiser et al., 1996; Masompour et al., 2018). Thus, although ghost fishing is not included in this study as a direct cost to the fisheries sector, if included, ghost fishing would increase the cost estimates by increasing the estimated losses to the fisheries sector due to marine plastics.

### 3.2.3. Potential risk of marine plastics to tourism (2019)

**Table 12** presents the results on the maximum potential loss that Saint Lucia could suffer if the estimated amount of coastline plastics were accumulating without being removed or ending up on the seafloor. For Saint Lucia, results are the same for each impact transfer, regardless of the plastic accumulation scenario used.

***Table 12 – Estimated results of maximum potential impact on international coastal tourism in Saint Lucia (2019)***

| Result based on | Plastic accumulation scenario | Percentage of tourists not willing to visit | Number of tourists not willing to come | Potential loss in revenue (XCD) | Potential loss in revenue (USD) |
|---|---|---|---|---|---|
| Ballance et al., 2000 | Both plastic accumulation scenarios give the same results | 97% | 1,183,400 | 3,522,350,091 | 1,303,608,472 |
| Krelling et al., 2017 | Both plastic accumulation scenarios give the same results | 82.4% | 1,005,280 | 2,992,181,933 | 1,107,395,238 |

Relative to the contribution of the tourism sector to GDP, the potential risk (i.e., the potential loss in revenue from international tourists visiting Saint Lucia) is estimated to be **XCD 3,522,350,091** (USD 1,303,608,472) based on Ballance et al. (2000), and **XCD 2,992,735,631** (USD 1,107,395,000) based on Krelling et al. (2017). Thus, the maximum risk to the tourism industry is estimated to be a potential loss equivalent to 61% and 52%, respectively, of Saint Lucia’s GDP.

*Plastic toys found on a beach, Saint Lucia (IUCN).*

The estimate of the potential impact on tourism is very large. Although marine plastics can have a negative impact on tourism in the Caribbean (see for example Schuhmann, 2011), the actual impact may not be of the magnitude of the potential impact as presented above. For example, UNEP (2014a) and Trucost (2016), assumed that 3% of global marine tourism revenue was lost because of marine litter, including plastics, while McIlgrom et al., (2020) used a value of 1.5% of marine tourism GDP for their study on the economic costs of marine debris to the Asia-Pacific Economic Cooperation (APEC) economies. These; however, are studies that focus on a global or regional impact, including many countries that are not as dependent on beach-going tourists as Saint Lucia. Conversely, Jang et al., (2014) found that visitor numbers at Geoje island's beaches, in the Republic of Korea, decreased by 63% after litter washed up on the beaches after a storm. This is an impact value closer to what was found by Ballance (2000) and Krelling et al. (2017) and is used here in this study to estimate the highest potential impact or overall risk to Saint Lucia's tourism sector.

The potential revenue loss estimates for Saint Lucia are based on the premise that all plastics that could end up on the shoreline accumulate sufficiently to have a visible impact on the aesthetic value of Saint Lucia's marine environment, and particularly its beaches and coastal areas. It also assumes all plastic items have a size that relates to this visible impact. This illustrates the magnitude of risk for Saint Lucia's economy. As a proxy for the actual cost of marine plastics on Saint Lucia's tourism economy in 2019, the costs of cleaning up the entire amount of plastics estimated to end up on Saint Lucia's shoreline is estimated.

### 3.2.4. Coastal clean-up costs (2019)

According to the data from the last five years of the International Coastal Clean-up (ICC), 360 person days were used to clean 5.6 tonnes of plastics from the coastline of Saint Lucia (Ocean Conservancy, 2019). This study considers that one person works eight hours a day. Given that Saint Lucia had an estimated 1,337 tonnes (plastic accumulation scenario 1) of plastics ending up on its coastline in 2019, it is estimated that approximately 85,811 person-days would have been needed to clean all the plastics from the coastline in 2019. Minimum wage for 2019 was estimated at XCD 13.6, based on minimum daily wage published by the Ministry of Labour of Saint Lucia (2006). Based on these data, the cost of coastal clean-ups in 2019 – so as not to have an impact on tourism – is estimated to be **XCD 1,167,029** (USD 431,913) for plastic accumulation scenario 1. **Table 13** displays the details for both plastic accumulation scenarios.

*Table 13 – Estimated coastal clean-up costs according to the two plastic accumulation scenarios (2019)*

| | Plastics (in tonnes) | Coast cleaning cost (XCD) | Coast cleaning cost (USD) |
|---|---|---|---|
| Plastic accumulation scenario 1 | 1,337 | 1,167,029 | 431,913 |
| Plastic accumulation scenario 2 | 3,914 | 3,415,098 | 1,263,914 |

This estimated coastal clean-up costs will be used in the future scenarios presented in **Chapter 5** to obtain the gross benefit of reducing plastics in the marine environment.

Although these clean-up costs are potentially an overestimation, they should be understood as the minimum cost necessary to prevent plastic accumulation that could potentially impact the tourism industry in the future.

**Figure 5** presents the risks due to potential losses and the estimated clean-up costs, as well as the total revenue from tourism for 2019 under plastic accumulation scenarios.

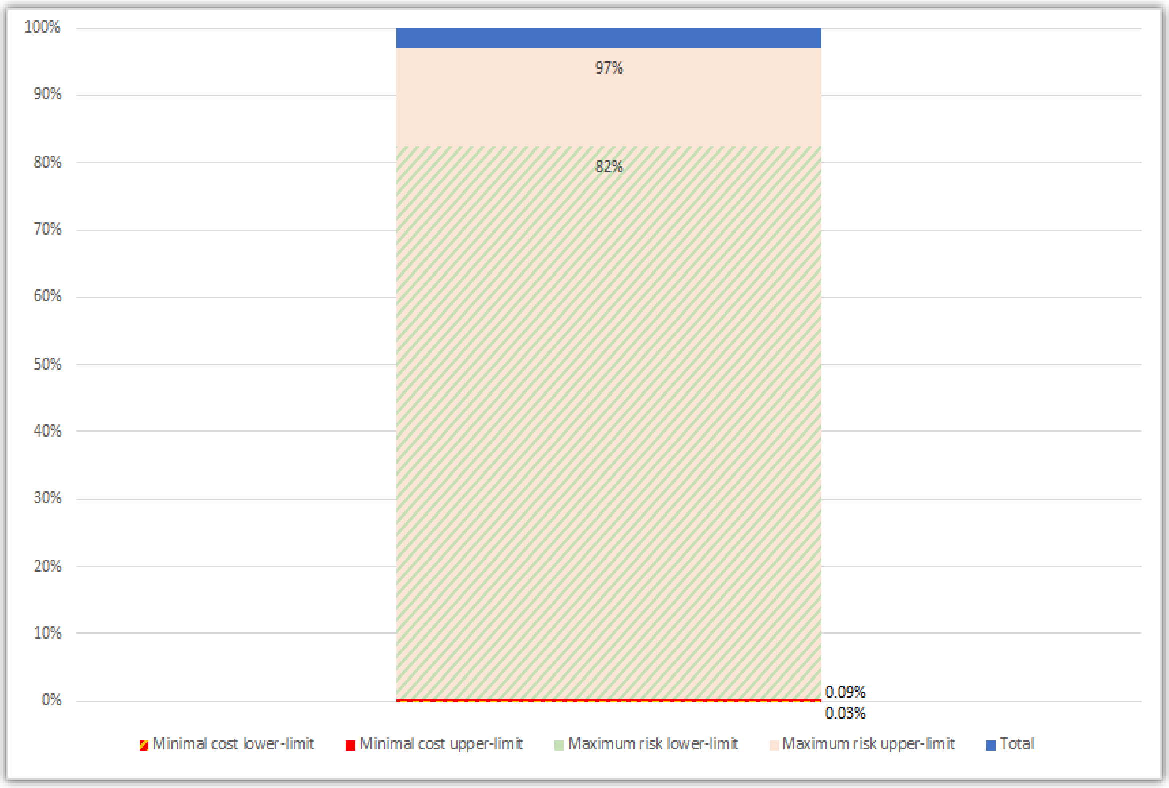



*Figure 5 – Actual and potential costs of plastic pollution to the tourism industry in 2019 and total tourism receipts under plastic accumulation scenarios*

### 3.2.5. Summarised impact (2019)

The impact of marine plastics can be divided into direct costs, which are the cost on fisheries, through loss of revenue, and coastal clean-up costs[11]; and the risk or potential impact (loss in tourism revenue, should plastic accumulation be left unchecked).

The estimated impact in Saint Lucia in 2019 (looking at the direct costs) amounts to **XCD 2,001,556 (USD 740,768)** under plastic accumulation scenario 1 and **XCD 4,249,625 (USD 1,572,770)** under plastic accumulation scenario 2. This impact is respectively equal to 0.03% and 0.07% of Saint Lucia's GDP.

The broader impact (costs to fisheries, and potential loss to tourism revenue) is estimated at between **XCD 2,994,183,489** (USD 1,108,136,006) or 52.2% of Saint Lucia's GDP and **XCD 3,525,765,189** (USD 1,304,872,386) or 61.5% of Saint Lucia's GDP.

[11] The proxy for the effort needed to keep the complete coastline clean by removing all plastic items.

# 4. PROPOSED SOLUTIONS

A broad range of instruments and policies have the potential to decrease the use of plastics and especially reduce plastic leakage into the marine environment, including bans of certain types of plastics, substitutions, or deposit-refund schemes, among others.

Among the recommendations for Saint Lucia to improve its waste management system, APWC (2021b) proposes strengthening the current recycling system by improving waste collection and separation and establishing a regional recycling hub. Thus, in the next sections, the solution that will be analysed is establishing a system to collect, separate and transport recyclable plastics, to a yet to be established regional recycling hub[12]. APWC (2021b) found that in Saint Lucia, 70% of households expressed a willingness to separate their waste, even if there was no economic incentive.

*Household waste ready to be collected, Saint Lucia (APWC).*

Currently, recycling in Saint Lucia is very limited. There is no separation at the source of recyclable materials (plastics, glass, paper, and cardboard) or organic waste prior to collection from households or commercial businesses. (APWC, 2021b). In addition, according to APWC (2021b), the economies of scale in Saint Lucia do not allow for major impetus toward larger scale waste recycling, mainly because the volume of available recyclable material is limited. There are, however, several recyclers collecting, processing, and exporting plastics for recycling already operating in Saint Lucia. In order to include a broader focus on economies of scale, in this study the impact of recycling will be considered first for Saint Lucia alone, but then also from a regional cooperation point of view. The main focus, however, will be the costs and benefits of implementing a broader recycling system in Saint Lucia.

[12] As such a hub does not yet exist, transport costs to Miami are used, which currently already has recycling infrastructure and a well-established container transport system to Saint Lucia.

# 5. IMPACT OF MARINE PLASTICS IN SAINT LUCIA UNDER BUSINESS-AS-USUAL (BaU) AND PROPOSED SOLUTIONS (2023-2040)

## 5.1. METHODOLOGY (RECYCLING SCENARIOS)

### 5.1.1. Forecasting of plastics, fisheries, avoided cost on tourism and coastal clean-up costs

To estimate the impact of implementing a broader recycling system, two recycling scenarios are proposed, and compared to a business-as-usual (BaU) scenario. The two recycling scenarios are:

1. **National recycling scenario**: Only Saint Lucia will implement strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC (2021b).
2. **Regional recycling scenario:** All the countries of the region will cooperate and start to better manage their mismanaged plastic waste (MPW) as their GDP per capita increases. This scenario is based on Lebreton and Andrady (2019). (See **Annex A3**, where **Table A10** provides the estimated growth rate for each country).

Future plastic flows under a BaU scenario have been estimated using the growth rate of mismanaged waste used by Lebreton and Andrady (2019) for the period 2020-2040 for the non-PWFI countries, while estimates from APWC data have been used for data of Saint Lucia (APWC, 2021b), as well as Antigua and Barbuda and Grenada, where needed (APWC, 2021c and d).

For the national recycling scenario, the potential amount of recycled plastics by Saint Lucia has been obtained from APWC (2021b) data. It corresponds to 46% of the total plastic usage per year. The simulation assumes that Saint Lucia would gradually implement the recycling system (25% implementation rate in 2023, which means that 11.5% of the plastics would be recycled – up to 100% in 2026 and thereafter). In this study it is assumed that a recycling rate of 100% will generate an estimated average reduction of leakage of approximately 60% (U.S. GAO, 1990; Iowa the Policy Project, 2008; Waste et al., 2013; DEC, 2020; COEX, 2020). Thus, a 46% recycling rate implies that, according to the national recycling scenario, Saint Lucia's plastic leakage would be reduced by 27.6%.

In addition, for the fisheries sector, the analysis considers two different scenarios regarding fish stocks:

- Constant fish catch during the period considered.
- Fish catch decreases by 0.5% per year, because of climate change, whereby fish stock is estimated to decrease by 0.5% per year (FAO, 2018).

For tourism, to illustrate potential future risk of marine plastic pollution to revenue from the tourism sector, the expected number of tourists without any impact from marine plastic pollution is estimated for the coming decades. The expected growth from 2031 to 2040 in the tourism sector for Saint Lucia is based on an extrapolation of the UNWTO (2011) estimates until 2030, combined with past data on annual growth in this sector (see **Annex A2.2.4** for more details on the extrapolation). This study assumes that tourism will be back to pre-Covid figures in 2025 (**Figure 6**) (McKinsey & Company, 2020).

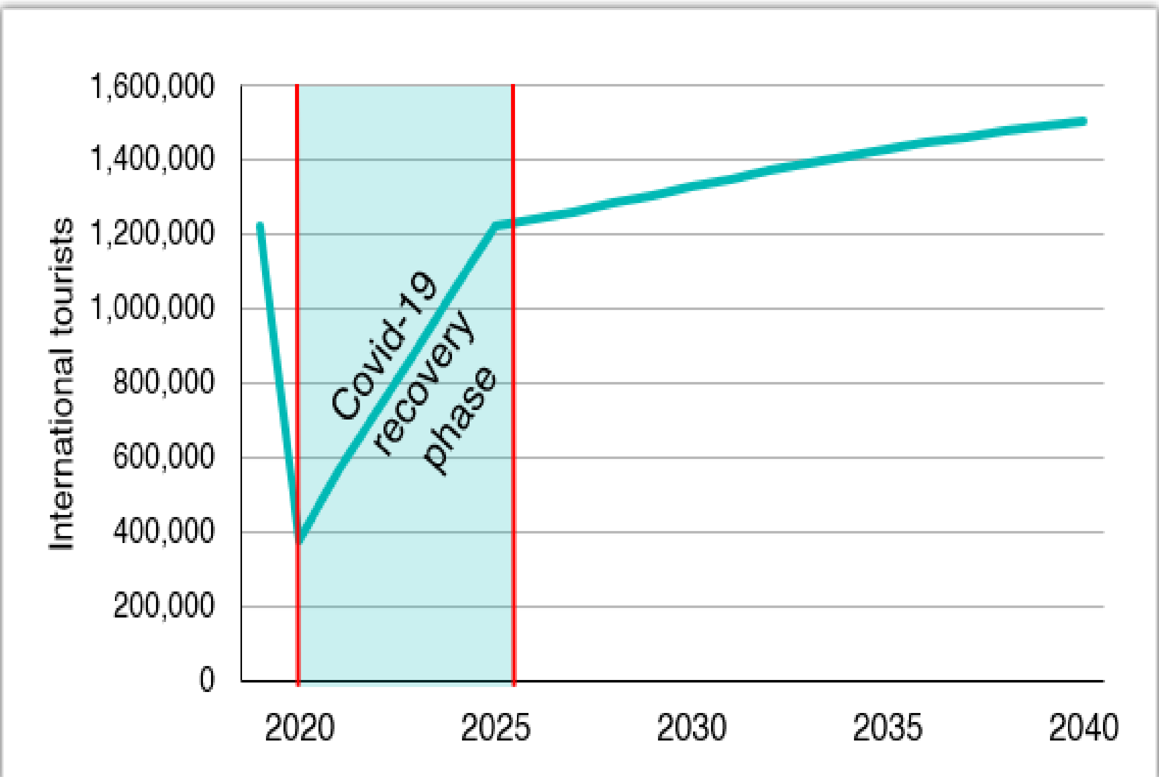



***Figure 6 – Estimated number of international tourists in Saint Lucia (2020-2040)***

The expected continuous increase of tourists in the coming decades indicates that the potential loss of tourism revenue caused by the existence of polluted shorelines will increase, especially if plastic leakage remains the same or, even worse, increases[13]. In the next sections, this study only focuses on estimating the impact on fisheries and coastal clean-ups. However, given the importance of tourism for the Saint Lucian economy, there is a potentially much higher cost related to marine plastics than what is presented here.

[13] Tourism is also an important source of marine plastics (APWC, 2021b).

Lebreton and Andrady's (2019) data on a future scenario of MPW[14] were first used to estimate the impact of marine plastic pollution for the period 2023-2040 under the BaU scenario following the steps shown in **Figure 7**.

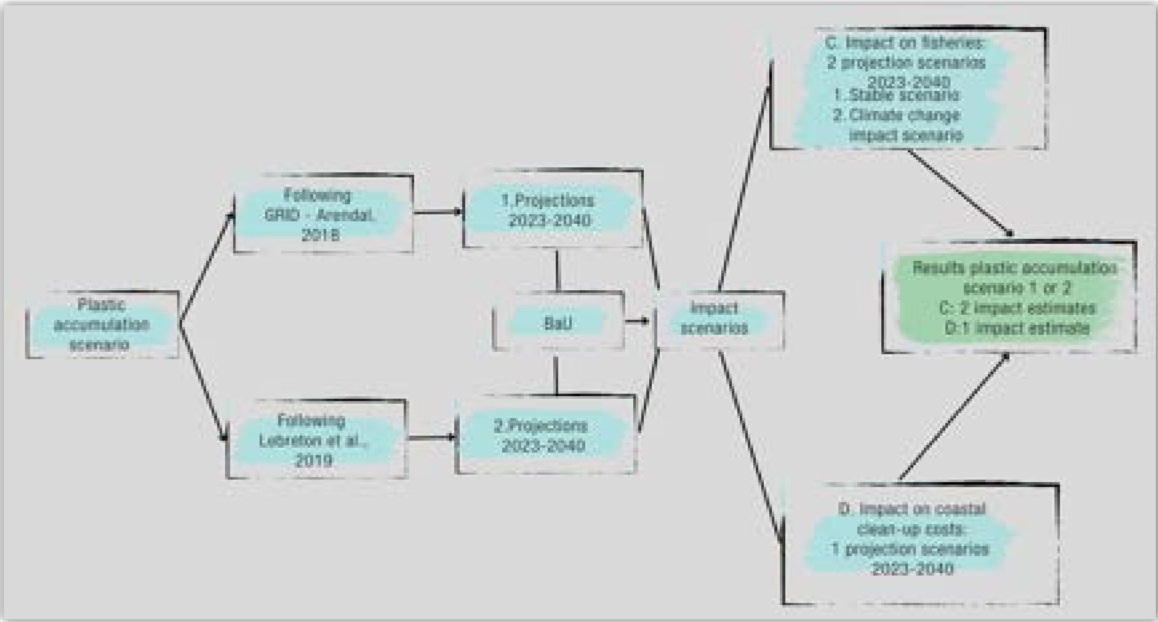



***Figure 7 – Schematic representation of the impact of marine plastic pollution under BaU***

The estimated impact for the two plastic recycling scenarios were then calculated as shown in **Figure 8**.

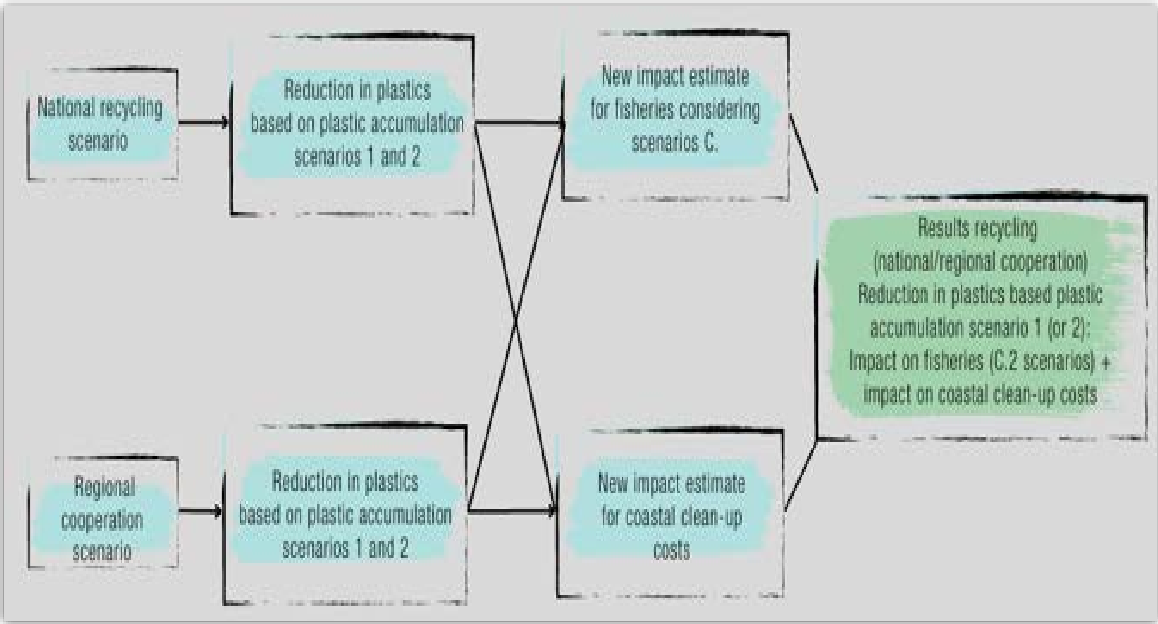



***Figure 8 – Schematic representation of the impact of both recycling scenarios (National recycling and regional cooperation scenario)***

[14] Lebreton and Andrady 2019 published scenarios called "Future emission scenarios". For the BaU scenario, the scenario called "MPW Scenario A" was applied. It assumes that countries will not implement any measures to mitigate plastic emissions.

### 5.1.2. Cost-benefit analysis of BaU versus recycling

To estimate the impact of recycling, and compare this to a BaU scenario, a cost-benefit analysis (CBA) is applied. CBA is an analytical tool used to judge the advantages and disadvantages of an investment or decision by assessing its costs and benefits to put the welfare change attributable to it in perspective. Therefore, it is often used to guide policy alternatives (European Commission, 2014). To conduct a CBA, key considerations are the period of analysis, the discount rate, the different alternatives to be considered and the estimated costs and benefits related to these alternatives.

***Period of analysis***

The period of analysis for all the CBA models was set to 17 years, from 2023 to 2040. The final year of the analysis was based on data available from Lebreton and Andrady (2019).

***Discount rate***

The discount rate is used in the CBA analysis to transform future monetary values to net present monetary values (NPV). By doing this, the cash flows of the system can be compared. There are two key reasons for applying a discount rate. First, individuals normally prefer benefits in the present compared to obtaining them in the future (Boardmand et al., 2011). This assumption is based on the uncertainty of obtaining future benefits compared to the certainty of obtaining the benefits in the present (Staehr, 2006). Second, there is an opportunity cost of forgoing the present benefits for future benefits. In this case, the discount rate represents the opportunity cost of forgoing the benefits of any other investments (Boardmand et al., 2011). Based on this, it is important to decide which discount rate is adequate to use; a higher discount rate represents a higher decrease of future values.

The process in which future values are converted and expressed in terms of present values is called discounting (Boardmand et al., 2011). The discounting process uses a discount rate to convert future values to present values. In this study, the discount rate was calculated as the average of multiple discount rates and is equal to 6.35% (see **Annex A2.1** and **Table A8** for details on its calculation).

***Net Present Value (NPV)***

CBA methodology allows the use of financial indicators to assess the performance of any investment and compare it with others. In this case, the recycling scenarios and the related BaU scenario are compared. To assess the performance of each scenario, the indicator used is the NPV of the BaU and of the two recycling scenarios.

The NPV is the difference between the benefits and cost using the discounting process to get the present net benefits. The result is the NPV of an investment. **Equation 2** shows how to calculate the NPV:

$$NPV = \sum_{t=0}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \qquad (\textbf{Equation 2})$$

Where:

*NPV* = Net Present Value of an investment
*Benefit* = gross benefits of the investment in year t
*Cost* = gross costs of the investment in year t
*T* = period of analysis
*t* = year; and
*r* = discount rate

The reference year of 2022 is used to present costs and benefits, and the resulting NPV for the analysis of the impact of recycling.

***Benefits***

The impact of marine plastics on fisheries and coastal clean-ups for the scenarios presented previously is done in the same manner as presented for the impact assessment in 2019. Benefits of implementing the recycling scenarios are based on the reduction of negative impact by implementing recycling on a national or regional basis. Thus, the benefits are calculated based on the difference between the impacts under BaU versus recycling. **Figure 9** illustrates the different steps taken to estimate the benefit of implementing recycling only on a national basis in Saint Lucia under recycling scenario 1 (national recycling scenario):

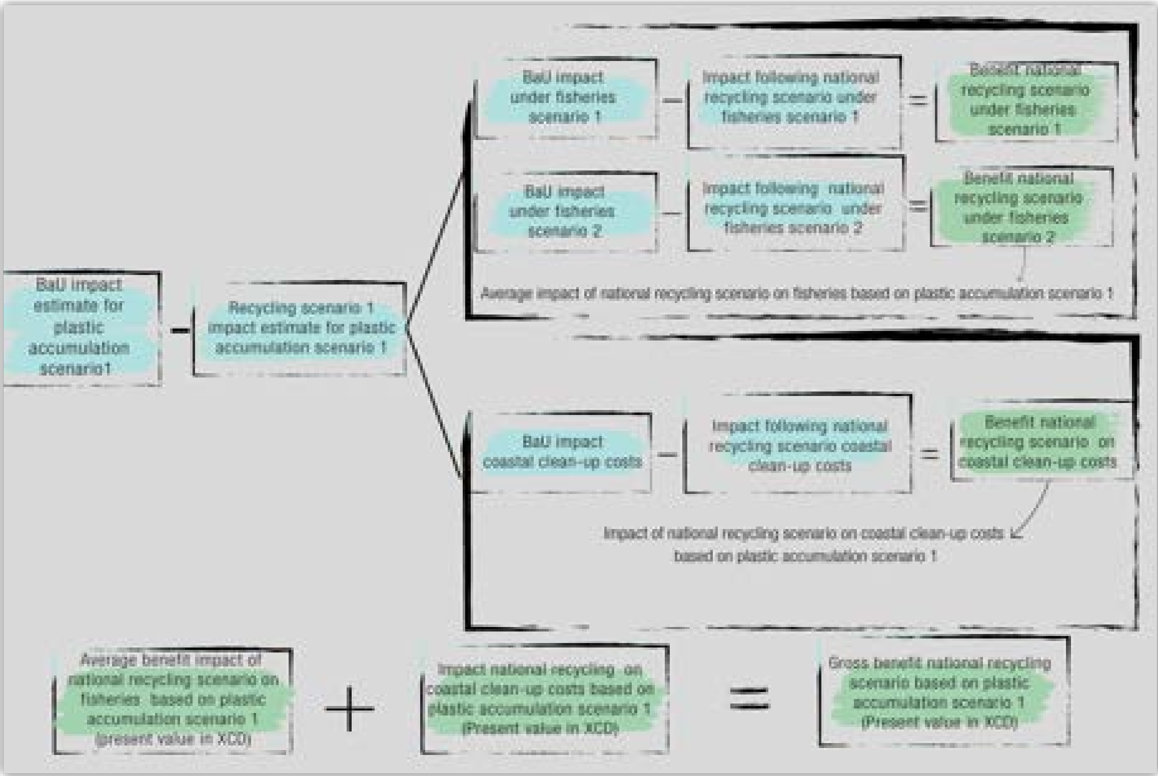



***Figure 9 – Schematic representation of the estimation of the gross benefit for a given recycling and plastic accumulation scenario***

***Costs***

Under BaU, costs were estimated using the total waste management budget (WMB) provided by APWC (2021b).

Under the national recycling and regional cooperation scenario, the final cost of recycling plastics was estimated as follows in **Equation 3**:

$$Final\ Cost_{recycling\ plastic} = (Cost^{WMB}_{recycling\ plastic} + Cost_{recycling\ plastic}) - Cost^{WMB}_{BaU}$$

(**Equation 3**)

Where,

$Cost_{recycling\ plastic}$ was estimated by including the cost of collection and sorting of plastics as well as its shipping to Miami for treatment (and potential sale afterwards). For collection cost, data from Searious Business (2021) on labour, investment, and fixed costs were used. Sorting costs were estimated using PEW (2020). Finally, Satney, M. (2022) provided data for the shipping costs. As a simplification, no impacts of scale (neither economy nor diseconomy) were considered for the cost of recycling plastics. This means that for any amount of plastics that needs to be recycled, the costs remain constant.

$Cost^{WMB}_{BaU}$ was estimated using the average cost per tonne during 2019 provided by APWC (2021b). An assumption applied was that general waste grows at the same rate as plastic waste.

$Cost^{WMB}_{recycling\ plastic}$ was estimated considering a simplified assumption of a linear relationship between cost and amount of waste collected (i.e., x tonnes of plastics recycled induce a decrease by y% of waste ($\frac{plastic\ recycled}{Total\ waste}$) leading to a savings of y% to the WMB). The same assumption as above was applied, namely that general waste grows at the same rate as plastic waste.

## 5.2. RESULTS RECYCLING SCENARIOS

### 5.2.1. Plastic accumulation scenarios under BaU (2023-2040)

To measure the benefits for the fisheries sector and of a reduction in coastal clean-up costs of increased recycling of plastics, a counterfactual BaU scenario is first constructed (see **Figure 10** for plastic accumulation scenario 1, and **Figure 11** for plastic accumulation scenario 2) (see **Annex A1** for the assumptions used to construct plastic stocks). These figures allow for **isolating which part of the plastic stock that is accumulating is impacting the sectors analysed in this study**; it can either be costs for the fisheries sector or coastal clean-ups. The impact that is not captured corresponds to the plastics that previously got buried into the seabed or shoreline according to the plastic accumulation scenarios[15].

For instance, in 2023, following this study's methodology, 45,809 tonnes of plastics could be found within Saint Lucia's jurisdiction. This study captures the impacts of plastics on the economy in two ways: loss of revenue for the fisheries sector and costs of coastal clean-ups. Fisheries will be impacted by 23,153 tonnes of that stock (shown

[15] For 2019 and future scenarios, coastal clean-up costs are used as a proxy for overall costs, considering the minimum costs to not continue the increase in plastic accumulation on coast and shoreline, but does not consider plastics that accumulated in the past. This does not imply it is considered this plastic does not create any impacts, it is just not captured here in this study.

by the blue part in **Figure 10**). Coastal clean-ups will be impacted depending on the amount of plastics that washes up on land; in this example, the plastics should amount to 1,429 tonnes (shown by the blue part in **Figure 10**). A certain amount of plastics (equal to 21,227 tonnes, shown by the grey hashed section in **Figure 10**) are already buried in the sea floor or shoreline, thus not impacting any of the two activities/sectors considered.

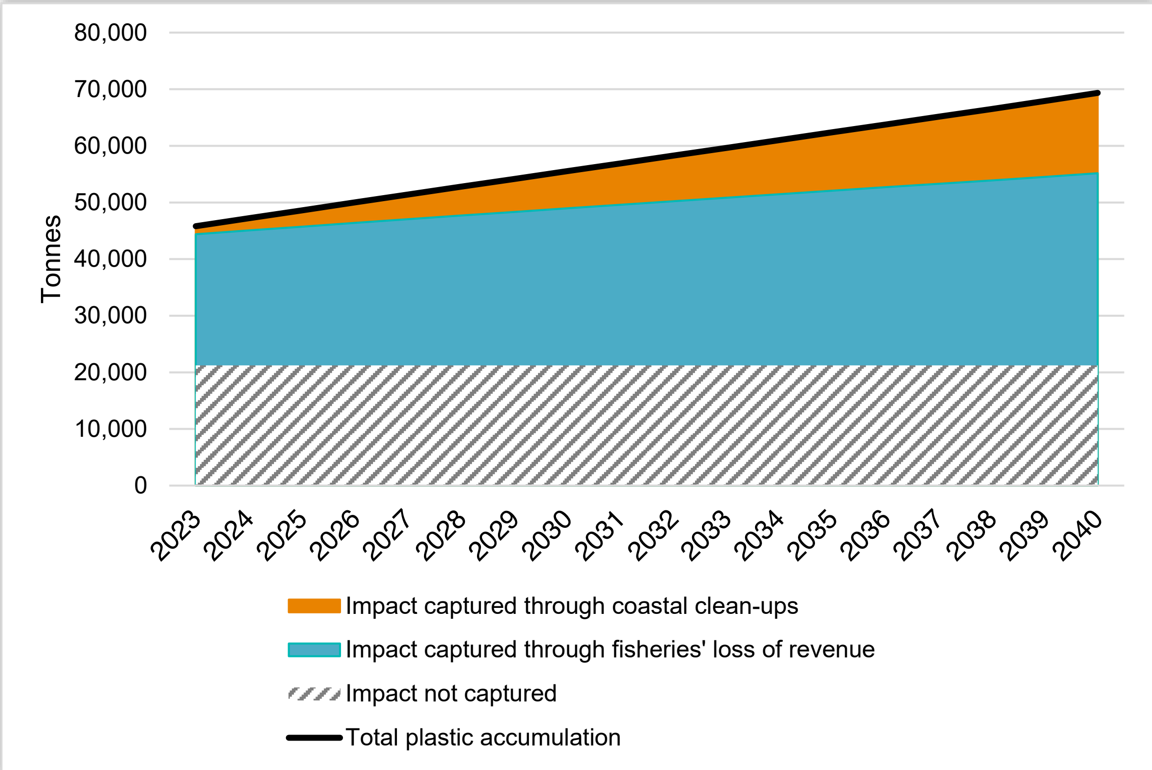



*Figure 10 – Future plastic accumulation under plastic accumulation scenario 1, BaU*

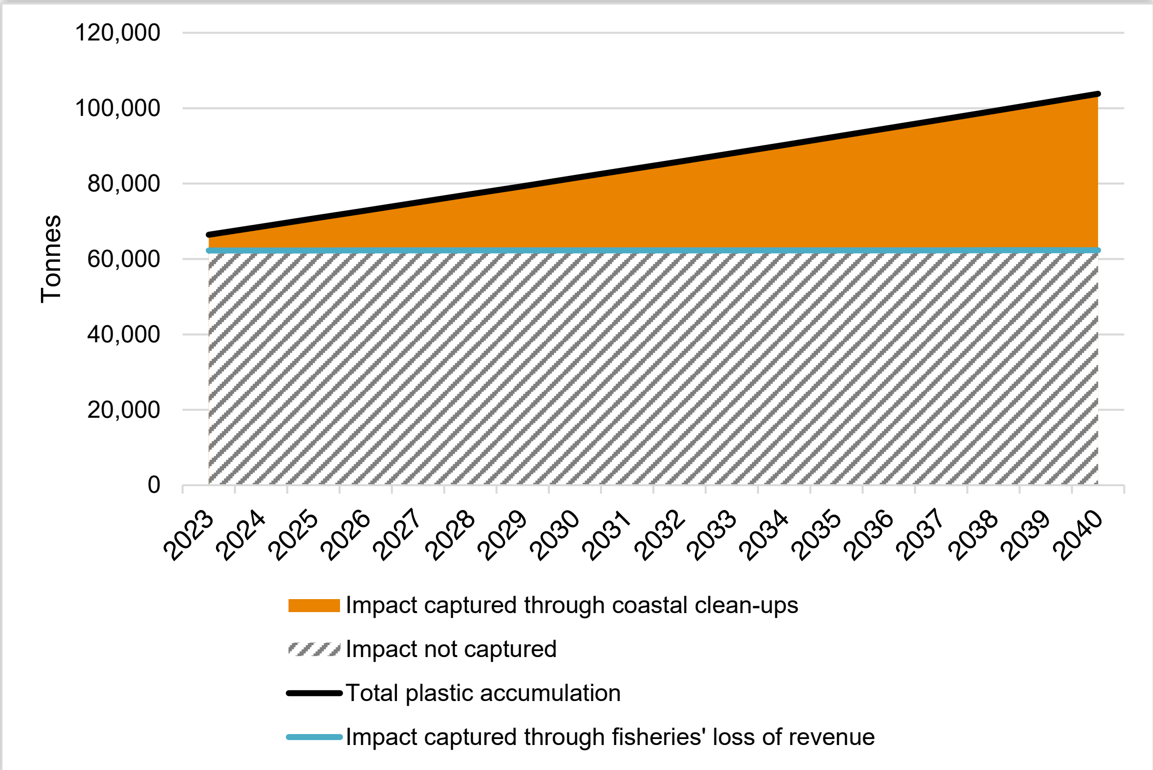



*Figure 11 – Plastic accumulation under plastic accumulation scenario 2*

According to Lebreton and Andrady (2019), leaked plastics in the Caribbean region could increase by an estimated 82% by 2040. Analysing the results for Saint Lucia based on the two different plastic accumulation scenarios yields the results displayed in **Tables 14** and **15** (see **Annex A1.3** for more explanation on the construction of future plastic stocks).

*Table 14 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 1 (tonnes)*

| Location | Plastics (tonnes) | Percentage increase compared to 2019 |
|---|---|---|
| Sea surface | 337 | 81.2% |
| Coastline and seafloor | 35,407 | 94.9% |
| Coastal waters | 7,306 | 81.6% |
| Open ocean | 26,294 | 81.6% |
| **Total** | **69,344** | **88.1%** |

*Table 15 – Location and quantity of plastic stock in 2040 according to plastic accumulation scenario 2 (tonnes)*

| Location | Plastics in tonnes | Percentage increase compared to 2019 |
|---|---|---|
| Shoreline | 103,615 | 94.9% |
| Coastal water (less than 200m) | 49 | 81.6% |
| Offshore (more than 200m) | 809 | 81.4% |
| **Total** | **104,473** | **94.8%** |

### 5.2.2. Impacts under BaU (2023-2040)

***Impacts fisheries BaU (2023-2040)***

Having estimated the future stock of plastics for each year between 2023 and 2040 (see **Annex A2, Annex A2.2.1**, **Annex A2.2.2** and **Annex A2.2.3** for details), the impacts, benefits, and costs of recycling for that period can also be estimated. In the following sections, these estimates will always be presented twice. First, by giving their future value, and second by presenting them in present value using a discount rate of 6.35%.

The total future value of the costs for the period (2023-2040) to the fisheries sector is estimated at **XCD 22,635,371** (USD 8,377,265). By using the average discount rate of 6.35%, the present value is estimated to amount to **XCD 12,414,606** (USD 4,586,112). This value is more or less the same for both plastic accumulation scenarios, so only one value is used for both.

***Coastal clean-up costs BaU (2023-2040)***

The total value of the **coastal clean-up costs is** estimated to amount to **XCD 25,829,825** (USD 9,559,520) in future value and **XCD 14,261,999** (USD 5,278,312) in present value under the **plastic accumulation scenario 1,** and to **XCD 75,588,644** (USD 27,975,071) in future value and **XCD 41,736,450** (USD 15,446,503) in present value under **plastic accumulation scenario 2**. **Annex A2.2.5** and **Annex A2.2.6** provides more details.

***Overall direct cost mismanaged plastics (2023-2040)***

The future and present values of the overall impact, direct cost to the fisheries sector and clean-up costs are displayed in **Table 16**. They depend on which plastic scenario is chosen; thus, four different values are presented.

***Table 16 – Future and present values of the overall direct costs to fisheries and coastal clean-ups (2023-2040) (discount rate: 6.35%)***

| Plastic Accumulation Scenarios | | |
|---|---|---|
| | **Scenario 1 (XCD)** | **Scenario 2 (XCD)** |
| Future value | 48,465,196 | 98,224,015 |
| Present value | 26,676,605 | 54,151,056 |

### 5.2.3. Cost of implementing the recycling scheme

The operating cost of the general waste management system is estimated to amount to XCD 196.9 per tonne of waste (details in **Annex A3.5**).

Establishing improved infrastructure to collect and store general waste, such as bins with lids for all households comes at a cost. This estimated cost per tonne of recycling plastics is presented in **Table 17** (details in **Annex A3.4**). **Figure 12** compares the WMB under the BaU scenario with the WMB under the recycling scenario, which is combined with the cost of recycling. The difference between the two waste management scenarios is presented in **Figure 13** and is equal to the actual cost of recycling.

*Table 17 – Estimated costs of recycling per tonne of plastics (2019)*

| Types of cost | | XCD per tonne | USD per tonne |
|---|---|---|---|
| Collecting cost | Labour cost | 332.8 | 123.2 |
| | Investment cost | 41.2 | 15.3 |
| | Fixed cost | 37.5 | 13.9 |
| Sorting cost | | 296.0 | 109.5 |
| Shipping cost | | 66.3 | 24.6 |
| **TOTAL** | | 773.8 | 286.5 |

*Source: Searious Business, 2021; PEW, 2020.*

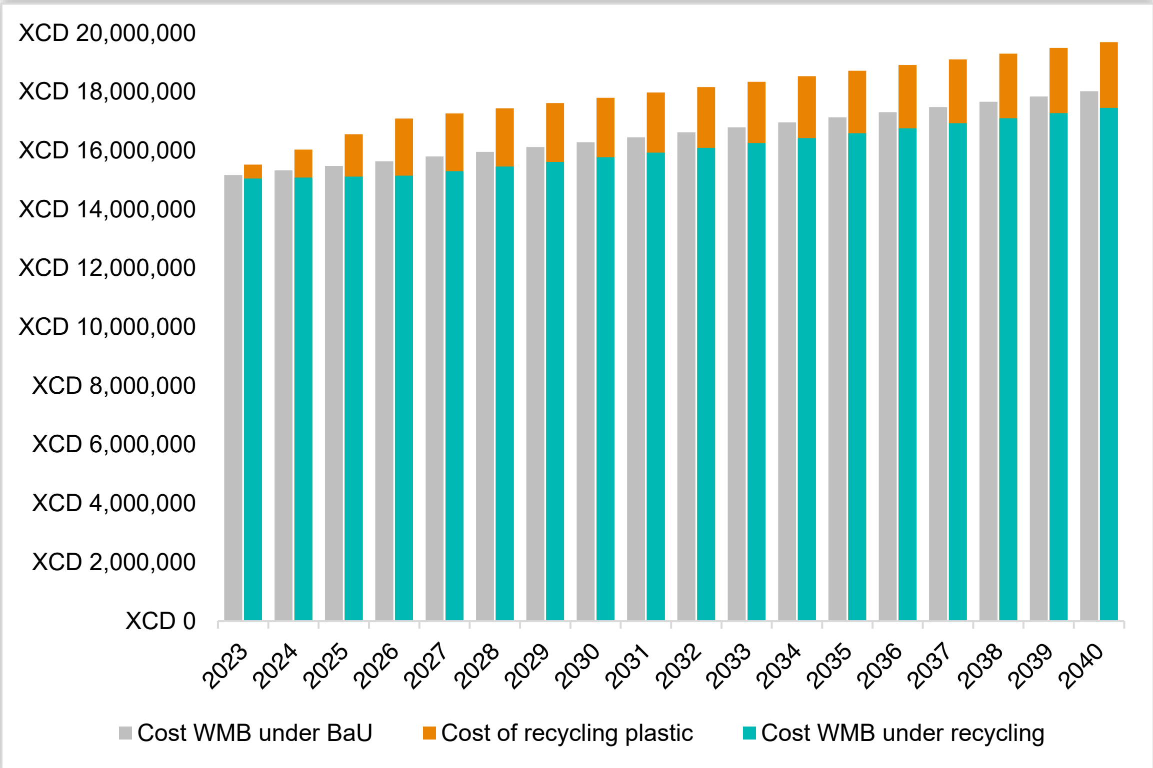



*Figure 12 – Estimated cost of recycling, and the waste management budget under BaU scenario and the national recycling scenario (XCD/year)*

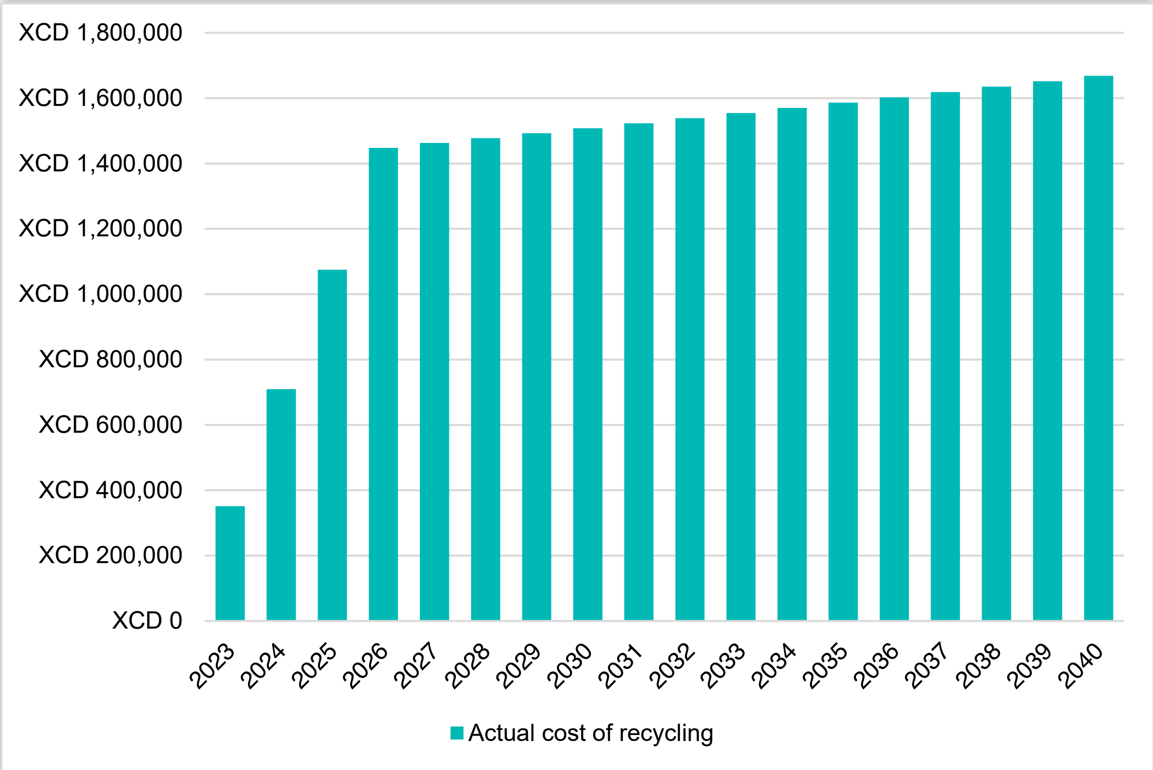



*Figure 13 – Actual cost of recycling (XCD/year)*

The future value of the overall cost is estimated to be **XCD 25,473,259** (USD 9,427,556). Applying the discount rate of 6.35% results in an estimated present value of **XCD 13,495,094** (USD 4,994,483).

### 5.2.4. Recycling scenarios – plastic stocks (2023-2040)

The impact in terms of the amount of plastics under the two recycling scenarios (national recycling and regional cooperation) is displayed in **Figure 14** for the fisheries sector and in **Figure 15** for the coastal clean-ups.

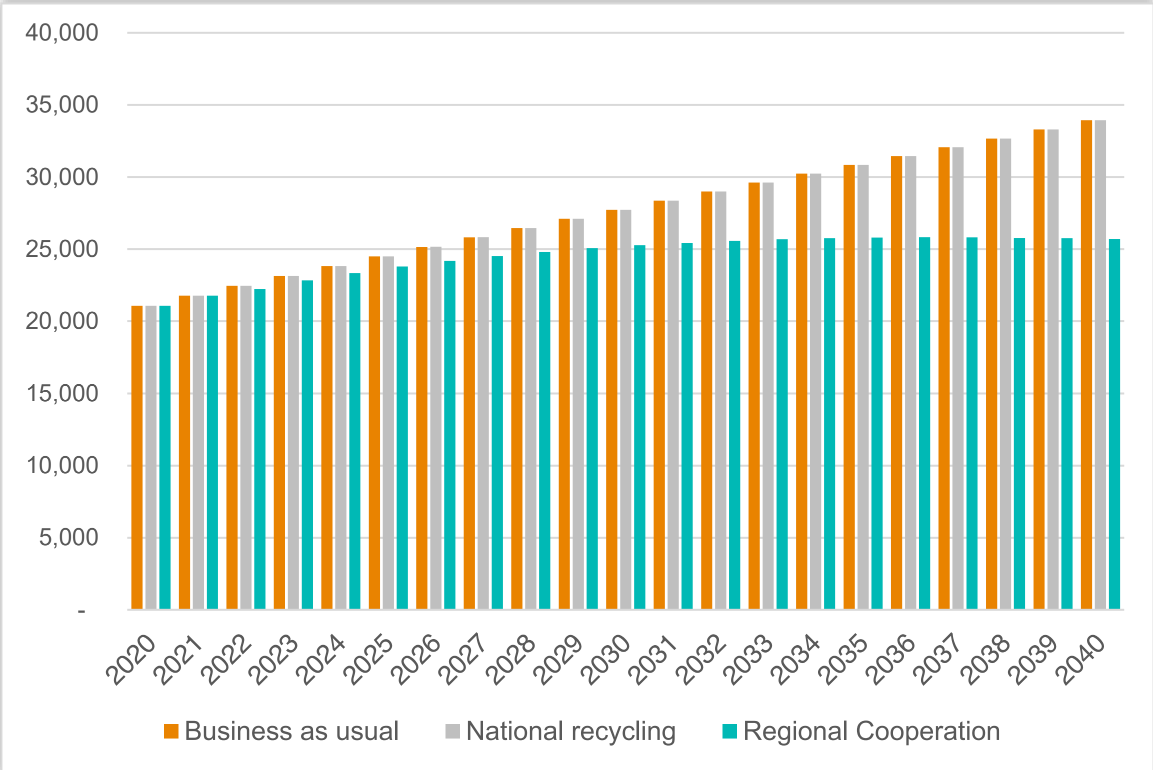



***Figure 14 – Estimated tonnes of plastics in Saint Lucia's waters under the three future plastic management scenarios***

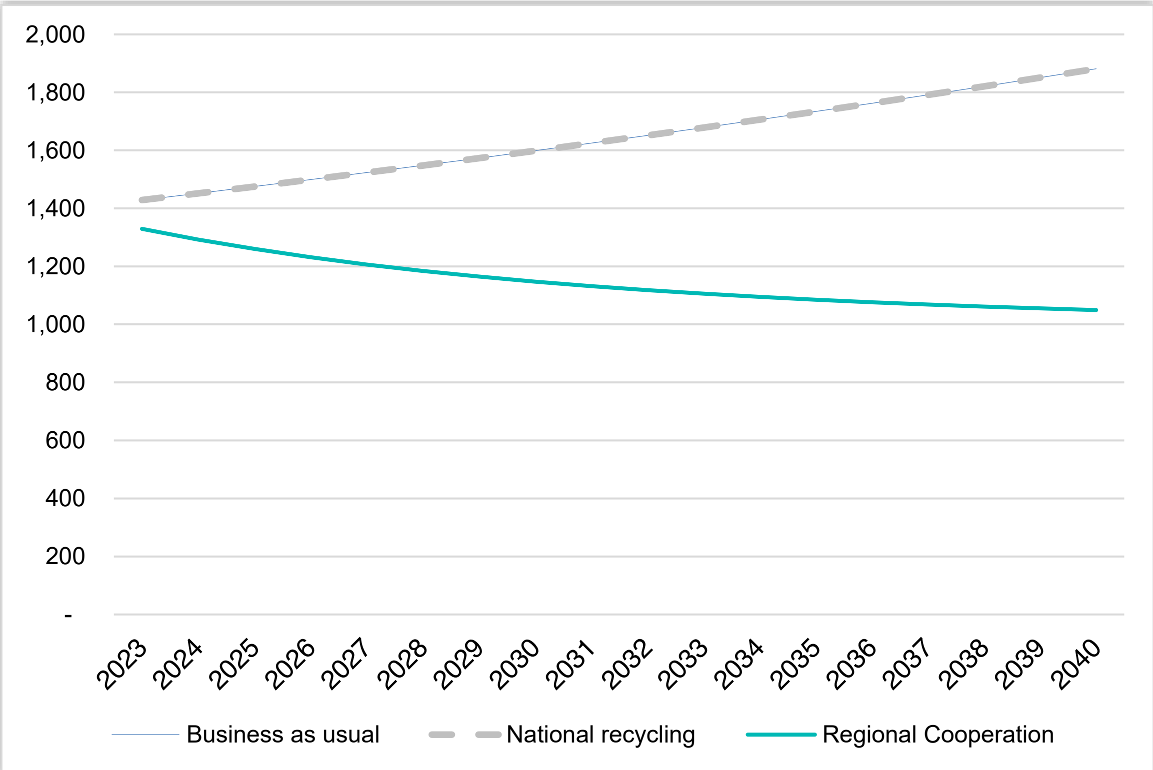



***Figure 15 – Estimated tonnes of plastics ending up on Saint Lucia's shoreline each year under the three future plastic management scenarios***

### 5.2.5. National recycling scenario: costs and benefits of national recycling

The estimated future value of the reduction in loss of revenue for the fisheries sector is **XCD 2,654** (USD 982) while the present value is **XCD 1,260** (USD 466). **Table 18** presents the future values of the reduction of coastal clean-up costs under the two plastic accumulation scenarios compared to the BaU scenario while **Table 19** shows the present value of the same estimations (discount rate of 6.35%). Details are available in **Annex A3.1**, **Figure A6** for the fisheries sector and **Annex A3.2**, **Table A12** for the coastal clean-ups.

***Table 18 – Future value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 5,895 | USD 2,182 | XCD 17,250 | USD 6,384 |

***Table 19 – Present value estimations of the benefits of the national recycling scenario for coastal clean-ups under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 3,130 | USD 1,158 | XCD 9,159 | USD 3,390 |

### 5.2.6. Regional recycling scenario: benefits of regional implementation of recycling

The future value of the reduction in loss of revenue for the fisheries sector is **XCD 1,175,425** (USD 435,020), while the present value is **XCD 1,175,425** (USD 435,020).

The future values of the reduction of the coastal clean-up costs are displayed in **Table 20**. **Table 21** shows the present value of the benefits of a reduction in coastal clean-up costs In Saint Lucia. The calculations follow the same methodology used for the national recycling scenario, details of which are available in **Annex A3.3**, **Figure A7** for the fisheries sector and **Annex A3.2**, **Table A13** for the coastal clean-ups.

***Table 20 – Future value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 7,797,392 | USD 2,885,785 | XCD 22,818,361 | USD 8,444,989 |

***Table 21 – Present value estimations of the benefits of the regional cooperation scenario for the tourism sector under both plastic accumulation scenarios (2023-2040)***

| Plastic Accumulation Scenarios | | | |
|---|---|---|---|
| Scenario 1 | | Scenario 2 | |
| XCD 3,772,670 | USD 1,396,251 | XCD 11,040,377 | USD 4,086,002 |

The benefits of the national recycling scenario alone for both sectors are relatively low. This result stems from the fact that the existing stock (impacting fisheries) and the additional plastics accumulating every year (impacting both fisheries and clean-up costs) – based on this study's assumptions – come mostly from elsewhere. The Lebreton and Andrady (2019) dataset on countries' MPW shows that Saint Lucia occupies the 26th rank out of 35 countries of the Caribbean region in terms of MPW. Therefore, Saint Lucia's efforts to reduce its plastic pollution will only contribute to decreasing the amount impacting the country by a small fraction; hence, the relatively low benefits displayed above. Contrasting the national recycling scenario results with the benefits from the regional cooperation scenario. Results also highlight the importance of nations working together to efficiently tackle marine plastic pollution.

### 5.2.7. Overall results national and regional recycling scenarios

**Figures 16** and **17** show the annual benefits of both recycling scenarios (national and regional cooperation) as well as the annual costs of implementing a national recycling system. **Figure 16** shows the results under plastic accumulation scenario 1, while **Figure 17** shows results under plastic accumulation scenario 2. Results are displayed both in discounted and non-discounted values. **Table 22** shows the net future and present values of the regional cooperation and national recycling scenario. Negative values are highlighted in light orange whereas positive values are highlighted in turquoise.

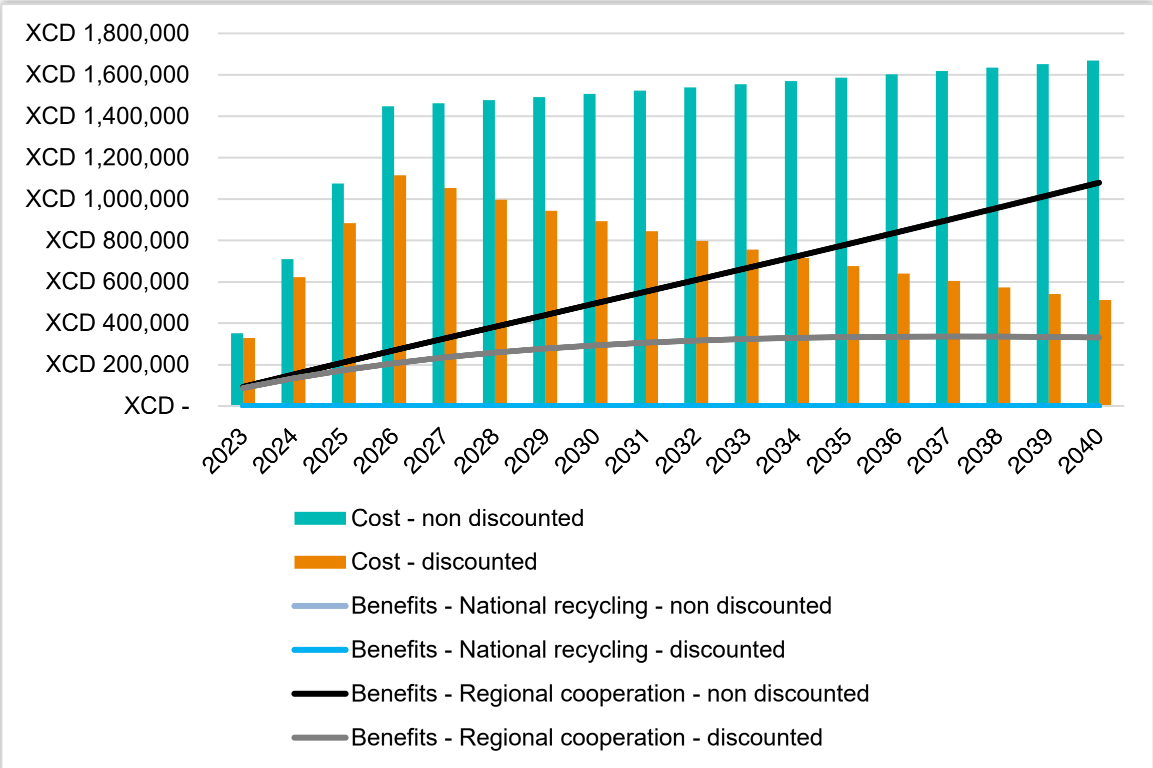



*Figure 16 – Cost of recycling plastics for Saint Lucia (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 1 (future and present values) (discount rate: 6.35%)*

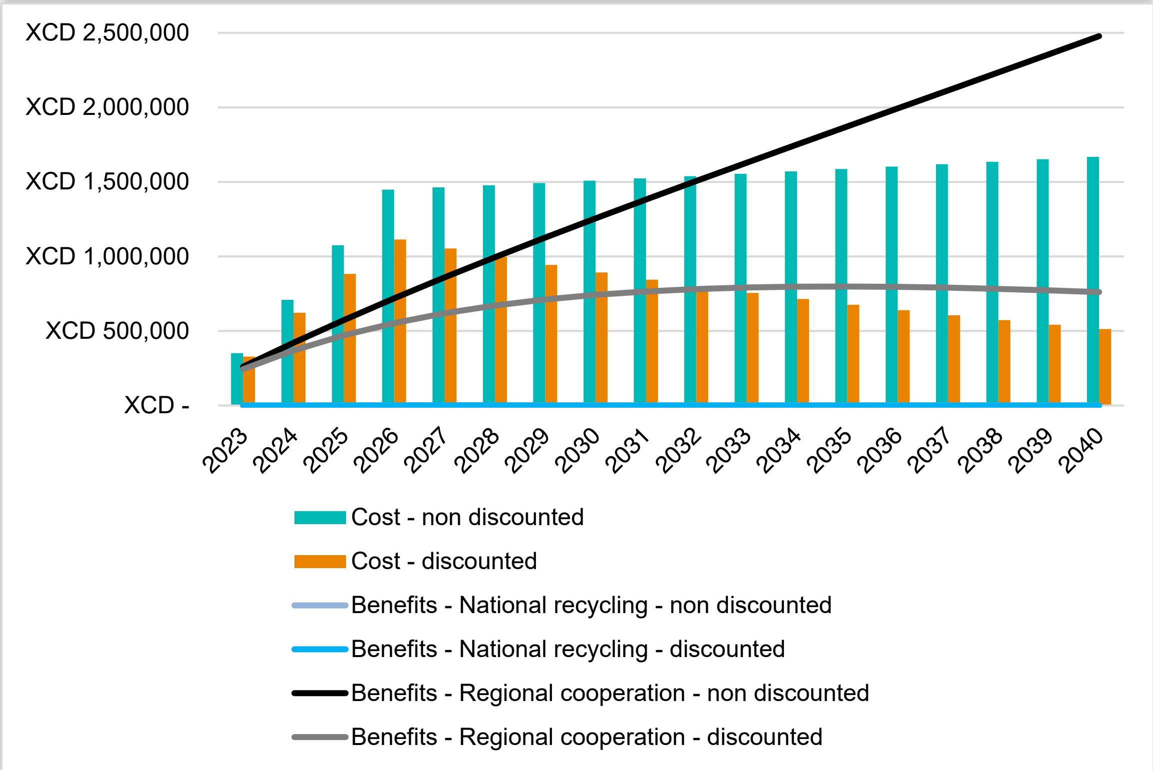



***Figure 17 – Cost of recycling plastics for Saint Lucia (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 2 (future and present values) (discount rate: 6.35%)***

**Table 22** shows that from a NPV perspective, none of the scenarios are profitable based on the benefits, costs and discount rate considered, and without considering the avoided costs to the tourism sector, an avoided cost that with the assumptions used here does not change between the BaU and recycling scenarios. However, under plastic accumulation scenario 2 and considering regional cooperation, the sum of the net benefits in future value (without the discount rate) is positive. In this case the sum of the benefits become higher than the costs of recycling starting in 2033, which leads to a positive net future value after this period.

***Table 22 – Net future and present values of the national and regional cooperation scenario under both plastic accumulation scenarios (discount rate: 6.35%)***

| Recycling Scenario | Plastic Accumulation Scenarios | Net Future Value | | Net Present Value | |
|---|---|---|---|---|---|
| | | XCD | USD | XCD | USD |
| National recycling | 1 | -25,464,710 | - 9,424,393 | - 13,490,704 | - 4,992,859 |
| | 2 | -25,453,354 | - 9,420,190 | - 13,484,675 | - 4,990,627 |
| Regional Cooperation | 1 | -14,974,562 | - 5,542,029 | - 8,547,000 | - 3,163,212 |
| | 2 | 46,407 | 17,175 | - 1,279,293 | - 473,461 |

The results show the impact that the chosen discount rate can have on the NPV. A discount rate set to 0% instead of 6.35% gives the same weight to the benefits and costs regardless of when they occur during the period of analysis. When looking at environmental policy, this approach (i.e., a discount rate of 0%) has been advocated for decades by some scholars. For instance, by Harrod (1948) who argues that "[…] discounting is ethically indefensible and is, indeed, a "polite expression for rapacity".

This result diverges from the outcome of Antigua and Barbuda (Mittempergher et al 2022) and Grenada (Raes et al., 2022). There the regional cooperation scenarios are highly profitable, both in terms of net future and present values. This difference stems from the fact that the Saint Lucian minimum wage used here is lower and that, according to the data used here, Saint Lucia collects more plastics per person per day. The combination of both factors makes initiatives to reduce plastic pollution less cost efficient in Saint Lucia, considering that this generates a reduction in coastal clean-up costs.

However, not all benefits from recycling and reducing plastic leakage have been considered thus far. For instance, plastic scraps can be sold on the appropriate market, the price depending on various factors such as the country, the type of polymer, and/or the quality. Saint Lucia could resell some or all its recycled plastics. For example, if the average price of USD 245.5[16] per tonne, observed in the EU is applied (Eurostat, 2021), then the present value of the recycled plastics for Saint Lucia would amount to **XCD 16,545,919** (USD 6,112,272) for the period considered, creating a positive NPV. This price is potentially higher than what could be obtained in a market accessible for Saint Lucian plastic scrap material. To breakeven in NPV over the 18-year period considered, Saint Lucia would need to resell the plastics at least at a constant price of **XCD 577.23** (USD 213.63) per tonne under the least profitable scenario (national recycling under plastic accumulation scenario 1) and **XCD 54.74** (USD 20.26) per tonne under the best case (regional cooperation under plastic accumulation scenario 2).

Furthermore, sending containers with recyclable plastics back to the port of origin can potentially have a positive price effect. As many goods in Saint Lucia are imported, sending back full containers (with plastics for recycling) could potentially reduce the costs of marine transport for imported goods within the country.

Additional benefits could also be generated not only through the sale of plastics as raw materials for recycling, but by directly using collected plastics for the development of new value chains. For example, within the PWFI project, Searious Business (2021) has developed a product concept for reusable food containers from recycled plastics (Polypropylene) as an alternative value chain for Saint Lucia. An improved recycling system and especially the development of alternative value chains can also generate employment opportunities.

*Plastic containers made from recycled plastics (Serious Business).*

[16] Exchange rate of 1.0031 USD per EUR used to convert Eurostat (2021) data (Exchange rate retrieved 15 July 2022).

Finally, Saint Lucia has one functioning landfill (the Deglos Landfill), with an estimated lifespan of 20 years. The landfill has already been operational for 18 years (APWC, 2021b). By reducing the amount of waste that ends up at the landfill, this lifespan can be moderately extended, providing another financial benefit for the waste management system (Graham et al., 2022).

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influence costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example, to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Saint Lucia.

*Deglos Landfill (IUCN).*

# 6. OTHER ASPECTS OF THE IMPACT OF MARINE PLASTIC POLLUTION AND INSTRUMENTS TO REDUCE IT

## 6.1. ADDITIONAL ECONOMIC AND SOCIAL BENEFITS

***Employment***

If plastic pollution accumulating on the coastline decreases the number of visitors, this will not only reduce the revenue generated by the tourism sector but can also have a significant impact on the number of people employed in this sector. The tourism sector is responsible for providing between 14,000 and 20,000 direct jobs[17], and 38,500 indirect jobs (WTTC, 2018b; Central Statistical Office, 2020), accounting for around 78% of total employment (Government of Saint Lucia, 2021). Tourism plays a key role in the economic, socio-cultural, and environmental welfare of Saint Lucia (Department of Sustainable Development, 2018).

Marine plastic pollution has a negative impact on fisheries revenue, and consequently, on the number of people employed in the fisheries sector. In 2019, an estimated 14,640 people were employed in the fisheries sector, around 14.5% of the labour force. Of these, 3,364 were employed in direct commercial capture (with 5.5% being women), and 10,980 in other fisheries dependent activities[18] (CRFM, 2020).

In addition, according to a census conducted by the Department of Fisheries in 2012, 30% of people employed in the fisheries sector in Saint Lucia earn between 25 to 50% of their household income from fishing. The fishing sector has also been an important vehicle to sustain the livelihood of many families, especially in rural coastal communities, where underemployment and unemployment are still pressing problems. Moreover, the small-scale fishery sector contributes significantly to poverty reduction and food security (FAO, 2022).

[17] This number varies with high/ low seasons; The statistics here do not include ancillary independent/ self-employed associated with the industry (e.g., taxi drivers, venders, creatives, etc.); Note: In national statistics, tourism is referred to generally as “Accommodation and Food Services”.

[18] The fisheries sector also provides employment for many persons who supply services and goods to the primary producers. This includes persons engaged in processing, preserving, storing, transporting, marketing and distribution or selling fish or fish products, as well as other ancillary activities, such as net and gear making, ice production and supply, vessel construction and maintenance as well as persons involved in research, development and administration linked with the fisheries sector.

### *Food security*

In the Caribbean, fisheries not only contribute to employment and household income, but also to food security (Bovarnick et al. 2010). Although the importance of fish as a vital source of food has declined in recent years in Saint Lucia, currently it still supplies around 12% of the animal protein supply, with a per capita supply of around 21kg in 2019 (FAO, 2022; CRFM, 2020). Furthermore, fish is one of the few food products, locally produced, available in the country (FAO, 2022).

### *Balance of trade*

Tourism is responsible for over 40% of Saint Lucia's GDP (Government of Saint Lucia, 2021; Knoema, 2022). As the leading foreign exchange earner, the sector contributes significantly to total exports of goods and services (Department of Sustainable Development, 2018). Although smaller in magnitude in terms of contribution to the GDP, a reduction in fish capture will also have an impact on the balance of trade, as reduced local production may increase fish imports. Currently, fish imports complement domestic production, accounting for approximately 50% of the domestic consumption of fish. Tourism is also an important consumer of fishery products in the country, and imports are used to satisfy the demand from the tourism sector. Fishery exports, on the other hand, are negligible (FAO, 2022).

### *Other impacts*

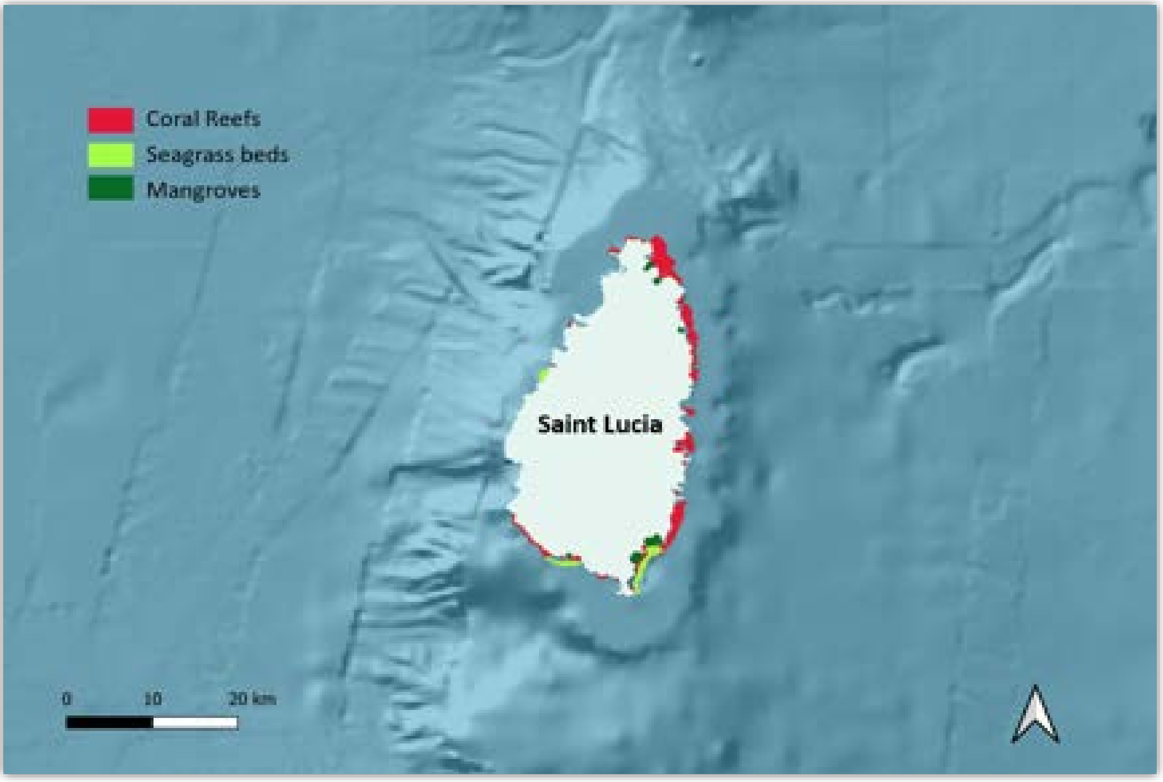
Although the aim of this study was to analyse the direct cost of marine plastics on the fisheries and tourism sectors, and the potential effects from activities to reduce this, marine plastics is not the only problem affecting these sectors and the Saint Lucian economy in general. Recently, the biggest impact on the tourism sector in Saint Lucia has been the global travel restrictions, creating the worst economic crisis in a century (UNDP, UNICEF, and UN Women, 2020). Although improving, the tourism sector has not yet fully recovered. In addition, the tourism sector is also vulnerable to the impact of climate change (Government of Saint Lucia, 2021), manifested by: sea level rise, an increased frequency and intensity of storms, which can deter tourists from visiting the island, and coastal erosion, which can create a loss or degradation of tourism resources such as beaches (Simpson et al., 2010; Department of Sustainable Development, 2018; Government of Saint Lucia, 2021).

While this study includes a climate change impact scenario in the future fisheries revenue estimates, the full extent of the impact of climate change – including for example: shifting fish migration and distribution patterns, changes in reproduction of certain fish species, or altered habitats of fish species, and impacts of more frequent extreme weather events on fishing efforts (CANARI, 2019; Palacios-Abrantes et al., 2022) – has not been considered. Furthermore, in addition to the potential long-term impact of ghost fishing, Caribbean fishery resources are among the most overexploited in the world; regional production has declined by more than 40% over the last two decades (FAO, 2014). 54% of species or species groups in the Caribbean are considered overfished or over-to-fully fished (Western Central Atlantic Fishery Commission 2017). Overexploitation is the main threat to bony fishes in the Caribbean; it directly affects half the species in the greater Caribbean listed by IUCN as globally 'threatened' or 'near threatened' (Linardich et al., 2017).

## 6.2. IMPACT ON MARINE AND COASTAL ECOSYSTEMS

Beyond the direct impact of marine plastics on fish stocks, there are several challenges that could seriously impact the future of marine natural assets. Saint Lucia's coastal zone and marine ecosystems are not only characterised by beaches, but also by mangroves (180 ha, FAO, 2020), seagrass beds (680 ha, Chatenoux and Wolf, 2013) and coral reefs (6,400 ha, Sea Around Us, 2005) (**Map 3**). These ecosystems not only play an increasingly vital role in tourism but are also an integral component in natural coastal defence and the ecology of the island. Coastal and marine resources also provide for livelihoods in several rural communities in the fisheries sector, as well as for recreation, sports, and enjoyment, and are an overall source of employment for many people (Department of Sustainable Development, 2018).

Coral reefs, mangroves and seagrass beds provide a range of key ecosystem services, such as protection of the shoreline from erosion and storm damage, breeding grounds for many species of fish and other marine species, water purification, disease control, carbon sequestration, nutrient cycling, sediment reduction, and recreation (Barbier et al., 2011; Luisetti et al., 2013; Ondiviela et al., 2014; Dudley et al., 2010, 2015; Mtwana Nordlund et al., 2016; Ruiz-Frau et al., 2017; Himes-Cornell et al., 2018; CANARI, 2019; Government of Saint Lucia., 2021). These essential ecosystem services underline the importance of conserving and restoring these ecosystems. In addition, some species – specifically certain coral species – have a critical or vulnerable conservation status (**Figure 18**).




*Source: Giri et al., 2011; UNEP-WCMC, 2021a, UNEP-WCMC, 2021b.*

***Map 3 – Areas of coral reefs, seagrass beds, and mangroves in Saint Lucia***

| RED LIST | Warm-water corals | Mangroves | Seagrasses | Coral-water corals |
|---|---|---|---|---|
| CR Critically Endagered | 2 | 0 | 0 | 0 |
| EN Endangered | 3 | 0 | 0 | 0 |
| VU Vulnerable | 6 | 0 | 0 | 1 |
| NT Near Threatened | 0 | 0 | 0 | 0 |
| LC Least Concern | 42 | 7 | 4 | 7 |

*Source: UNEP-WCMC, 2022.*

***Figure 18 – IUCN Red List status of coral, mangrove, and seagrass species in Saint Lucia (2022)***

Coral reefs, seagrasses and mangroves are affected by marine plastics (NOAA Marine Debris Program, 2016; Tekman et al., 2022). For example, plastic debris interferes directly with the ecological role of mangrove forests (Ivar do Sul et al., 2014) and obstructs water flows in mangrove areas (Kantharajan et al., 2018). Coral populations can decrease significantly as the amount of litter increases (Richards and Beger, 2011; Yoshikawa and Asoh, 2004). Plastics can also increase the degree of disease contracted by corals (Lamb et al., 2018). Marine litter can also negatively affect seagrass ecosystems (Ganesapandian et al., 2011). Abandoned fishing gear damages seagrass beds by re-suspending sediments, disturbing rhizomes, and impacting the root structure of seagrasses (Barnette, 2001). In addition, mangrove forests and seagrass beds function as both traps and filters for marine plastics, including microplastics (Debrot et al., 2013; Sanchez-Vidal et al., 2021).

The impact of plastics should not be seen as an isolated effect. Plastic pollution is an additional stressor on marine ecosystems that are already dealing with multiple stressors (Lartaud et al., 2020; Tekman, 2022). Climate change causes coral bleaching (CANARI, 2019; Petit and Prudent 2010), ocean acidification (Bégin et al., 2016), and rising sea levels, accompanied by more frequent and severe storms (Sippo et al., 2018; Hughes et al., 2017). Further impacts occur through pollution from leakage of sediments, fertilisers and pesticides, and chemicals (Orth et al., 2006; Government of Saint Lucia, 2021; Silbiger et al., 2018; van Dam et al., 2011), as well as due to overfishing (Burke et al., 2011; Zaneveld et al., 2016), unsustainable tourism (Burke et al., 2011; Lamb et al., 2014), algal blooms (Franks et al. 2016), sand mining (Government of Saint Lucia, 2021), and invasive species (Biswas et al., 2018; Unsworth et al., 2019).

An ecosystem’s degradation caused by plastic pollution in marine and coastal habitats impacts tourism, the fish stocks that depend on these habitats, as well as marine wildlife in general. Marine biodiversity that is not directly targeted by fisheries – such as seabirds and marine mammals – are not only impacted through habitat degradation, but also suffer directly from marine plastic pollution.

## 6.3. IMPACT ON MARINE WILDLIFE

There are at least 22 different species of marine mammals that are found in the waters of Saint Lucia, one of which is currently listed as threatened (IUCN, 2022; UNEP, 2022). There are also four sea turtle species found in the waters of Saint Lucia, all listed as threatened (Auvergne et al., 2022; IOSEA, 2002). There are 36 seabird species in Saint Lucia, out of which 32 are listed as "least concerned", given that, for now, they are plentiful in number (**Table 23**) (BirdLife International, 2022).

*Table 23 – IUCN Red List status of threatened marine species in Saint Lucia (2022)*

| | | |
|---|---|---|
| **Marine mammals** | | |
| Sperm Whale | Physeter microcephalus | Vulnerable |
| **Sea turtles** | | |
| Green Turtle | Chelonia mydas | Endangered |
| Loggerhead Turtle | Caretta caretta | Vulnerable |
| Leatherback | Dermochelys coriacea | Vulnerable |
| Hawksbill Turtle | Eretmochelys imbricate | Critically endangered |
| **Seabirds** | | |
| Black-legged Kittiwake | Rissa tridactyla | Vulnerable |
| Black-capped Petrel | Pterodroma hasitata | Endangered |
| Leach's Storm-petrel | Hydrobates leucorhous | Vulnerable |
| Matsudaira's Storm-petrel | Hydrobates matsudaira | Vulnerable |

*Sources: Taylor et al., 2019; Seminoff et al., 2004; Casale et al., 2017; Wallace et al., 2013; Mortimer et al., 2008; BirdLife International, 2018a; BirdLife International, 2018b; BirdLife International, 2018c;BirdLife International, 2019).*

*Turtle in the Caribbean (Goodwin, W.).*

Marine plastics can also be a danger to marine fauna. Kanhai et al., 2022, classify the impact of marine plastics on biodiversity as follows: (1) Biological effects (e.g., plastic ingestion); (2) Physical effects (e.g., entanglement); (3) Ecological effects (e.g., introduction of invasive alien species); and (4) Chemical effects (e.g., transporter of pollutants). Tekman et al. (2022), in their extensive literature review on the effects of plastic debris and hazardous substances on marine species, classify these impacts on marine fauna as: (i) Physical interactions, specifically: entanglement, ingestion, colonisation, and contact or coverage; and (ii) Chemical interactions: additives and absorbed substances.

The interactions have impacts on marine species such as seabirds, sea turtles, marine mammals, sharks, rays, and sponges (Tekman et al., 2022). According to the Convention on Biodiversity (CBD) Report, 'Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity' (2016), the total number of species known to be affected globally by marine debris (mainly plastics) is around 800; of those, the proportion of cetacean and seabird species affected by marine debris ingestion is 40% and 44%, respectively (CBD, 2016).

**Ingestion:** A wide range of animals ingest plastics. Certain marine animal populations – especially those that feed exclusively at sea, such as seabirds and sea turtles - present plastic debris in their stomachs (Hammer et al., 2012; Wilcox et al., 2015). Sea turtles can, while feeding, ingest plastic debris at all stages of their lifecycle (Mascarenhas et al., 2004), which can potentially have lethal consequences (Schuyler et al., 2014). For example, Wilcox et al. (2018), found a 50% probability of mortality once the sea turtles they analysed had 14 pieces of plastics in their digestive system. Discarded and semi-inflated, floating bags are of particularly hazardous as they are often mistaken for jellyfish and can block the oesophagus once ingested (Gregory, 2009). Tekman et al. (2022), analysing the studies collected in the LITTERBASE database[19], found a total of 272 seabird species had encountered plastic debris by ingestion. Reinert et al. (2017), found that 11% of 6,561 examined manatees had ingested marine debris or had become entangled, 50 of which died as a direct result.

**Entanglement:** happens if a plastic item wraps itself around the body, for example abandoned or lost fishing gear (Macfadyen et al., 2009; Richardson et al., 2019b). Marine mammals are among the species most affected by entanglement (Hammer et al., 2012). Fishing gear poses special risks for large, air-breathing marine animals, such as whales, dolphins, seals, sea lions, manatees, and dugongs, drowning after they become entangled in the nets (Laist, 1997; Lusher et al., 2018). Other species that are affected through entanglements are sharks, rays, and chimaeras (Parton et al., 2019).

**Colonisation** by alien species can be facilitated by plastic debris, which can be a threat to marine biodiversity and ecosystems. Aggressive invasive species can be dispersed by free-floating marine plastics. Their introduction can endanger sensitive or at-risk coastal environments (García-Gómez et al., 2021). Plastic debris can

[19] https://litterbase.awi.de/.

function as vectors, transporting viral and bacterial pathogens (harmful to both humans and animals), potentially spreading them to new areas (Bowley et al., 2021).

**Contact** or **coverage** with plastics, also called smothering, is another type of interaction. For example, coverage of sponges with plastics can impair prey capture and growth rates (Mouchi et al., 2019).

**Chemical** impacts occur: (1) because of harmful substances associated with plastics, such as Bisphenol A (BPA) or flame retardants; and (2) through sorption and desorption of chemical pollutants (Hermabessiere et al., 2017, Tekman et al., 2022).

According to Tekman et al. (2022), plastic pollution should always be considered in the context of the many other stressors affecting the marine environment. At present, plastic pollution alone may, by itself, not drive critical decreases in populations; it may just push an individual, population or ecosystem into decline and possibly over a critical threshold. For example, habitat destruction impacts all marine wildlife in Saint Lucia (Department of Sustainable Development, 2018). Globally, seabirds are threatened by bycatch and overfishing, climate change, and invasive species (Croxall et al., 2012; Dias et al., 2019). Turtles are also threatened by climate change (Laloë et al., 2016), as well as by predation by pigs and dogs, human harvesting of turtles and their eggs, and beach erosion (Department of Sustainable Development, 2018; Tekman et al., 2022). Other impacts on marine wildlife come from collisions with boats (Jägerbrand et al., 2019), chemical pollution (Arzaghi et al., 2020), noise pollution (Badino et al., 2016) and ocean deoxygenation (Laffoley and Baxter, 2019).

The impact analyses on fisheries and tourism sectors, as well as the presentation of the effects on marine ecosystems and wildlife discussed above, focus mainly on interactions with macroplastics. However, **microplastics** are also of concern. Marine plastics, specifically those with a lifetime of hundreds of years, tend to degrade into micro- and nano-plastics over time. The size of these plastic pieces facilitates their uptake, can block the digestive tract, and contribute to the chemical body burden eliciting toxicological effects (Carbery et al., 2018; Tekman et al., 2022). These plastics may contain chemical additives and contaminants, some of them with suspected endocrine disrupting effects that when ingested may be harmful for marine animals (Gallo et al., 2018; Prokić et al., 2019). In addition to the direct ingestion of plastic debris, larger animals, higher in the food chain also ingest plastics. Microplastics are easily ingested by small organisms, such as plankton; contaminants leached from plastics tend to bioaccumulate in those organisms that ingest them – the higher the trophic level, the higher the chemical concentrations (Hammer et al., 2012).

## 6.4. MARINE PLASTICS IN MARINE PROTECTED AREAS

Marine protected areas (MPAs) are an essential tool in the recovery and protection of marine ecosystems and the vital services they provide (Reuchlin-Hugenholtz, 2015). MPAs protect marine biodiversity and ecosystems by limiting the economic activities in the area (IUCN, 2013). A large proportion of MPAs in Saint Lucia are located outside the marine area with a depth of more than 200 metres. Around 74% of Saint Lucia’s coastline is designated as MPAs, which provide protection to the coastal ecosystem and habitats, comprising coral reef areas, seagrass beds, mangroves, and marine species therein (MALFF, 2007) (see **Map 4**, below). The area coverage of MPAs for Saint Lucia is estimated to be 401 km² (UNEP-WCMC, 2021).


*Sources: UNEP-WCMC, 2021c ; Marine Conservation Institute, 2021.*

***Map 4 – Marine protected areas in Saint Lucia***

MPAs in Saint Lucia are impacted by several factors, including poor demarcation and non-enforced management practices (Department of Sustainable Development, 2018). However, in addition, the global pervasiveness and high abundance of plastic debris in the marine environment are growing threats for MPAs (OECD, 2016). The delineated boundaries for MPAs cannot stop plastics from entering and posing risks to vulnerable habitats and species (Giuseppe, 2022).

The estimated amount of plastics present in 2019 in Saint Lucia's MPAs (**Map 4**) is presented in **Tables 24** and **25**.

***Table 24 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 1***

| Accumulation areas | Plastics in MPA (tonnes) |
|---|---:|
| Sea surface | 0.0019 |
| Coastline and seafloor | 128 |
| Coastal waters | 33 |
| Open ocean | 0.148 |

***Table 25 – Plastic accumulation estimates in MPAs based on plastic accumulation scenario 2***

| Accumulation Areas | Plastics In MPA (Tonnes) |
|---|---:|
| Offshore – Deeper water | 0.005 |
| Shallow water | 0.043 |
| Shoreline – Dry land | 374 |

# 7. SUMMARY AND CONCLUSIONS

The results of this study show the estimated impact of marine plastics on fisheries in 2019 to be 3.7% of revenue, excluding the impact of ghost fishing. The estimated losses due to plastic leakage in the marine environment for the Saint Lucian fisheries sector is **XCD 834,527** (USD 308,781).

For tourism, the potential percentage of tourists who would no longer be willing to visit the country if all plastics accumulated on beaches is estimated to be between 82% and 97%. To avoid this loss, the cleaning of beaches and coastline is estimated to cost between **XCD 933,633** and **2,732,079** (USD 345,530 and 1,011,132) in 2019.

The total direct cost of mismanaged waste in Saint Lucia in 2019, looking at fisheries and coastal clean-ups, is estimated to be between **XCD 1,768,160** (USD 654,389) under plastic accumulation scenario 1 and **XCD 3,665,712** (USD 1,356,666) under plastic accumulation scenario 2.

From 2023 to 2040 and under a BaU scenario, the estimated direct impact -which is the sum of the revenue loss for the fisheries sector and the estimated coastal clean-up costs -in present value is **XCD 26,676,605** (USD 9,872,910) under plastic accumulation scenario 1 and **XCD 54,151,056** (USD 20,041,101) under plastic accumulation scenario 2.

The present value of the overall cost of recycling is estimated to be **XCD 13,495,094** (USD 4,994,483). The present value of the benefits under plastic accumulation scenario 1 of the national recycling scenario alone is estimated to be **XCD 4,390** (USD 1,624) compared to **XCD 10,419** (USD 3,856) as estimated under plastic accumulation scenario 2. The present value of the benefits of the regional cooperation scenario, is estimated to be **XCD 4,948,095** (USD 1,831,271) under plastic accumulation scenario 1 and **XCD 12,215,802** (USD 4,521,022) under plastic accumulation scenario 2.

The cost-benefit analysis resulted in an estimated net present value that varies between **XCD -13,490,704** (USD -4,992,858) (national recycling and plastic accumulation scenario 1) and **XCD -1,279,292** (USD -473,461) (regional cooperation and plastic accumulation scenario 2) for the period 2023-2040. The results of the cost-benefit analysis highlights the importance of regional collaboration, due to the transboundary nature of the marine litter. This is consistent with what was found by Macias et al., 2022 for the Mediterranean.

This study mainly focused on estimating direct costs for the economy of Saint Lucia, looking at costs for the fisheries and tourism sectors. Some costs, such as the impact of ghost fishing, and benefits, such as the potential of selling plastics on the market for recyclables, were not included. In addition, mismanaged plastics also have broader impacts on blue natural capital assets and marine biodiversity, which can generate additional impacts to the economy. With this said, it is difficult to quantify the impact on marine ecosystems and biodiversity (Tekman et al., 2022). The impact of marine plastics must be seen in light of the multiple stressors, which impact the marine environment and the blue economy that depends on it.

While the results demonstrate that the implementation of a national recycling scenario in Saint Lucia can, in and of itself, generate a positive environmental impact in terms of reducing marine plastic pollution over the current BaU practices, although potentially with a negative NPV, the implementation of a regional recycling collaboration can have an even greater positive impact in terms of reducing MPW. Notwithstanding, in both cases, additional social, economic and environmental benefits can be derived from the simultaneous implementation of a range of policy solutions and tools to address the problem and generate a larger reduction in mismanaged plastic and potentially also in plastic stocks. These include, for example: reducing and substituting plastic use to systems such as extended producer responsibility, market-based instruments such as deposit refund schemes or landfill taxes, and the improvement of waste collection systems and infrastructure, including fishing systems and gear (Newman et al., 2015). Further cost-effectiveness and cost-benefit analyses will be needed to continue supporting the decision-making process, including further work around the cost-and benefits of establishing a regional recycling hub in the Caribbean Region. While a regional hub will provide the needed economies of scale, it is recommended that any efforts towards its development and implementation should include collaborations with existing recyclers in Saint Lucia.

In addition to recycling, a range of instruments and initiatives have been proposed globally to reduce MPW, and beyond the scope of this study, such as, product taxes, to include the externalities caused by plastic leakage into the environment and to generate revenue. This; however, comes with additional challenges, including, for example, where to tax the products (during production, export, import, usage). If plastics are taxed at the production source, it may not be collected where the main impact is caused. For example, according to APWC (2021a), the costs of plastic pollution on SIDS are hugely disproportionate to their contributions. These global and distributional issues highlight the importance of not only developing national legislation and regional collaboration, but also a global treaty on plastics.

There is also a need for further data on mismanaged plastics and leakage, and where it accumulates in the marine environment. Additional work is also needed to understand the real cost of plastics, including microplastics. Although efforts have been undertaken, such as the studies conducted by Trucost (2016) and WWF (2021), more empirical evidence is needed on the costs of marine plastics to fisheries, tourism, and the blue economy as a whole.

Finally, a broader accounting framework is needed to provide a more comprehensive picture of how marine plastics, together with multiple stressors, impact the national economy. Ocean Accounting[20] seems particularly suited for this. Future national assessments should aim to include this accounting system as part of economic impact estimates and scenario analyses.

[20] https://www.oceanaccounts.org/.

***Remarks***

This study uses survey-based data available on the plastic leakage for Saint Lucia, Antigua and Barbuda and Grenada (APWC, 2021b, 2021c and 2021d), and is complemented by data on global estimates (Lebreton and Andrady, 2019), which can potentially be less accurate. The more local and national data are available, the stronger the understanding of plastic leakage into the marine environment.

Different models exist on global plastic accumulation (e.g., Lebreton et al., 2012 and Eriksen, 2014) and where these plastics accumulate within the marine environment (e.g., GRID-Arendal, 2018 and Lebreton et al., 2019 as used in this study). More evidence is needed on what types of plastics are accumulating in which location to improve the understanding of the impacts of marine plastics on the economy and the blue natural capital on which it depends.

Within the limitations of this study, it was not possible to estimate the amount of plastics that enter the Caribbean Sea and accumulate within its boundaries. Instead, only exchanges among countries bordering the Caribbean Sea were considered, while equating inflow with outflow was assumed for the rest. Given that the focus of this study was to estimate the benefits of a national and a regional recycling system, and not a broader Atlantic Ocean wide system, this assumption should not drastically affect these impact estimates. However, it may create an underestimation of the current impact caused by marine plastics. However, the highest plastic accumulations in the Atlantic take place in the North Atlantic gyre, in an area located around the Yucatan Peninsula and North of Cuba, outside of the research area (Eriksen, et al, 2013).

The allocation of plastics among the different countries limiting the Caribbean Sea was done based on size of EEZ and coastline. However, for the Lesser Antilles, the complete area of the EEZs was considered, including both areas within the Caribbean Sea, and those in the Atlantic Ocean. This provides these relatively smaller countries, with a comparatively larger share of EEZs and coastline, and thus of plastic allocated to each of them, as compared to countries where only the area within the Caribbean Sea was considered. This was necessary, given the focus on the complete EEZs and coastlines for the PWFI project countries in this study. Although this could cause a potential overestimation of the percentage of plastics allocated to these countries as compared to other countries bordering the Caribbean Sea, for the actual impact estimates, this additional allocation may somewhat offset the no consideration of plastics accumulating from outside the Caribbean Sea in the EEZs and on the coastlines of the countries that are the focus of this study.

The impact of marine plastics on Saint Lucian fisheries was done transferring the impact estimates of a study conducted elsewhere. The study of Mouat et al. (2010) was also used by others (Arcadis, 2013; UNEP, 2014a). There is a clear need for more field survey data on the impact on fisheries to strengthen an understanding of this issue.

Estimates of the amounts of plastics potentially affecting tourism through beach pollution differed from field data reported in the TIDES database. More data on marine plastic accumulation on beaches and coastal areas will improve the accuracy of the potential impact on tourism.

The potential impact on tourism was illustrated with studies from South Africa and Brazil, not based on empirical evidence on how plastic pollution affects the behaviour of international tourists visiting the Caribbean.

No actual impact on the tourism sector was included in the assessment of the recycling scenarios, only a maximum impact scenario to illustrate the potential risk to the tourism industry if plastic accumulates on beaches. Even a 3% impact (see UNEP 2014a) would have increased the positive impact of recycling as compared to the BaU scenario. However, as this impact estimate could not be accurately transferred to the beach-oriented tourism industry in Saint Lucia, this study only considers impacts that could be explained based on plastic stock estimates.

This study focused on the impact of marine plastics on two sectors of the economy, versus a broader range, which would include the impact on property values, or the impact caused by greenhouse gas emissions from plastic production (see for example UNEP, 2014a and Graham et al., 2022).

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influence costs. Scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example: to reduce costs of services, a minimum specific number of trucks may be required, or if containers are not completely full, it makes their shipping cost more expensive per tonne of plastics transported. Additionally, the potential costs of establishing a regional recycling hub were not considered, focusing instead on shipping the plastics to existing recycling plants in Miami, a port which has regular shipping traffic with Saint Lucia).

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WTTC (World Travel and Tourism Council). 2018b. Saint Lucia Tourism Statistics. Available at https://wttc.org/Research/Economic-Impact/moduleId/704/itemId/209/controller/DownloadRequest/action/QuickDownload.

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Zaneveld, J.R., Burkepile, D.E., Shantz, A.A., et al. 2016. Overfishing and nutrient pollution interact with temperature to disrupt coral reefs down to microbial scales. *Nature Communications* 7 (1), 11833. https://doi.org/10.1038/ncomms11833.

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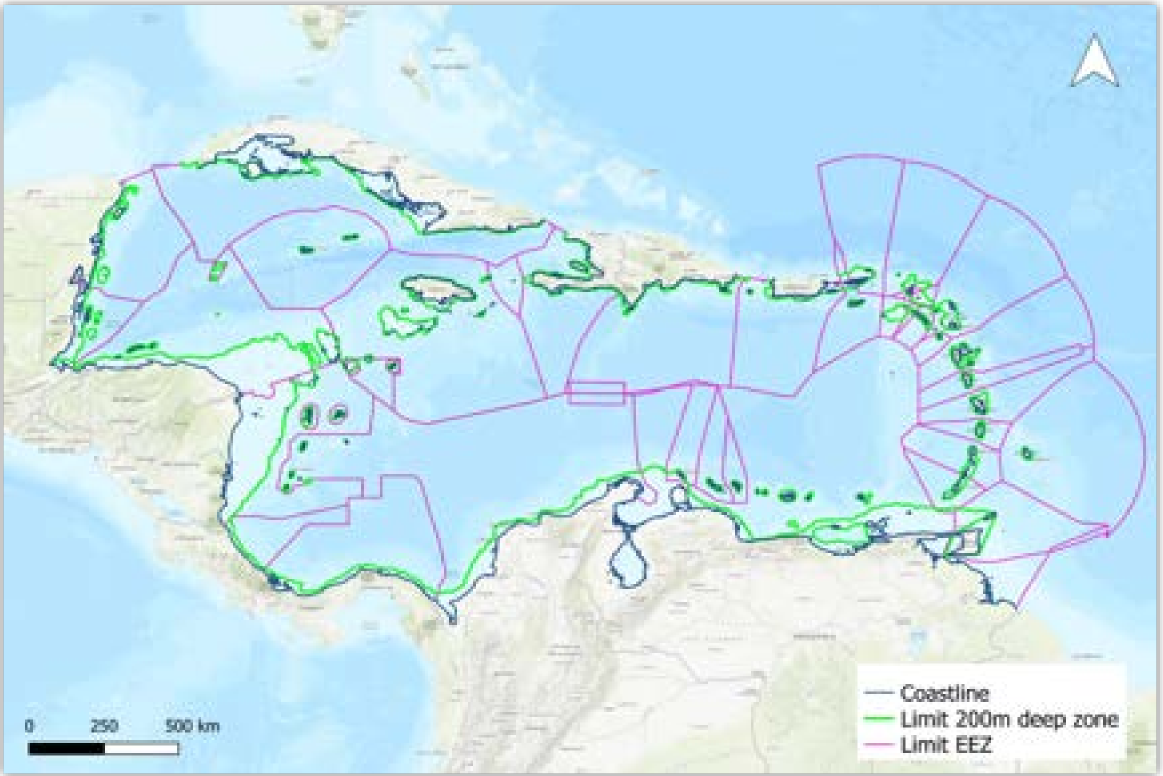
# Annexes

## ANNEX A1. METHODOLOGY USED FOR IMPACT ESTIMATIONS

### Annex A1.1. PLASTIC STOCK ESTIMATION

As a starting point, a semi-closed marine system is defined to estimate plastic stocks. This definition is used since plastics present in a country's EEZ or shoreline, often does not only come from a country's own terrestrial and marine mismanaged plastic waste but can from other countries as well. In addition, plastics will also flow out, accumulating in one of the oceanic accumulation zones (see for e.g., Lebreton et al., 2012[21], Eriksen et al., 2014[22]). For Antigua and Barbuda, the interactions between countries bordering with the Caribbean Sea (**Map A1**), based on a shared marine area, proximity, currents (Gyory et al., 2008[23]), as well as additional impacts of hurricanes in the region were mainly considered.




***Map A1 – Presentation of the Caribbean Region as used in this study***

[21] Lebreton, L.C.M., Greer, S.D., and Borrero, J.C. (2012). Numerical modelling of floating debris in the world's oceans. Marine Pollution Bulletin, 64 (3), 653-661 https://doi.org/10.1016/j.marpolbul.2011.10.027
[22] Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J. (2014). Plastic Pollution in the World's Oceans: More than 5 trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLoS ONE 9(12): e111913. doi:10.1371/journal.pone.0111913.
[23] Gyory, J., Mariano, A. and Ryan, E. (2008). Surface Currents in the Caribbean Sea. Available at: https://oceancurrents.rsmas.miami.edu/caribbean/loop-current.html.

To estimate the amount of plastics, present in 2019, the following steps were taken, and assumptions made:

- Use of data on MPW floating into the Caribbean Sea for non-PWFI countries provided by Lebreton et al. (2019)[24] and estimates by APWC for PWFI countries.
- Regressive analysis going back to 1950 (**Figure A1**):
    - o Consider annual growth rate of plastic production based on data from Geyer et al. (2017) (1950-2015)[25]
    - o Average annual growth rate of plastic production from 2015 to 2020 of 4% as predicted by Ryan (2015)[26]

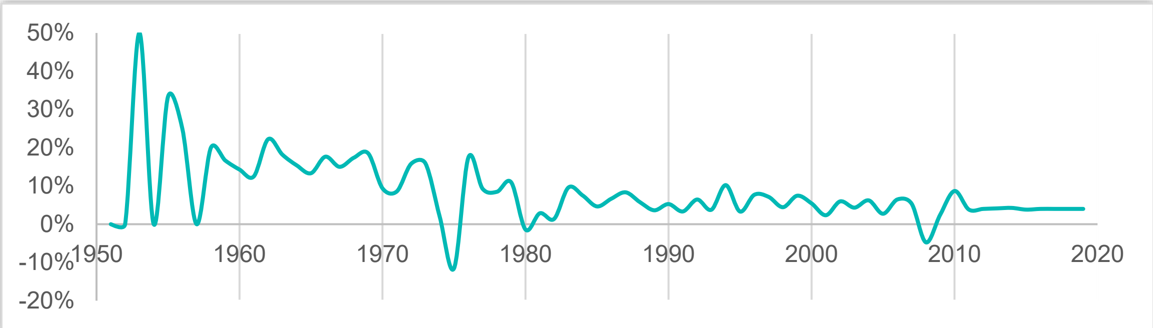



***Figure A1 – Plastic growth used for each year (1950-2019)***

- Two assumptions:
    - o After 30 years, plastics either move to accumulation zones or get buried in the seafloor (Eriksen et al. (2014)[27].
    - o Macroplastics deteriorate into microplastics at an annual rate of 3% (Lebreton et al. (2019); Lebreton et al. (2018))[28,29].
- Finally, once the total amount of plastics is estimated, it is distributed among countries according to the relative area of their EEZ, area of their coastal waters (i.e., less than 200 metres deep), and length of their coastline compared to the total areas of the region analysed in the report. In the case of Saint Lucia, these values are respectively equal to 0.5%, 0.2%, and 0.7% of the total area/length of the Caribbean region. Each parameter used to distribute plastics is related to one of these figures.

[24] Lebreton, L., Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 6 (2019). Available at: https://doi.org/10.1057/s41599-018-0212-7.
[25] Geyer, R., Jambeck, J.R., Law, K.L., (2017). Production, use, and fate of all plastics ever made. Science Advances 3, e1700782. Available at: https://doi.org/10.1126/sciadv.1700782.
[26] Ryan, P.G., (2015). A Brief History of Marine Litter Research, in: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 1–25. Available at: https://doi.org/10.1007/978-3-319-16510-3_1.
[27] Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., (2014). Plastic Pollution in the World's Oceans: More than 5 trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLOS ONE 9, e111913. Available at: https://doi.org/10.1371/journal.pone.0111913.
[28] Lebreton, L., Egger, M., Slat, B., (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. Sci Rep 9, 12922. Available at: https://doi.org/10.1038/s41598-019-49413-5.
[29] Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., Debeljak, P., Maral, H., Schoeneich-Argent, R., Brambini, R., Reisser, J., (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Sci Rep 8, 4666. Available at: https://doi.org/10.1038/s41598-018-22939-w.

- For GRID-Arendal (2018)[30]:
  - The amount of plastics on the coastline and seafloor is dependent on the relative length of the coastline (Saint Lucia has 0.7% of the Region's total);
  - The amount of plastics in the coastal ocean waters is dependent on the relative size of the coastal water (Saint Lucia has 0.2% of the Region's total); and
  - The amount of plastics in the open ocean waters and floating on sea surface is dependent on the relative size of the EEZ (Saint Lucia has 0.5% of the Region's total).
- For Lebreton and Andrady (2019):
  - The amount of plastics on the shoreline – dry land depends on the relative length of the coastline (Saint Lucia has 0.7% of the Region's total);
  - The amount of plastics in the coastal – shallow water depends on the relative size of the coastal water (Saint Lucia has 0.2% of the Region's total); and
  - The amount of plastics in the offshore – deeper water depends on the relative size of the EEZ (Saint Lucia has 0.5% of the Region's total).

## Annex A1.2. PLASTIC ACCUMULATION ESTIMATES

**Table A1** displays the amount of plastics that has accumulated in Saint Lucia's jurisdiction until 2019 for both plastic accumulation scenarios.

***Table A1 – Plastic waste accumulated within Saint Lucia's jurisdiction for both plastic accumulation scenarios (2019) (tonnes)***

| Plastic accumulation scenario | MWP scenario | Average | Low | Midpoint | High |
|---|---|---|---|---|---|
| Scenario 1 | Coastline and seafloor | 18,169 | 15,511 | 18,387 | 20,608 |
| | Coastal ocean waters | 4,023 | 3,435 | 4,072 | 4,563 |
| | Open ocean waters | 14,479 | 12,361 | 14,653 | 16,423 |
| | Floating on sea surface | 186 | 158 | 188 | 211 |
| | **Total** | **36,856** | **31,465** | **37,299** | **41,805** |
| Scenario 2 | Offshore – Deeper water | 446 | 381 | 452 | 506 |
| | Coastal – Shallow water | 27 | 23 | 27 | 31 |
| | Shoreline – Dry land | 53,168 | 45,390 | 53,807 | 60,306 |
| | **Total** | **53,641** | **45,794** | **54,286** | **60,843** |

## Annex A1.3. FISHERIES IMPACT ESTIMATES, METHODOLOGY

To estimate the impact of marine plastics on Saint Lucian fisheries revenue, results from Scotland presented by Mouat et al. (2010)[31] were transferred to Saint Lucia. Value (or impact) transfer is done using the 'direct rule of three.' The 'direct rule of three' helps solving the problems based on proportionality. It states:

[30] GRID-Arendal, (2018). How much plastic is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907 accessed on the 10th of June 2021.

[31] Mouat, T., Lopez-Lozano, R. and Bateson, H. (2010). Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).

$$If\ A \equiv B \qquad \&\ X \equiv Y \qquad Then\ X = \frac{A * Y}{B}$$

Where A, B, X and Y are random variables. If the values of A, B and Y are known, one can estimate the value of X. The 'direct rule of three' states that B is related to A in the same proportion as Y is related to X.

This proportional relation is key to understanding why only one plastic accumulation scenario has been used for the fisheries sector instead of the two scenarios used for the coastal clean-ups. Indeed, even though the amount of plastics impacting fisheries under plastic accumulation scenario 1 is more than 39 times greater than the amount under plastic accumulation scenario 2, the difference is reported on B and Y of the above equation. Thus, it cancels itself out, meaning that the impact is the same regardless of the plastic accumulation scenario.

Coming back to the current relation, revenue is the function of price of the fish catch in market and quantity of fish catch.

$$Revenue = Price\ * Quantity\ (or\ volume)$$

As revenue could not be assessed, due to price differences existing between the two countries, this study estimated revenue as being the price per volume multiplied by the volume (quantity in tonnes), using fisheries' volume as a proxy. Hence, the value or impact transfer is based on a four percent impact on fisheries volume in Scotland, and then the volume is translated to fisheries' revenue.

The aim is to translate the impact estimates obtained by Mouat et al. (2010), to the data of Saint Lucian fisheries, which is achieved by applying data derived from Scottish fisheries.

The relation is expressed as follows:

- Impact% on fisheries ⇐ Amount of plastics present in the sea (in tonnes)
- Impact% on fisheries ⇐ Quantity of fish catch (in tonnes)

The relation between amount of plastics and amount of fish catch, where both have an influence on the estimated impact, can also be written as:

$$Impact_1 = PL_x * FC_x$$

*Where" $Impact_1$ is the impact % of marine plastics on fisheries;*

*$PL_x$ is the amount of plastics present in the fishing zone in tonnes; and*

*$FC_x$ is the amount of fish caught in tonnes.*

Plastics' impact is not only related to the amount of catch, but also related to a number of other factors such as net size, existing fish stocks, time spent on sea by each vessel, etc. As a proxy for this range of factors, the number of vessels and the total size of the fishing area are used. Thus, the impact relation can be represented by the equation below:

$$Impact_1 = \frac{Pl_x}{V_x * EEZ_x} * \frac{FC_x}{V_x * EEZ_x}$$

Where, $V_x$ is the number of vessels in Saint Lucia's fishing zone, and $EEZ_x$ is the size of the fishing zone in km².

Given that both countries have a different amount of plastics present in their fishing zone and each country catches different amounts of fish, the relation of two countries can be stated as follows:

$$Impact_1 = \frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}$$

$$Impact_2 = \frac{PL_{Island}}{V_{St\ Lucia} * EEZ_{St\ Lucia}} * \frac{FC_{St\ Lucia}}{V_{St\ Lucia} * EEZ_{St\ Lucia}}$$

Applying the 'direct rule of three,' and solving for 'PI impact 2' (i.e., impact on fisheries' volume in Saint Lucia in percentage), it can be represented as follows:

$$\%Impact_2 = \%Impact_1 * \frac{\frac{PL_{St\ Lucia}}{V_{St\ Lucia} * EEZ_{St\ Lucia}} * \frac{FC_{St\ Lucia}}{V_{St\ Lucia} * EEZ_{St\ Lucia}}}{\frac{PL_{Scotland}}{V_{Scotland} * EEZ_{Scotland}} * \frac{FC_{Scotland}}{V_{Scotland} * EEZ_{Scotland}}}$$

***Input data from Scotland: Scotland fisheries overview***

Mouat et al., 2010[32] conducted a study through a survey on the Scottish fisheries that use net gears, to understand the extent by which this sector is impacted by marine litter. The study estimated that the impact on fisheries' revenue losses from marine litter was 5% in 2008, or 4% of the revenue if only considering marine plastics (Dunlop et al., 2020)[33].

**Table A2** provides the information that is needed to perform the impact transfer.

***Table A2 – Overview of data from Scottish net fisheries (2008)***[34]

| Vessels | Annual catch (tonnes) | Fishing area (km²) |
|---|---|---|
| 653 | 331,440 | 462,263 |

[32] Mouat, T., Lopez-Lozano, R. and Bateson, H. 2010. Economic Impacts of Marine Litter. KIMO (Kommunenes Internasjonale Miljøorganisasjon).
[33] Dunlop, B.J. Dunlop, M. Brown, (2020) plastics pollution in paradise: Daily accumulation rates of marine litter on Cousine Island, Seychelles, Marine Pollution Bulletin, Volume 151, 110803, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2019.110803.
[34] Scottish Government statistics, 2008. A National Statistics Publication for Scotland: Scottish Sea Fisheries Statistics 2008.

### *Input data from Scotland: amount of plastics present in Scottish fishing area*

Every year, a certain amount of plastics are leaked into the oceans due to factors such as inadequate waste management system, illegal waste disposal, littering, urbanisation, etc. These leaked plastics impact many economic activities, including fisheries (Boucher et al., 2019[35]). The estimated amount of plastics present in Scotland's fishing zone was 24,161 tonnes in 2008, based on the estimates from Lebreton and Andrady (2019)[36], and the plastic allocation from GRID-Arendal (2018)[37]. Thus, the assumption is that in 2008 the impact on Scottish fisheries of a 4% decrease in revenue was due to the presence of an estimated 24,161 tonnes of plastics in their fishing area.

### *Input data for refined analysis on fishing gear and types of boat*

**Table A3** and **A4** shows the details used to refine the data for the fisheries based on the context of Saint Lucia. As a reminder, the direct application of the rule of three in this study implies that fisherfolks are only using net gear. The following correction allows a better restitution of the context of Saint Lucia.

*Table A3 – Detailed data on the use of fish nets for refined impact on fisheries (2019)[38]*

| Fishing gear | Tonnes considered | Dumped catch | Net repairs | Fouling incidents | Time lost |
|---|---|---|---|---|---|
| Longline | 408.58 | X | | From the data on the types of boats (Table A4) | |
| Longline | 388.09 | X | | | |
| Longline | 126.64 | X | | | |
| Longline | 40.05 | X | | | |
| net | 0.02 | X | X | | X |
| Longline | 2.46 | X | | | |
| Pots and trap | 13.50 | X | | | X |
| Free diving | 68.91 | X | | | |
| Spear | 3.07 | X | | | |
| Longline | 81.87 | X | | | |
| Longline | 0.15 | X | | | |
| Net | 419.61 | X | X | | X |
| | | 100% | 27% | 89% | 28% |

[35] Boucher J. and Billard G., (2019). « The challenges of measuring plastic pollution », Field Actions. Science Reports Special Issue 19 October 2019. URL: http://journals.openedition.org/factsreports/53.

[36] Lebreton, L., Andrady, A., (2019). Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.

[37] GRID-Arendal (2018) How much plastics is estimated to be in the oceans and where it may be. https://www.grida.no/resources/6907. Accessed on 10 June 2021.

[38] Department of Fisheries. 2020. Fisheries related data. Department of Fisheries, Ministry of Agriculture, Physical Planning, Natural Resources and Co-operatives, Saint Lucia.

*Table A4 – Type of boats and their number (2019)*[38]

| Type of boats | # | Motor |
|---|---|---|
| Canoe | 72 | No |
| Long liner | 13 | Yes |
| Pirogue | 736 | Yes |
| Shaloop | 30 | No |
| Transom | 65 | Yes |
| Whaler | 10 | Yes |
| Other | 1 | Yes |
| Percentage of boat that might suffer from fouling incidents | 89% | |

## Annex A1.4. TOURISM IMPACT ESTIMATES, METHODOLOGY

The studies from Ballance et al. (2000)[39] and Krelling et al. (2017)[40] are used for Saint Lucia. Balance et al. (2000) studied the impact of marine plastics on tourism in Cape Town, South Africa. Krelling et al. (2017) studied the impact in Brazil.

Cape Town is one of the most visited cities in South Africa. Out of all the tourists visiting the country, 49% are international tourists (City of Cape Town report, 2019).[41] A study conducted on Cape Town's beaches by Ballance et al., 2000 found that a number of tourists were not willing to come to beaches if they were littered (**Table A5**).

*Table A5 – Willingness to visit (WTV) a beach under different littering scenarios in Cape Town*

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.8 items | No change |
| 1.8-8 items | 85% |
| 8 items and more | 97% |

*Source: Ballance et al. 2000.*

The different littering scenarios have been adjusted to reflect the fact that plastic items make up 80% of the litter found on the beach. Therefore, eight plastic items found per linear metre of beach shoreline imply that there are two non-plastic items along with them. This increased amount of marine litter on a given beach would make that beach fall under the last situation of Ballance et al. (2000) A 97% drop of WTV.

Krelling et al. (2017), used a contingent valuation to assess the WTV on two beaches of Brazil under different littering scenarios, as represented in **Table A6**. The same adjustment regarding the composition of littering on beaches has been made, e.g., 24 plastic items imply 30 items overall.

[39] Ballance, A., Ryan, P., Turpie, J. 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science 96, 210–213.
[40] Krelling, A.P., Williams, A.T., Turra, A. 2017. Differences in perception and reaction of tourist groups to beach marine debris that can influence a loss of tourism revenue in coastal areas. Marine Policy 85, 87–99. https://doi.org/10.1016/j.marpol.2017.08.021.
[41] City of Cape Town report. 2019. Annual report. Available at 2019_20_Integrated_Annual_Report.pdf (capetown.gov.za).

*Table A6 – Willingness to visit (WTV) a beach under different littering scenarios in Brazil*

| Plastic item present per linear metre | International tourists not willing to go to the beach |
|---|---|
| 0-1.2 items | No change |
| 1.2-9.6 items | 19.9% |
| 9.6-24 items | 42.7% |
| More than 24 items | 82.4% |

*Source: Krelling et al., 2017.*

The goal is to estimate the WTV of international tourists due to plastic beach pollution in Saint Lucia. For this study, it is assumed that the behaviour of international tourists in Saint Lucia will be similar to the tourists in Cape Town and Brazil.

**Table A7** shows an overview of the number of items per metre in the Lesser Antilles according to the TIDES database.[42] **Table A8** shows the result of the beach clean-ups by giving details for the location of where the items were retrieved from.

*Table A7 – Marine litter collected in Lesser Antilles (2019)*

| Country | Kilometres | Items | Items per metre |
|---|---|---|---|
| Antigua and Barbuda | 13.47 | 8,712 | 0.65 |
| Barbados | 12.87 | 47,355 | 3.68 |
| British Virgin Islands | 0.48 | 1,794 | 3.72 |
| Caribbean Netherlands | 15.92 | 8,050 | 0.51 |
| Cayman Islands | 0.40 | 900 | 2.24 |
| Dominica | 28.61 | 17,822 | 0.62 |
| Grenada | 1.85 | 2,753 | 1.49 |
| Guadeloupe | 1.21 | 338 | 0.28 |
| Sint Maarten | 3.40 | 1,869 | 0.55 |
| Saint Kitts & Nevis | 33.10 | 24,478 | 0.74 |
| Saint Lucia | 8.05 | 7,853 | 0.98 |
| Saint Vincent and the Grenadines | 12.47 | 5,515 | 0.44 |
| Trinidad and Tobago | 63.94 | 206,845 | 3.24 |
| US Virgin Islands | 65.45 | 46,964 | 0.72 |
| **Total** | **261.23** | **381,248.00** | **1.46** |

[42] https://www.coastalcleanupdata.org/reports. Accessed Oct. 15th, 2021.

*Table A8 – Marine litter collected per location for Saint Lucia*

| Year | Location | Plastics collected (tonnes) | Number of items collected | Items per tonne |
|---|---|---|---|---|
| 2020 | Land (beach, shoreline and inland) | - | - | - |
| | Underwater | - | - | - |
| 2019 | Land (beach, shoreline and inland) | 1.51 | 7853 | 5,199 |
| | Underwater | 0.001 | 32 | 28,959 |
| 2018 | Land (beach, shoreline and inland) | 1.42 | 11715 | 8,252 |
| | Underwater | 0.001 | 11 | 9,955 |
| 2017 | Land (beach, shoreline and inland) | 2.62 | 23806 | 9,083 |
| | Underwater | 0.011 | 22 | 1,937 |
| 2016 | Land (beach, shoreline and inland) | - | - | - |
| | Underwater | 0.001 | 27 | 27,000 |

# ANNEX A2. FUTURE SCENARIOS

## Annex A2.1. DISCOUNT RATE FOR NET PRESENT VALUE

To obtain a discount rate for this study, an average of different discount rates is used. **Table A9** presents the discount rates used.

*Table A9 – Series of discount rates used to estimate Saint Lucia's discount rate*

| Country | Discount Rate |
|---|---|
| European Union | 4 |
| Norway | 4 |
| UK | 3.5 |
| France | 4.5 |
| USA (CBO) | 2 |
| USA (OMB) | 5 |
| USA (EPA) | 5 |
| USA (GAO) | 0.1 |
| IDB | 12 |
| World Bank | 11 |
| Colombia | 12 |
| Costa Rica | 12 |
| Mexico | 10 |
| Calculated LA | 3.77 |

*Source: Moore et al. (2020)*[43].

[43] Moore MA, Boardman AE, Vining AR. (2020). Social Discount Rates for Seventeen Latin American Countries: Theory and Parameter Estimation. Public Finance Review.; 48(1) 43-71.

## Annex A2.2. BUSINESS-AS-USUAL (BAU) SCENARIOS (2023-2040)

### Annex A2.2.1. Plastics impacting fisheries (2023-2040)

**Figure A2** displays the amount of plastics impacting fisheries for each year.

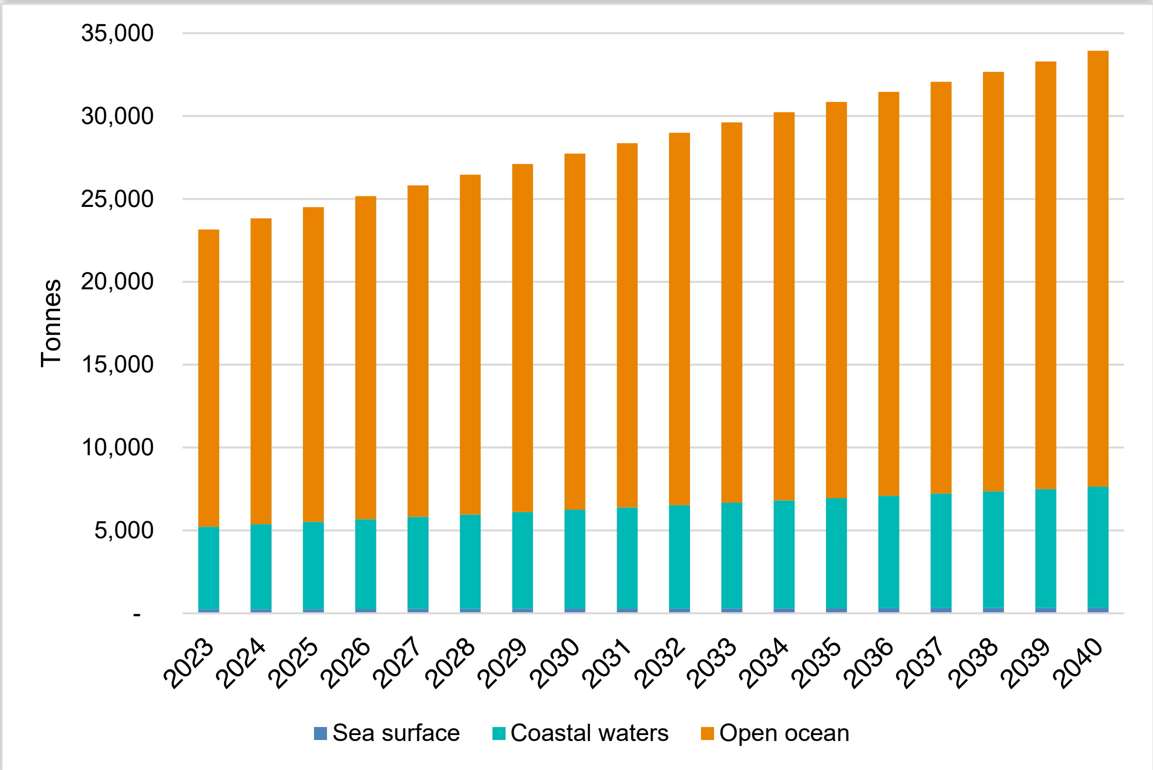



***Figure A2 – Plastics impacting fisheries under BaU scenario for each year***

### Annex A2.2.2. Fisheries sector (2023-2040)

To predict the impact on fisheries in Saint Lucia in the period 2020-2040, two different potential scenarios of how the fisheries sector will evolve are considered. **Fish scenario 1** corresponds to a BaU case where the **fish catch is stable** for the whole period considered. **Fish scenario 2** reflects a reduction in the fish catch due to climate change impacts by 2040. Therefore, **an annual decrease of 0.25% of fish catch potential** for Saint Lucia's fisheries has been considered until 2040 (FAO, 2018[44]). Prices are considered constant. Both results are displayed in **Figure A3**.

**Figure A3** shows the estimated fish catch under the different "fish scenarios".

[44] https://www.fao.org/3/i9705en/i9705en.pdf.

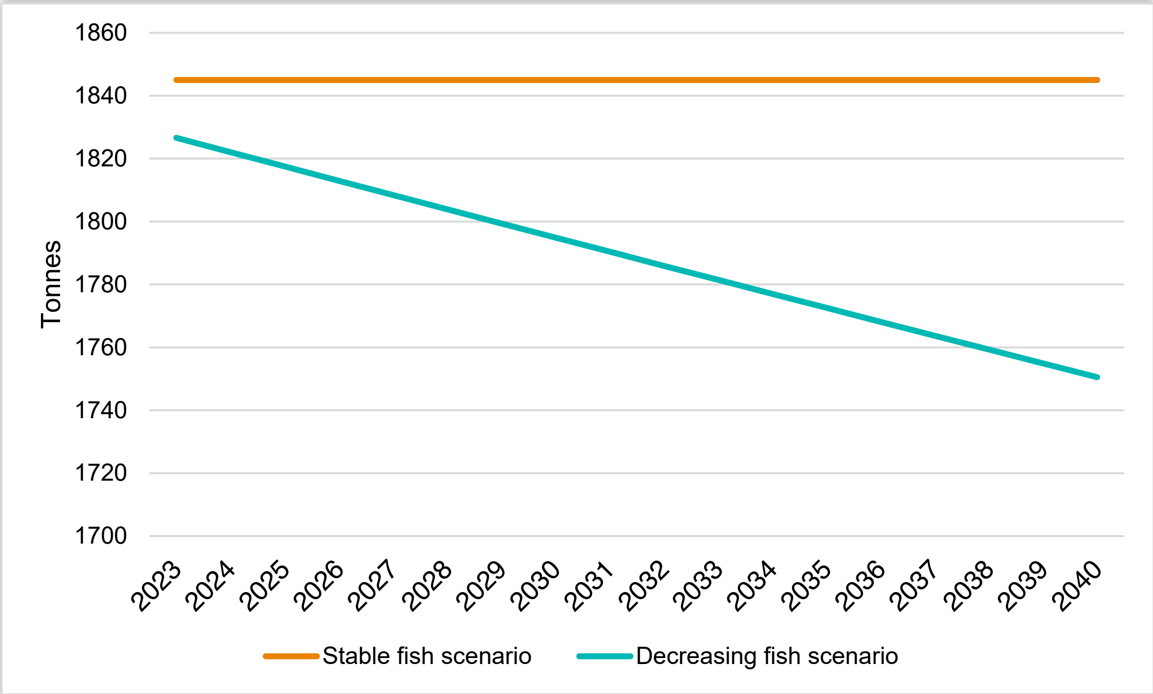



***Figure A3 – Evolution of fish catch for different fish scenarios (tonnes/year)***

### Annex A2.2.3. Impact on fisheries under BaU scenario (2023-2030)

The combination of the different plastic accumulation scenarios and fish scenarios allows for the generation of two impact scenarios (Presented in **Figure A4**):

- Fish scenario 1: Stable fish catch, no change over the period
- Fish scenario 2: Decrease in fish catch due to climate change

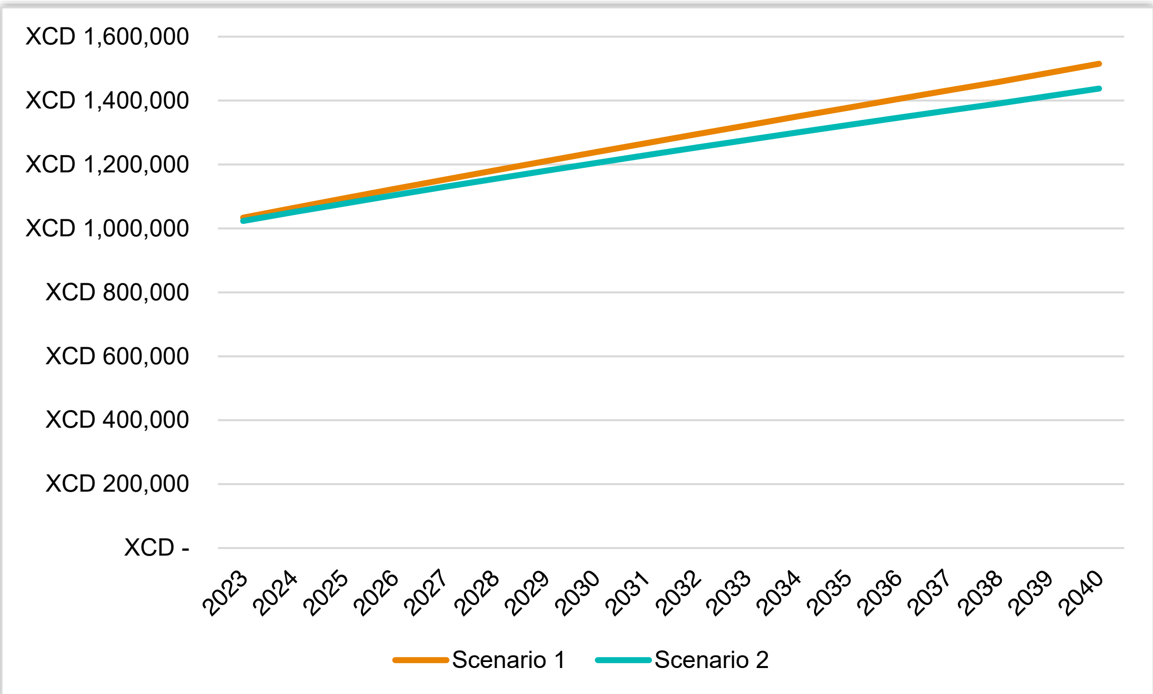



***Figure A4 – The estimated losses to the fisheries sector according to both fish scenarios (non-discounted values)***

### Annex A2.2.4. Tourism sector (2023-2040)

**Table A10** and **Figure A5** present the data used to estimate the future growth rate of the tourism sector in Saint Lucia.[45]

*Table A10 – Data used for the forecast of the growth rate of tourism sector*

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 1980 | 5.0% | | | |
| 1981 | 5.0% | | | |
| 1982 | 5.0% | | | |
| 1983 | 5.0% | | | |
| 1984 | 5.0% | | | |
| 1985 | 5.0% | | | |
| 1986 | 5.0% | | | |
| 1987 | 5.0% | | | |
| 1988 | 5.0% | | | |
| 1989 | 5.0% | | | |
| 1990 | 5.0% | | | |
| 1991 | 5.0% | | | |
| 1992 | 5.0% | | | |
| 1993 | 5.0% | | | |
| 1994 | 5.0% | | | |
| 1995 | 5.0% | | | |
| 1996 | 2.4% | | | |
| 1997 | 2.4% | | | |
| 1998 | 2.4% | | | |
| 1999 | 2.4% | | | |
| 2000 | 2.4% | | | |
| 2001 | 2.4% | | | |
| 2002 | 2.4% | | | |
| 2003 | 2.4% | | | |
| 2004 | 2.4% | | | |
| 2005 | 2.4% | | | |
| 2006 | 2.4% | | | |
| 2007 | 2.4% | | | |
| 2008 | 2.4% | | | |
| 2009 | 2.4% | | | |
| 2010 | 2.4% | | | |
| 2011 | 2.4% | | | |
| 2012 | 2.4% | | | |
| 2013 | 2.4% | | | |
| 2014 | 2.4% | | | |
| 2015 | 2.4% | | | |
| 2016 | 2.4% | | | |
| 2017 | 2.4% | | | |
| 2018 | 2.4% | | | |
| 2019 | 2.4% | | | |
| 2020 | 2.4% | | | |
| 2021 | 1.7% | | | |
| 2022 | 1.7% | | | |
| 2023 | 1.7% | | | |
| 2024 | 1.7% | | | |

[45] UNWTO (2011). Tourism Towards 2030 Global Overview.

| Timeline | Values | Forecast | Lower Confidence Bound | Upper Confidence Bound |
|---|---|---|---|---|
| 2025 | 1.7% | | | |
| 2026 | 1.7% | | | |
| 2027 | 1.7% | | | |
| 2028 | 1.7% | | | |
| 2029 | 1.7% | | | |
| 2030 | 1.7% | 1.7% | 1.7% | 1.7% |
| 2031 | | 1.6% | 0.9% | 2.3% |
| 2032 | | 1.5% | 0.6% | 2.5% |
| 2033 | | 1.5% | 0.3% | 2.6% |
| 2034 | | 1.4% | 0.0% | 2.7% |
| 2035 | | 1.3% | -0.2% | 2.8% |
| 2036 | | 1.2% | -0.4% | 2.9% |
| 2037 | | 1.1% | -0.6% | 2.9% |
| 2038 | | 1.1% | -0.8% | 3.0% |
| 2039 | | 1.0% | -1.0% | 3.0% |
| 2040 | | 0.9% | -1.2% | 3.0% |

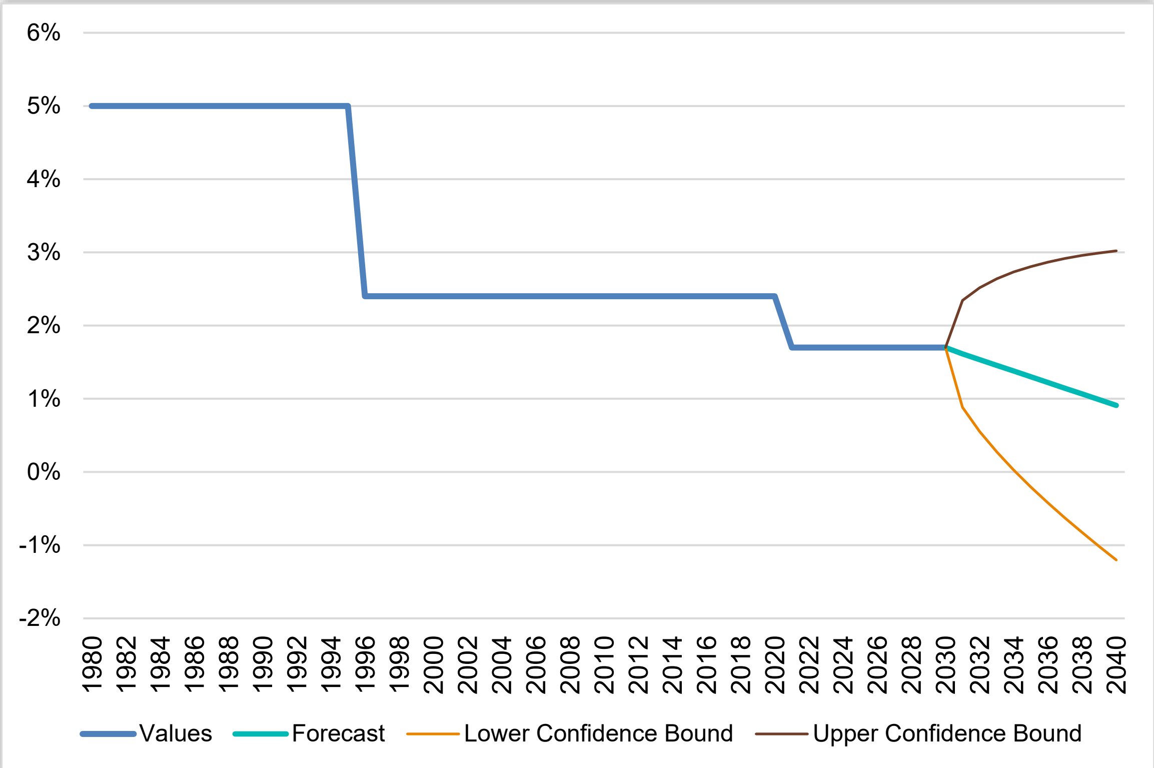



***Figure A5 – Estimated annual growth rate of the tourism sector and forecast for the years 2031 to 2040, 95% CI***

### Annex A2.2.5. Plastics impacting tourism (2023-2030)

To estimate the future impact of mismanaged plastics on tourism, only the impact on coastal clean-ups is considered. It is presented in **Figure A6**.

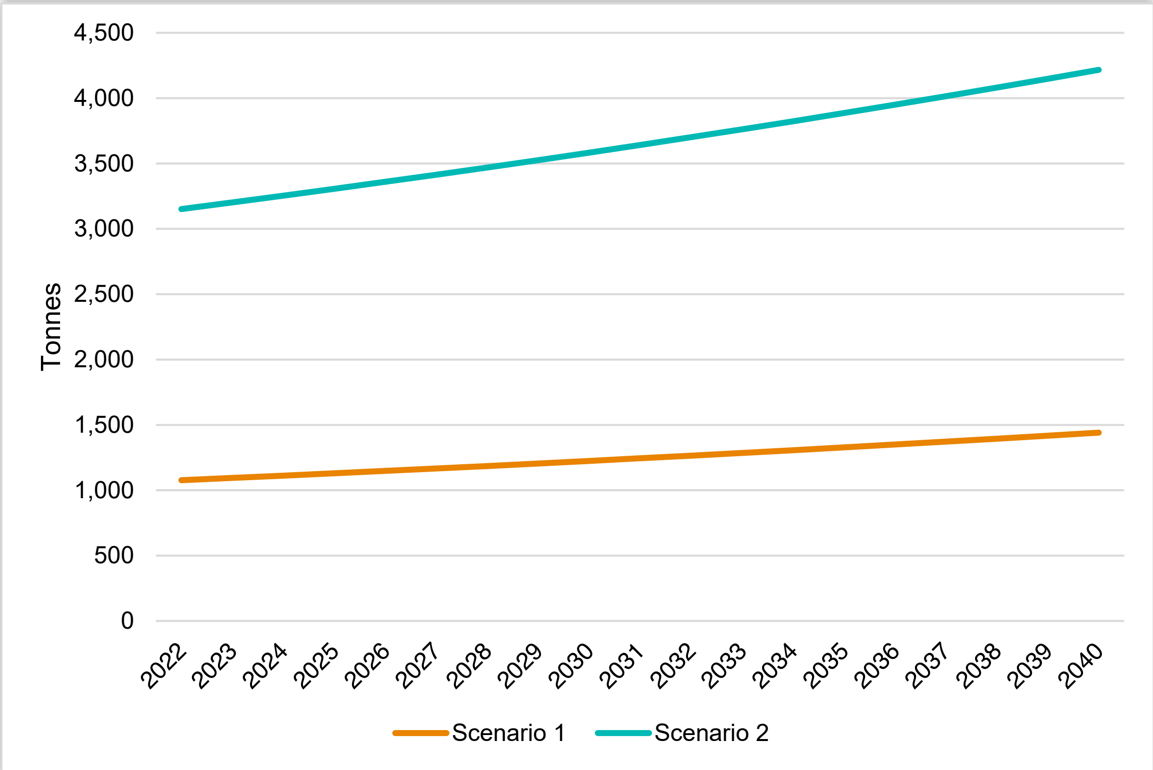



***Figure A6 – Estimated amount of plastics ending up on the Saint Lucian coastline under BaU scenario (tonnes/year)***

Based on these estimates, the total amount of plastic items per metre can be calculated to obtain the coastal clean-up costs to avoid any impact on the tourism sector and is presented in **Table A11**.

*Table A11 – Estimated amount of plastics ending up on the Saint Lucian coastline under BaU scenario under both plastic accumulation scenarios (items/metre)*

| Year | Items per metre according to | |
|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2020 | 45 | 130 |
| 2021 | 45 | 132 |
| 2022 | 46 | 135 |
| 2023 | 47 | 137 |
| 2024 | 47 | 139 |
| 2025 | 48 | 141 |
| 2026 | 49 | 143 |
| 2027 | 50 | 146 |
| 2028 | 51 | 148 |
| 2029 | 51 | 151 |
| 2030 | 52 | 153 |
| 2031 | 53 | 156 |
| 2032 | 54 | 158 |
| 2033 | 55 | 161 |
| 2034 | 56 | 163 |
| 2035 | 57 | 166 |
| 2036 | 58 | 169 |
| 2037 | 59 | 171 |
| 2038 | 60 | 174 |
| 2039 | 61 | 177 |
| 2040 | 62 | 180 |

### Annex A2.2.6. Impact on tourism and coastal clean-up costs under BaU scenario (2023-2030)

To maximise the probability that the predicted growth in tourism holds, coastal clean-ups will be necessary to avoid costs as presented earlier in this study. The same methodology as used for the 2019 impact is applied here for the different plastic accumulation scenarios. **Tables A12** and **A13** present how an increase in plastic flow throughout the years will change the cost of coastal clean-ups, avoiding costs in the form of loss of tourism revenue. It is presented as the non-discounted value.

*Table A12 – Coastal clean-up costs for plastic accumulation scenario 1 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 1,246,855 | 2032 | 1,441,096 |
| 2024 | 1,266,951 | 2033 | 1,464,647 |
| 2025 | 1,287,402 | 2034 | 1,488,620 |
| 2026 | 1,308,215 | 2035 | 1,513,025 |
| 2027 | 1,329,397 | 2036 | 1,537,868 |
| 2028 | 1,350,955 | 2037 | 1,563,159 |
| 2029 | 1,372,896 | 2038 | 1,588,907 |
| 2030 | 1,395,228 | 2039 | 1,615,120 |
| 2031 | 1,417,959 | 2040 | 1,641,809 |

*Table A13 – Coast al clean-up costs for plastic accumulation scenario 2 (2023-2040)*

| Year | Coastal clean-up costs (XCD) | Year | Coastal clean-up costs (XCD) |
|---|---|---|---|
| 2023 | 3,648,808 | 2032 | 4,217,236 |
| 2024 | 3,707,617 | 2033 | 4,286,157 |
| 2025 | 3,767,465 | 2034 | 4,356,313 |
| 2026 | 3,828,372 | 2035 | 4,427,729 |
| 2027 | 3,890,359 | 2036 | 4,500,431 |
| 2028 | 3,953,446 | 2037 | 4,574,443 |
| 2029 | 4,017,656 | 2038 | 4,649,792 |
| 2030 | 4,083,009 | 2039 | 4,726,503 |
| 2031 | 4,149,528 | 2040 | 4,804,604 |

# ANNEX A3. RECYCLING SCENARIOS

1. National recycling scenario: Only Saint Lucia will implement in-country strategies to reduce plastic pollution by recycling certain types of polymers identified by APWC.
2. Regional recycling scenario: This scenario is based on Lebreton and Andrady (2019)[46] and implies that **all countries** in the region will cooperate and start to better manage their MPW when their GDP per capita increases.

**Table A14** provides the linear growth rate used for the projections.

[46] Lebreton, L., Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 1–11. https://doi.org/10.1057/s41599-018-0212-7.

***Table A14 – Annual growth rate used to estimate future MPW from (2020-2040)***

| Country | Data in Lebreton and Andrady (2019) | Linear growth (2020-2040) |
|---|---|---|
| Anguilla | No data* | -4.8% |
| Antigua and Barbuda** | Yes | -8.3% |
| Aruba | No data* | -4.8% |
| Barbados | Yes | -5.1% |
| Belize | Yes | 0.7% |
| British Virgin Islands | No data* | -4.8% |
| Caribbean Netherlands (Bonaire, etc.) | No data* | -4.8% |
| Cayman Islands | No data* | -4.8% |
| Colombia | Yes | -4.5% |
| Costa Rica | Yes | -9.1% |
| Cuba | No data* | -4.8% |
| Curacao | No data* | -4.8% |
| Dominica | Yes | -5.3% |
| Dominican Republic | Yes | -13.5% |
| Grenada** | Yes | -13.7% |
| Guadeloupe | No data* | -4.8% |
| Guatemala | Yes | 0.5% |
| Haiti | Yes | 1.2% |
| Honduras | Yes | 0.9% |
| Jamaica | Yes | -1.5% |
| Martinique | No data* | -9.2% |
| Mexico/Yucatan (Nota 3) | Yes | 1.7% |
| Montserrat | No data* | -4.8% |
| Nicaragua | Yes | 0.4% |
| Panama | Yes | -9.3% |
| Puerto Rico | Yes | 1.0% |
| Saint Vincent | Yes | -5.1% |
| Saint Barthelemy | No data* | -4.8% |
| Saint Kitts and Nevis | Yes | -4.6% |
| Saint Lucia** | Yes | -10.7% |
| Saint Martin | No data* | -4.8% |
| Sint Maarten | No data* | -4.8% |
| Trinidad and Tobago | Yes | -16.6% |
| Venezuela | Yes | -1.0% |
| Virgin Island of the US | No data* | -4.8% |

** When no data is available, the growth rate is assumed to be equal to the average of the region.*
*** For PWFI countries, APWC (2021)[47] data have been used (Antigua & Barbuda – 58% of plastics might be recycled each year, Grenada – 74%, and Saint Lucia – 46%). Lebreton and Andrady (2019) data for these three countries have only been used to estimate the region average.*

[47] Asia Pacific Waste Consultants. (2021). Plastic Waste-Free Islands Project – Plastic Waste National Level Quantification and Sectorial Material Flow Analysis in Saint Lucia.

## Annex A3.1. IMPACT ON FISHERIES BY PLASTICS, NATIONAL RECYCLING SCENARIO

**Figure A7** presents the comparison for the fisheries between the BaU scenario and the national recycling scenario.

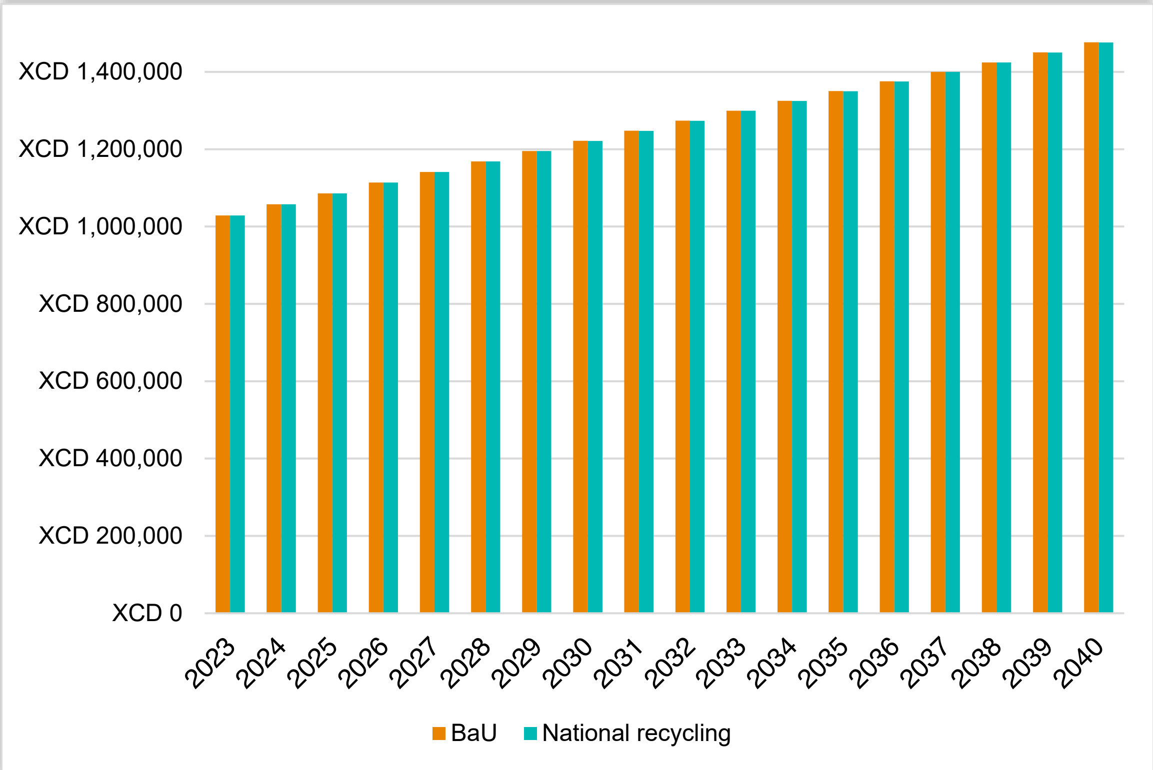



*Figure A7 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and national recycling scenarios*

## Annex A3.2. IMPACT ON TOURISM (COASTAL CLEAN-UP COSTS), NATIONAL RECYCLING

**Table A15** presents the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), considering the national recycling scenario.

*Table A15 – Annual plastic flow and items per metre (2023-2040) under national recycling scenario*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,429 | 4,181 | 47 | 137 |
| 2024 | 1,452 | 4,249 | 47 | 139 |
| 2025 | 1,475 | 4,317 | 48 | 141 |
| 2026 | 1,499 | 4,387 | 49 | 143 |
| 2027 | 1,523 | 4,458 | 50 | 146 |
| 2028 | 1,548 | 4,530 | 51 | 148 |
| 2029 | 1,573 | 4,604 | 51 | 151 |
| 2030 | 1,599 | 4,678 | 52 | 153 |
| 2031 | 1,625 | 4,755 | 53 | 155 |
| 2032 | 1,651 | 4,832 | 54 | 158 |
| 2033 | 1,678 | 4,911 | 55 | 161 |
| 2034 | 1,706 | 4,992 | 56 | 163 |
| 2035 | 1,734 | 5,073 | 57 | 166 |
| 2036 | 1,762 | 5,157 | 58 | 169 |
| 2037 | 1,791 | 5,242 | 59 | 171 |
| 2038 | 1,821 | 5,328 | 60 | 174 |
| 2039 | 1,851 | 5,416 | 61 | 177 |
| 2040 | 1,881 | 5,505 | 62 | 180 |

**Table A16** presents the coastal clean-up cost estimates for the national recycling scenarios.

*Table A16 – Impact on beach cleaning cost, national recycling scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,246,815 | 3,648,693 | 39 | 115 |
| 2024 | 1,266,871 | 3,707,385 | 79 | 232 |
| 2025 | 1,287,282 | 3,767,113 | 120 | 352 |
| 2026 | 1,308,053 | 3,827,898 | 162 | 474 |
| 2027 | 1,329,233 | 3,889,880 | 164 | 479 |
| 2028 | 1,350,789 | 3,952,963 | 165 | 484 |
| 2029 | 1,372,729 | 4,017,167 | 167 | 489 |
| 2030 | 1,395,059 | 4,082,515 | 169 | 494 |
| 2031 | 1,417,788 | 4,149,029 | 170 | 499 |
| 2032 | 1,440,924 | 4,216,732 | 172 | 504 |
| 2033 | 1,464,473 | 4,285,648 | 174 | 509 |
| 2034 | 1,488,445 | 4,355,799 | 176 | 514 |
| 2035 | 1,512,847 | 4,427,210 | 177 | 519 |
| 2036 | 1,537,689 | 4,499,907 | 179 | 525 |
| 2037 | 1,562,978 | 4,573,913 | 181 | 530 |
| 2038 | 1,588,724 | 4,649,256 | 183 | 535 |
| 2039 | 1,614,935 | 4,725,962 | 185 | 541 |
| 2040 | 1,641,622 | 4,804,058 | 187 | 546 |

### Annex A3.3. IMPACT ON FISHERIES BY PLASTICS, NATIONAL RECYCLING

**Figure A8** presents the comparison for the fisheries between the BaU scenario and the regional cooperation scenario.

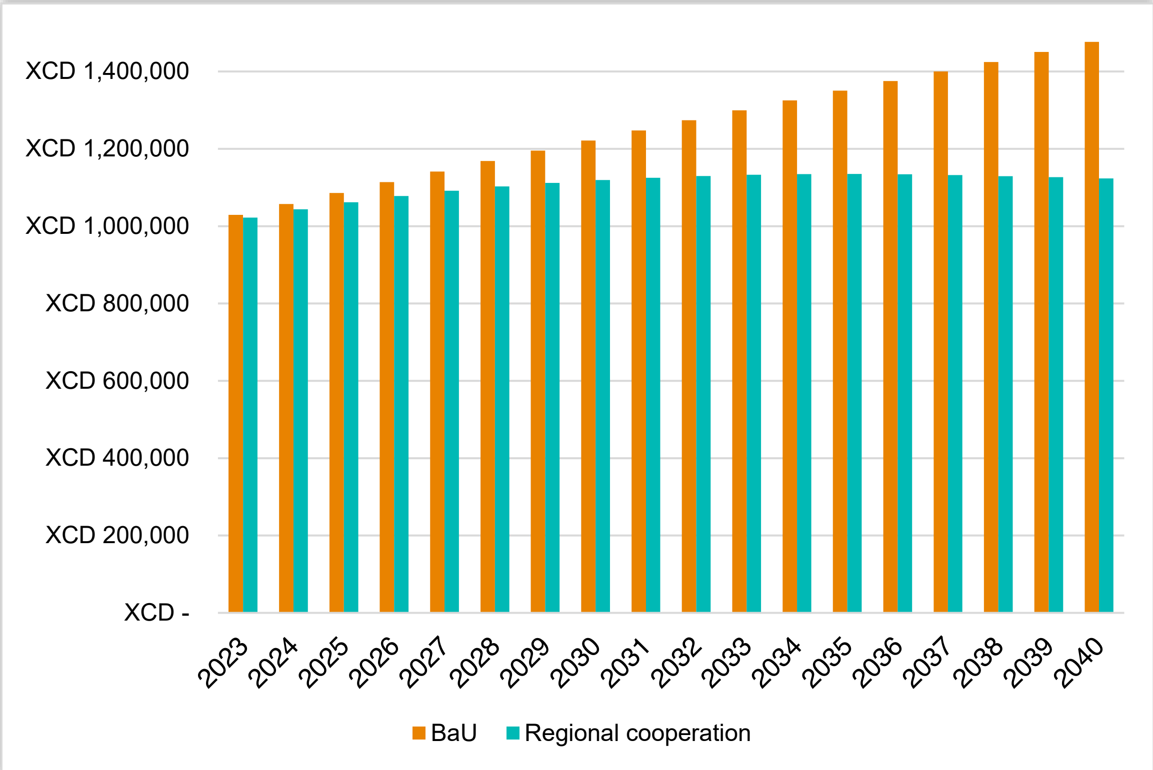



***Figure A8 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and regional cooperation scenarios***

## Annex A3.4. IMPACT ON TOURISM (COASTAL CLEAN-UP COSTS), REGIONAL COOPERATION SCENARIO

**Table A17** shows the change in plastics on the coastline (plastic accumulation scenarios 1 and 2), under the regional cooperation scenario.

*Table A17 – Annual plastic flow and items per metre (2023-2040) under regional cooperation scenarios*

| Years | Annual plastic flow (tonnes) | | Plastic items per metre | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,329 | 3,891 | 43 | 127 |
| 2024 | 1,293 | 3,783 | 42 | 124 |
| 2025 | 1,260 | 3,688 | 41 | 121 |
| 2026 | 1,232 | 3,604 | 40 | 118 |
| 2027 | 1,206 | 3,531 | 39 | 115 |
| 2028 | 1,184 | 3,466 | 39 | 113 |
| 2029 | 1,165 | 3,409 | 38 | 111 |
| 2030 | 1,147 | 3,358 | 38 | 110 |
| 2031 | 1,132 | 3,312 | 37 | 108 |
| 2032 | 1,118 | 3,272 | 37 | 107 |
| 2033 | 1,106 | 3,236 | 36 | 106 |
| 2034 | 1,095 | 3,204 | 36 | 105 |
| 2035 | 1,085 | 3,175 | 35 | 104 |
| 2036 | 1,076 | 3,150 | 35 | 103 |
| 2037 | 1,068 | 3,127 | 35 | 102 |
| 2038 | 1,061 | 3,106 | 35 | 102 |
| 2039 | 1,055 | 3,087 | 35 | 101 |
| 2040 | 1,049 | 3,071 | 34 | 100 |

**Table A18** presents the coastal clean-up cost estimates, under the regional cooperation scenario (plastic accumulation scenarios 1 and 2).

*Table A18 – Impact on beach cleaning cost, regional cooperation scenario (plastic accumulation scenarios 1 and 2)*

| Years | Coastal clean-up cost (XCD) | | Reduction in coastal clean-up cost (XCD) | |
|---|---|---|---|---|
| | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 | Plastic accumulation scenario 1 | Plastic accumulation scenario 2 |
| 2023 | 1,160,141 | 3,395,048 | 86,714 | 253,760 |
| 2024 | 1,127,987 | 3,300,953 | 138,963 | 406,664 |
| 2025 | 1,099,722 | 3,218,236 | 187,680 | 549,229 |
| 2026 | 1,074,819 | 3,145,361 | 233,396 | 683,011 |
| 2027 | 1,052,884 | 3,081,171 | 276,512 | 809,188 |
| 2028 | 1,033,587 | 3,024,700 | 317,367 | 928,746 |
| 2029 | 1,016,497 | 2,974,685 | 356,399 | 1,042,970 |
| 2030 | 1,001,330 | 2,930,302 | 393,898 | 1,152,707 |
| 2031 | 987,845 | 2,890,840 | 430,113 | 1,258,688 |
| 2032 | 975,835 | 2,855,693 | 465,261 | 1,361,543 |
| 2033 | 965,120 | 2,824,337 | 499,527 | 1,461,820 |
| 2034 | 955,547 | 2,796,321 | 533,074 | 1,559,991 |
| 2035 | 946,983 | 2,771,259 | 566,042 | 1,656,470 |
| 2036 | 939,314 | 2,748,816 | 598,554 | 1,751,615 |
| 2037 | 932,440 | 2,728,703 | 630,719 | 1,845,741 |
| 2038 | 926,278 | 2,710,670 | 662,628 | 1,939,122 |
| 2039 | 920,753 | 2,694,501 | 694,367 | 2,032,002 |
| 2040 | 915,802 | 2,680,010 | 726,007 | 2,124,594 |

## Annex A3.5. Cost of implementing the national recycling scheme

Satney M. (2022) (PWFI consultant and based in Saint. Lucia)[48] provided data on tonnes of waste collected and its attached cost. The annual average amount of waste collected between 2018 and 2021 amounts to 74,759 tonnes for an average annual cost of XCD 14,718,914. This leads to an average cost of XCD 196.88 per tonne. **Table A19** shows the base data needed to estimate the cost of the recycling of plastics.

*Table A19 – Additional data needed to perform the cost analysis (2019)*

| | |
|---|---|
| Maximum recyclable amount | 46.1% |
| Plastic waste (tonnes in 2019) | 5,071 |
| Growth rate from 2020-2040 | 1.02% |
| Discount rate | 6.35% |
| Hourly wage used (minimum wage times two) | XCD 16 |
| Waste management budget | XCD 14,718,944 |

[48] Satney, M., 2022. Personal communication – Data on shipping cost.

### *Collecting cost*

Given the cost/number of hours needed to collect 80 tonnes of plastics by Searious Business (2021), the following are the estimated costs corresponding to 2,336.1 tonnes of plastics (**Tables A20**, **A21**, and **A22**).

*Table A20 – Labour costs for 2,336.1 tonnes of plastics (2019)*

| Activity | Hours per week | Cost per week |
|---|---|---|
| Managing collection points and drop off sites | 730 | XCD 11,679.92 |
| Administration | 204 | XCD 3,270.38 |

*Table A21 – Investment costs for 2,336.1 tonnes of plastics (2019)*

| Items | Cost | Cost |
|---|---|---|
| Van | XCD 87,599 | USD 32,420 |
| Trailer for the van | XCD 8,760 | USD 3,242 |

*Table A22 – Fixed costs for 2,336.1 tonnes of plastics (2019)*

| Items | Cost per month | |
|---|---|---|
| Gas | XCD 4,380 | USD 1,621 |
| Car insurance / maintenance | XCD 2,920 | USD 1,081 |

### *Cost of sorting*

Based on data by PEW (2020)[49] and presented in **Table A23**.

*Table A23 – Estimated cost of sorting, based on PEW (2020)*

| Selected Countries and Economies | Year | GDP (PPP[50] - USD) | Operating expenditure per tonne (USD) | Capital expenditure per tonne (USD) | Total (USD) |
|---|---|---|---|---|---|
| Average Upper middle income | 2020 | 18,073.10[51] | 117 | 39 | 156 |
| Saint Lucia | 2020 | 12,709.80[52] | 82 | 27 | 110 |

### *Cost of shipping (to Miami)*

The cost of a 40-foot container to Miami is XCD 5,000 (data provided by Satney M., 2022). This type of container has a capacity of 67m$^3$. Based on data provided by APWC (2021b) (see **Table A24**). The average density of plastic waste in Saint Lucia is estimated to be 1.1536 tonnes per m$^3$.

49 PEW. (2020). Breaking the Plastic Wave. Available at: https://www.systemiq.earth/wp-content/uploads/2020/07/BreakingThePlasticWave_MainReport.pdf.
50 Product based on Purchasing Power Parity.
51 GDP, PPP (current international USD) – Upper middle income | Data (worldbank.org).
52 GDP per capita, PPP (current international USD) – Saint Lucia | Data (worldbank.org).

*Table A24 – Data to estimate average density of one tonne of plastics in Saint Lucia (2019)*

| | Tonnes recycled | Density |
|---|---|---|
| PET | 1164.8 | 1.38 |
| HDPE | 486 | 0.95 |
| LDPE | 289 | 0.925 |
| PP | 396.3 | 0.905 |

The total cost of recycling plastics in Saint Lucia is displayed in **Table A25**.

*Table A25 – Cost of implementing the recycling for Saint Lucia per year*

| Year | Implementation rate of the recycling policy | Amount recycled | Amount considered (tonnes) | Amount recycled (tonnes) | Cost (XCD) (non-discounted) | Cost (XCD) (Discounted at 6.35%) |
|---|---|---|---|---|---|---|
| 2021 | 0% | 0% | 5,175 | - | - | - |
| 2022 | 0% | 0% | 5,227 | - | - | - |
| 2023 | 25% | 12% | 5,281 | 608 | 470,921 | 441,027 |
| 2024 | 50% | 23% | 5,334 | 1,229 | 951,424 | 834,467 |
| 2025 | 75% | 35% | 5,389 | 1,862 | 1,441,654 | 1,184,171 |
| 2026 | 100% | 46% | 5,443 | 2,508 | 1,941,762 | 1,493,712 |
| 2027 | 100% | 46% | 5,499 | 2,533 | 1,961,516 | 1,413,125 |
| 2028 | 100% | 46% | 5,555 | 2,559 | 1,981,472 | 1,336,885 |
| 2029 | 100% | 46% | 5,611 | 2,585 | 2,001,630 | 1,264,759 |
| 2030 | 100% | 46% | 5,668 | 2,611 | 2,021,994 | 1,196,525 |
| 2031 | 100% | 46% | 5,726 | 2,638 | 2,042,565 | 1,131,971 |
| 2032 | 100% | 46% | 5,784 | 2,665 | 2,063,345 | 1,070,900 |
| 2033 | 100% | 46% | 5,843 | 2,692 | 2,084,337 | 1,013,124 |
| 2034 | 100% | 46% | 5,902 | 2,719 | 2,105,542 | 958,465 |
| 2035 | 100% | 46% | 5,963 | 2,747 | 2,126,963 | 906,755 |
| 2036 | 100% | 46% | 6,023 | 2,775 | 2,148,601 | 857,835 |
| 2037 | 100% | 46% | 6,084 | 2,803 | 2,170,460 | 811,554 |
| 2038 | 100% | 46% | 6,146 | 2,832 | 2,192,542 | 767,770 |
| 2039 | 100% | 46% | 6,209 | 2,860 | 2,214,847 | 726,348 |
| 2040 | 100% | 46% | 6,272 | 2,890 | 2,237,380 | 687,161 |

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