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

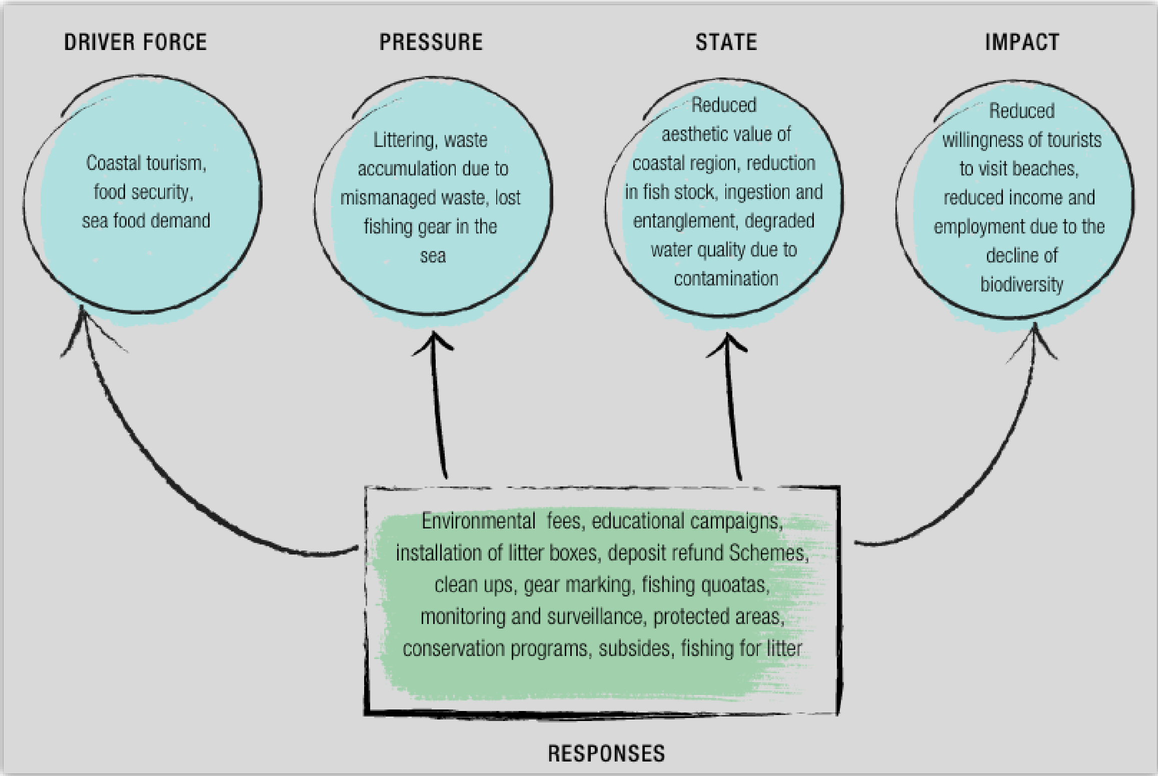
In 2019, with support from the Norwegian Agency for Development Cooperation (Norad), IUCN launched the Plastic Waste-Free Islands (PWFI) project. The initiative's overarching goal is to drive the circular economy agenda forward and to reduce plastic waste generation and leakage from island states. The 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).

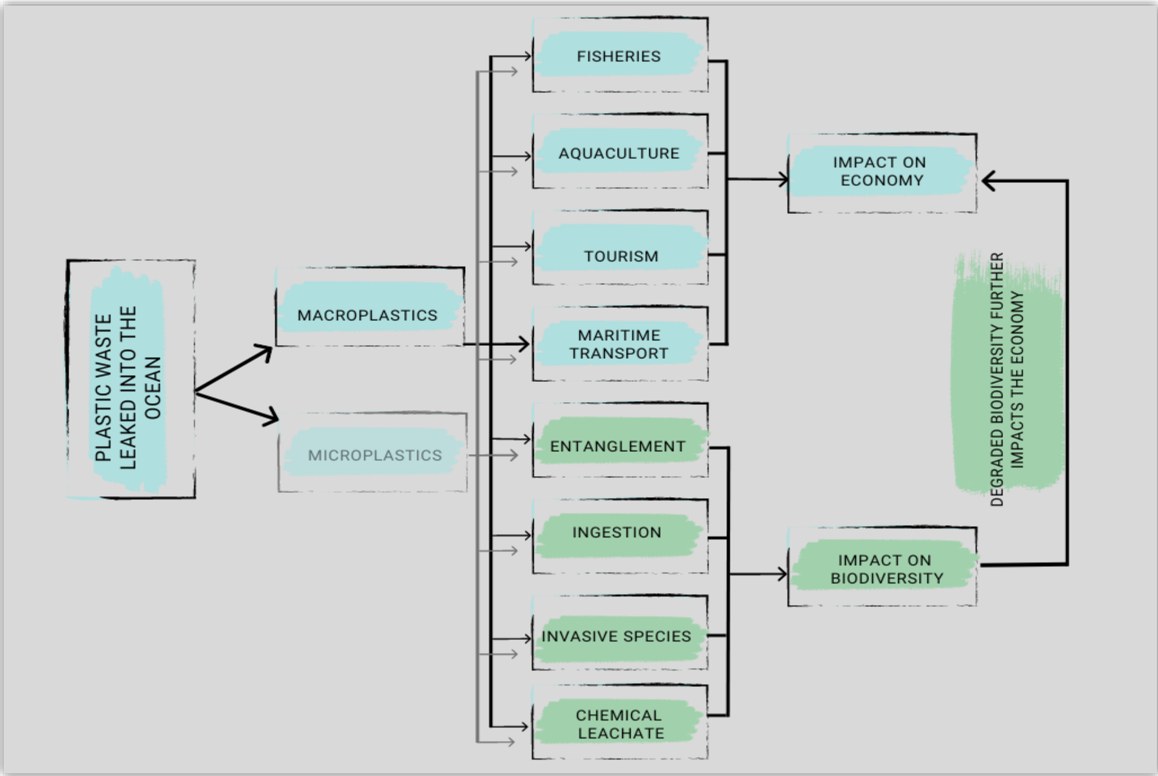
The marine plastic problem can be explained using the 'Driver, Pressures, States, Impacts and Responses' framework (Löhr et al., 2017; Miranda et al., 2019) (**Figure 1**). The drivers of plastic production originate from human needs such as food security, movement of goods and services, and shelter (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).

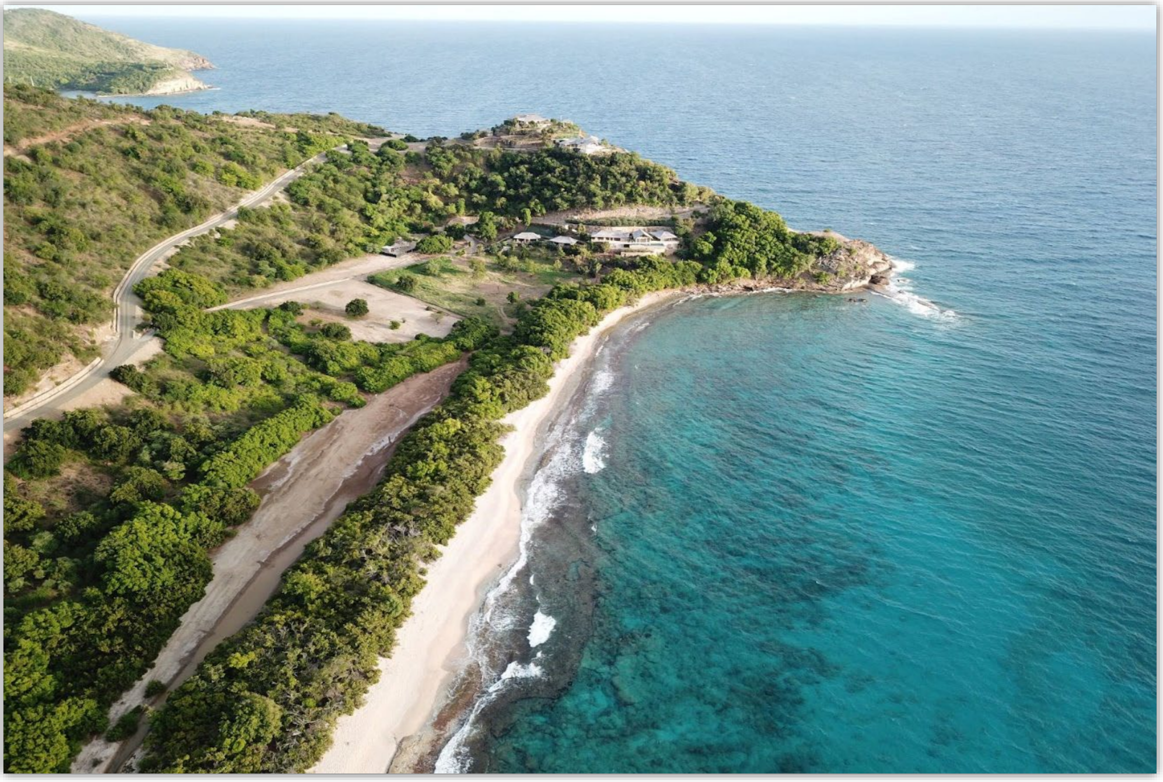
However, the lucrative marine and coastal ecosystems are in danger, given that the Caribbean Sea is the second most plastic-contaminated sea in the world (UNEP, 2019b). According to a 2019 report by Forbes, 10 of the top 30 global polluters per capita are from the Caribbean region (Ewing-Chow, 2019). 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

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

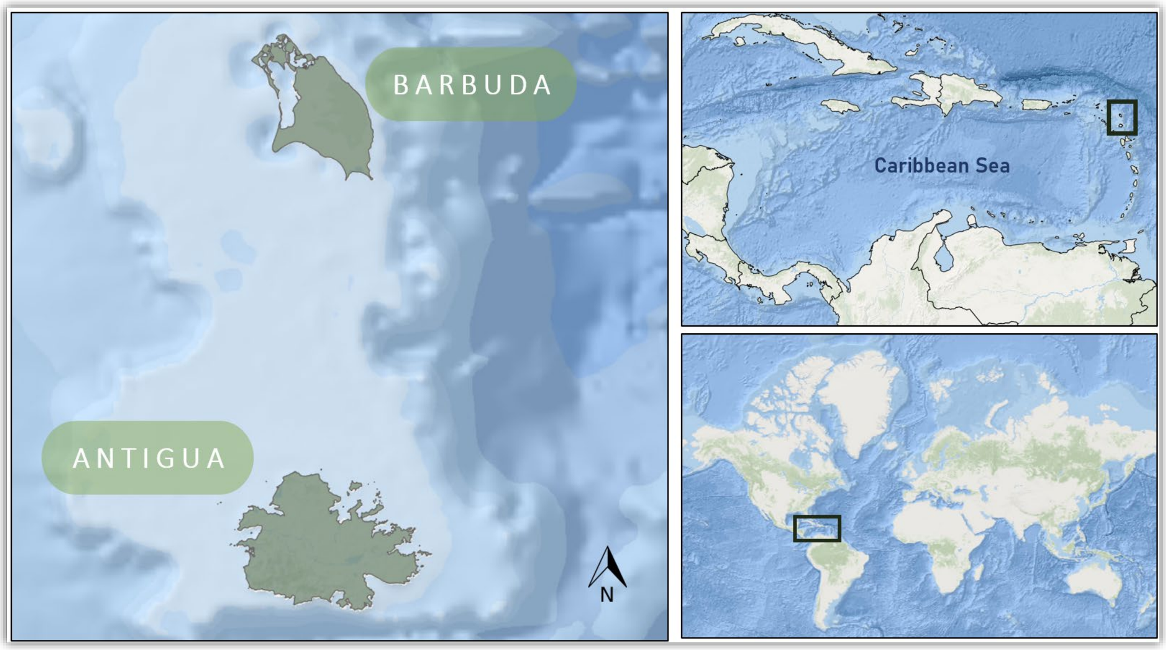
determine their efficacy (Chen, 2015; Rochman, 2016). To ensure sustainability of the Caribbean Sea's ecosystems, an integrated management approach with local stakeholders and government as well as with other nations is needed (Winther et al., 2020).



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 3/4th of the total tourists, while 1/4th 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

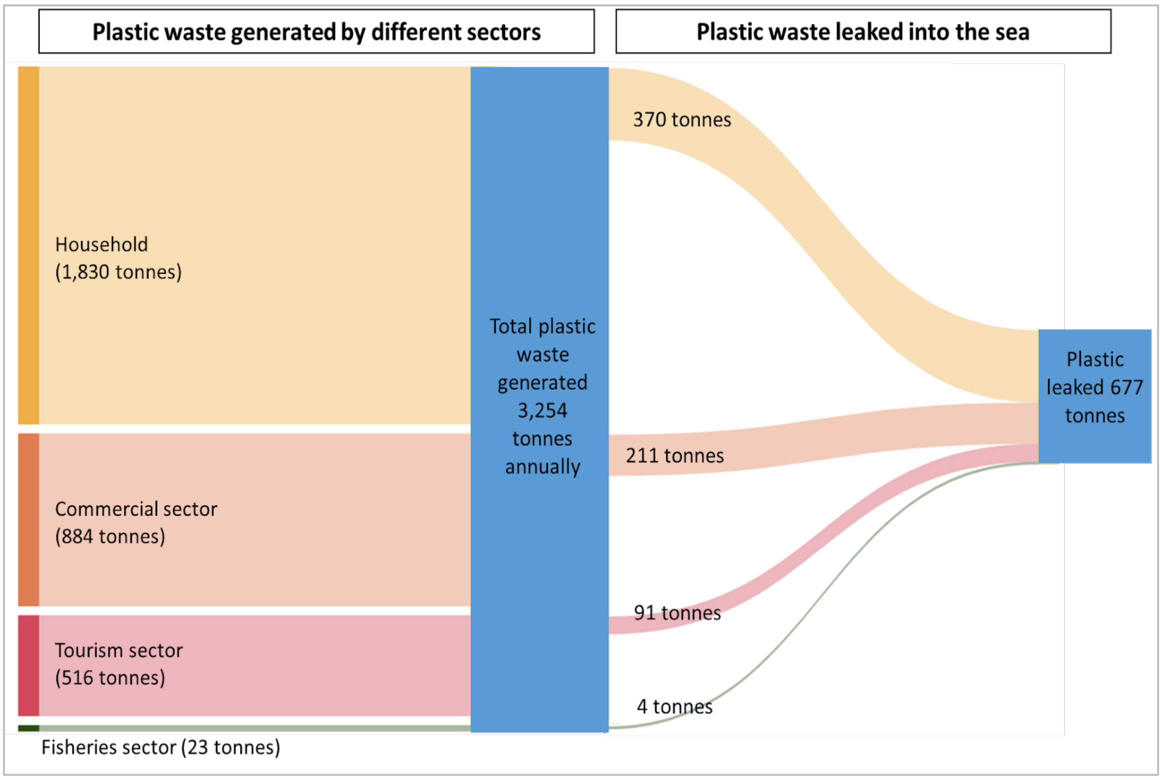
Sources: WTTC, 2022 and World Bank, 2022b.

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

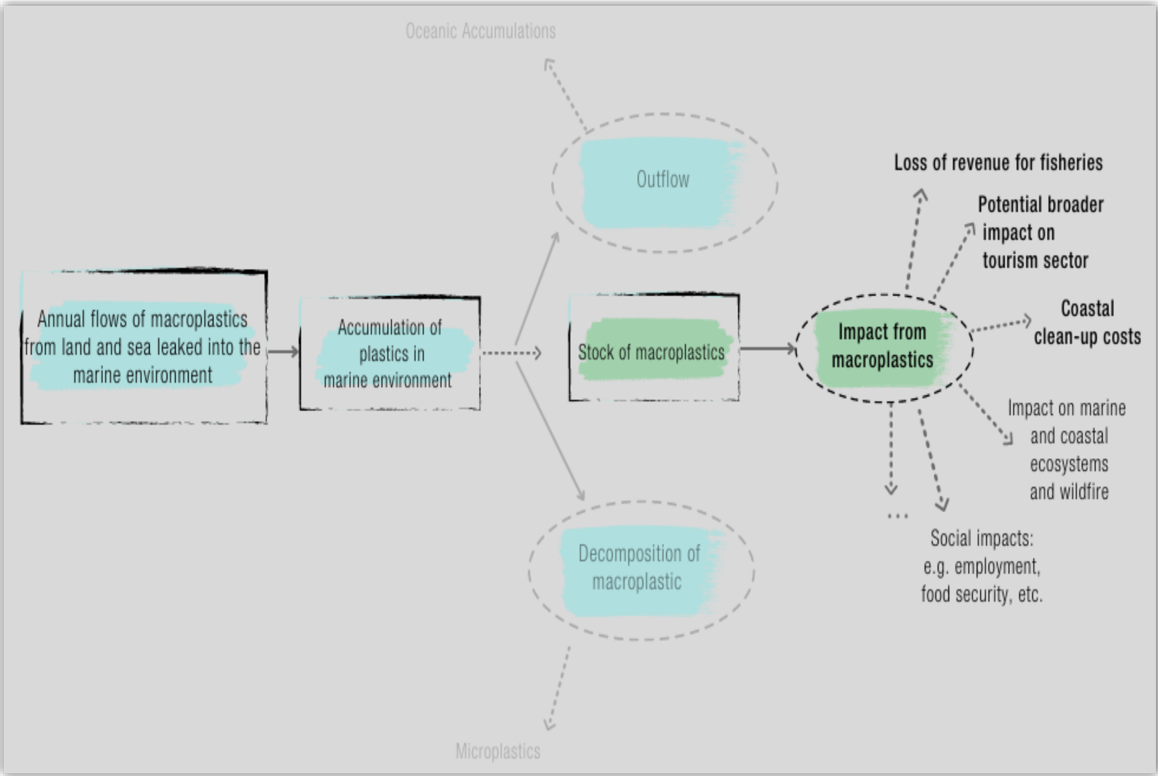
3.1.1. Data collection

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.

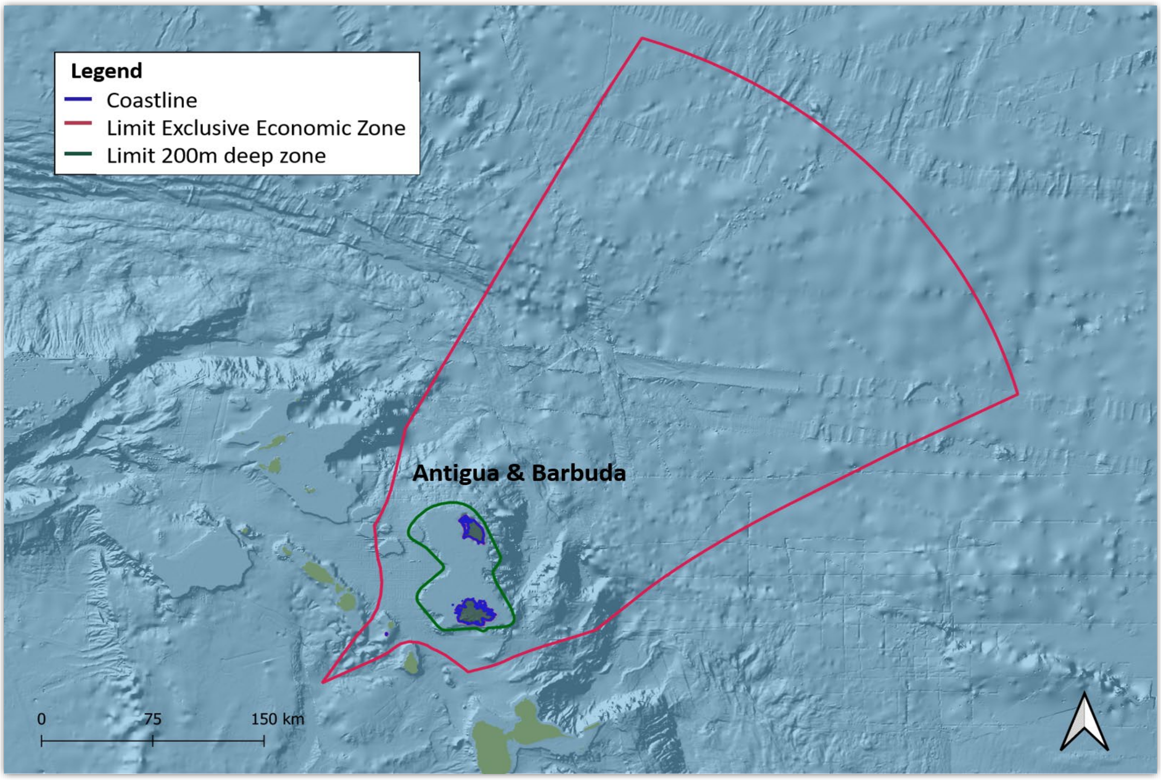
Since no clear budget allocation on the different beach clean-up efforts could be estimated (considering the combined cleaning efforts of municipalities, non-profit organisations (NGOs), hotels, etc.), and considering that no studies were available on where on the shore-or coastline plastics end up exactly 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.

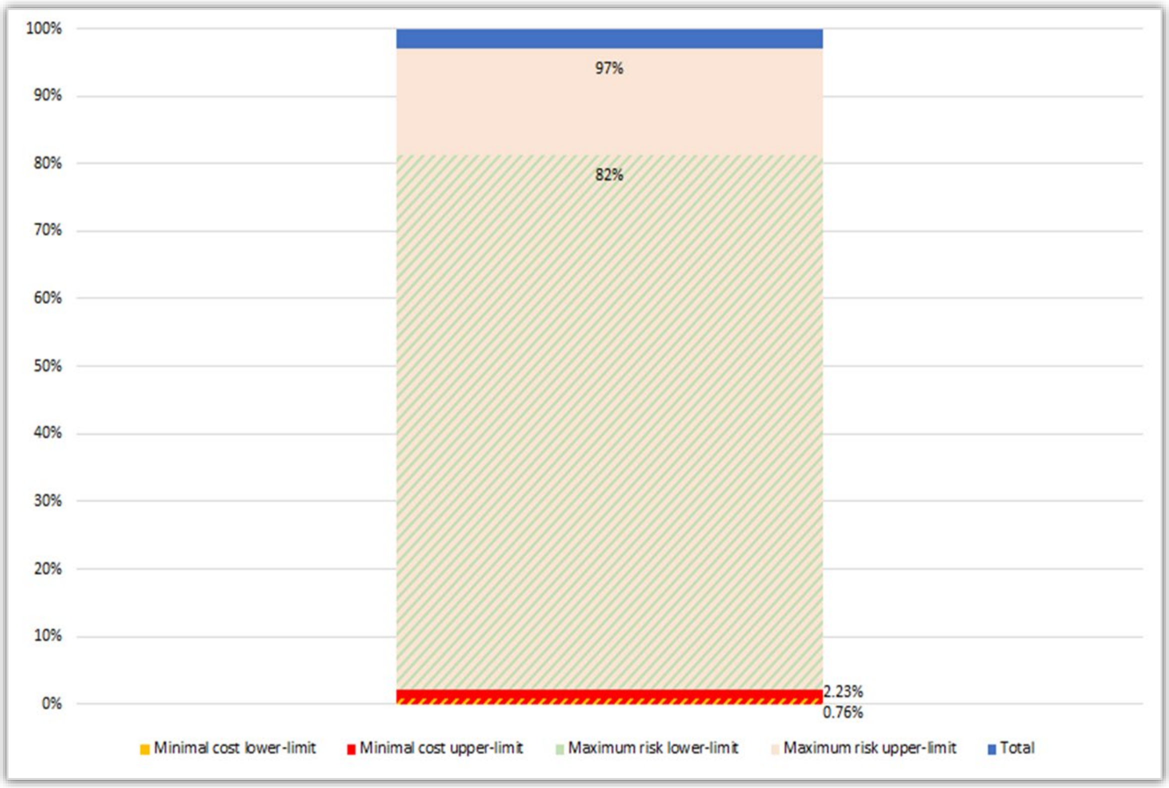


Figure 5 – Actual and potential costs of plastic pollution to the tourism industry in 2019 and total tourism receipts under plastic accumulation scenarios

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).

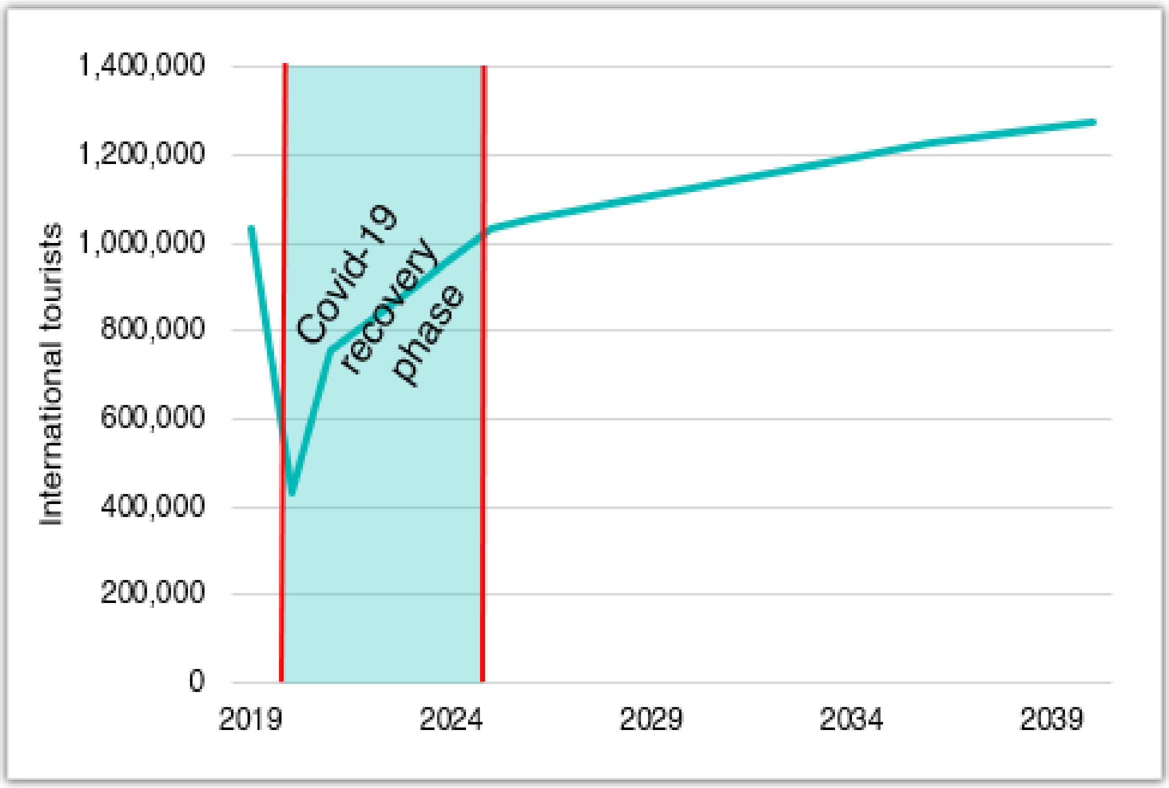


Figure 6 – Estimated number of international tourists in Antigua and Barbuda (2020-2040)

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**.

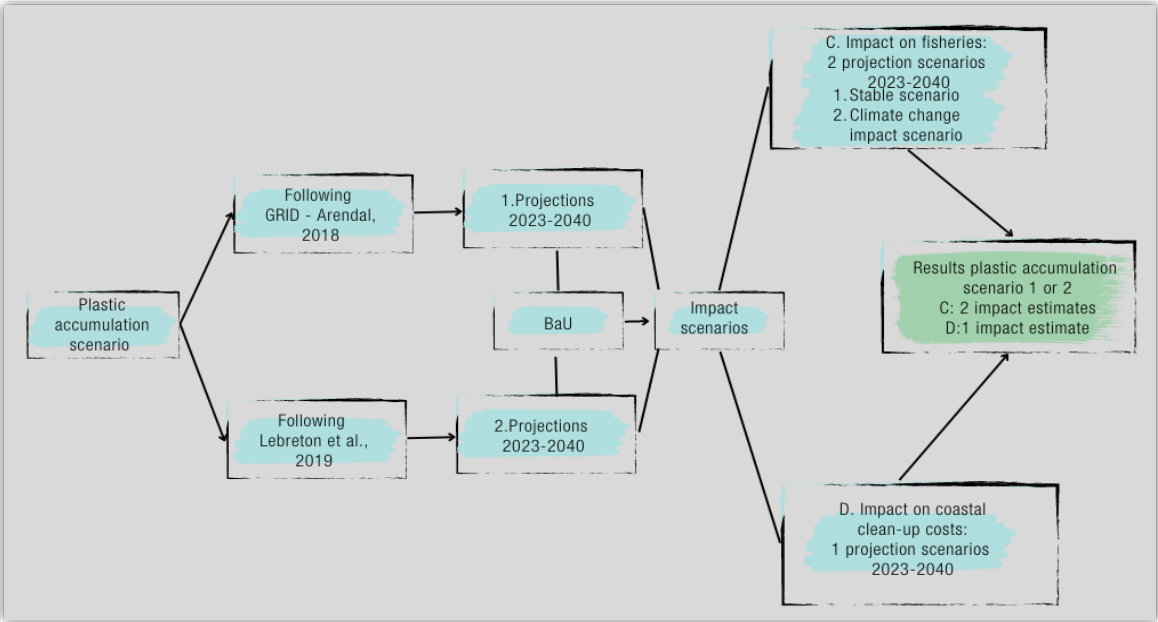


Figure 7 – Schematic representation of the impact of marine plastic pollution under BaU

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

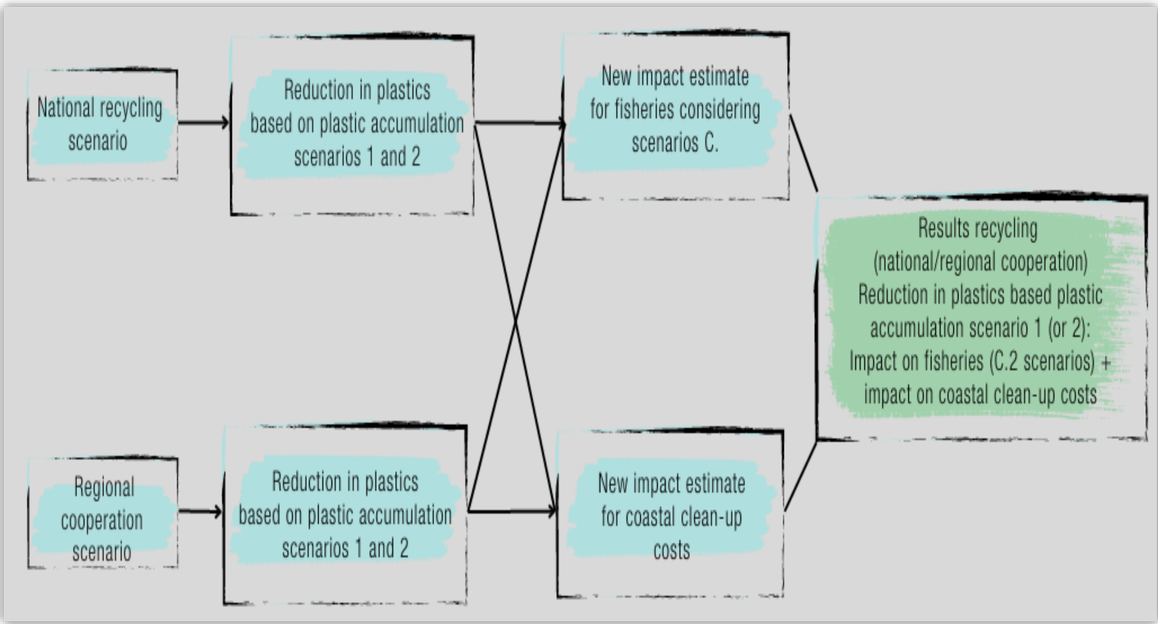


Figure 8 – Schematic representation of the impact of both recycling scenarios (National recycling and regional cooperation scenario)

[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):

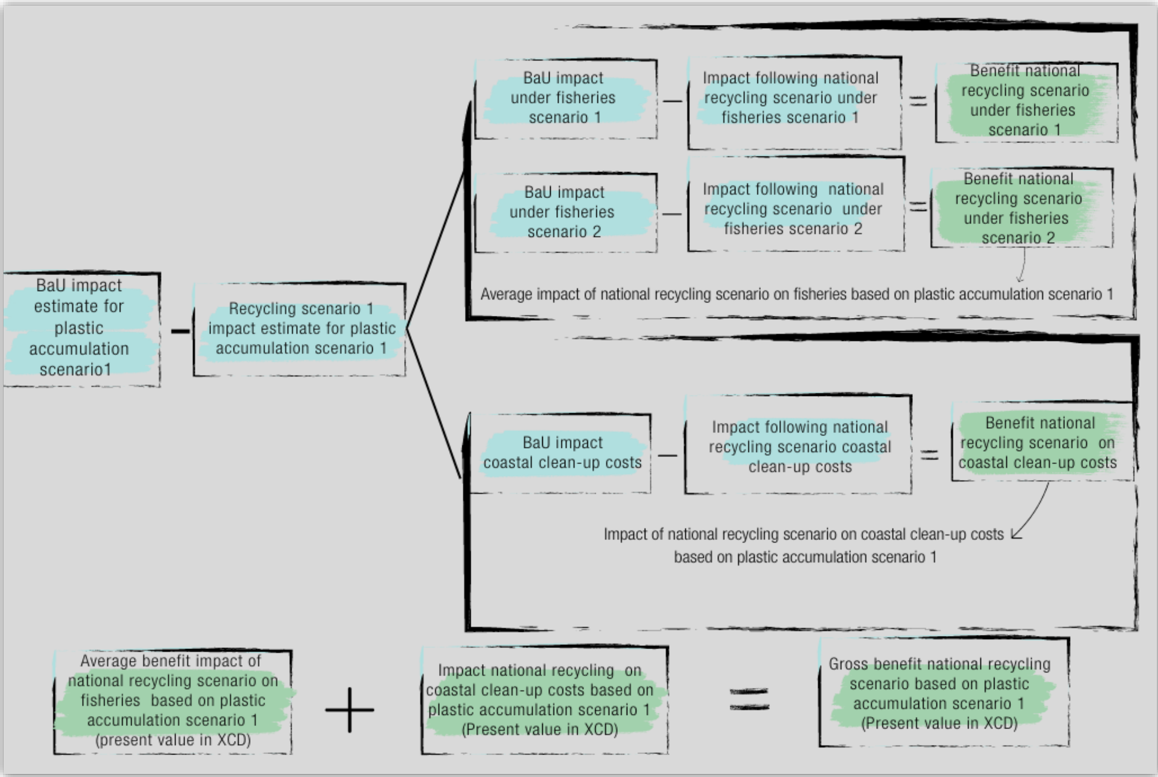


Figure 9 – Schematic representation of the estimation of the gross benefit for a given recycling and plastic accumulation scenario

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.

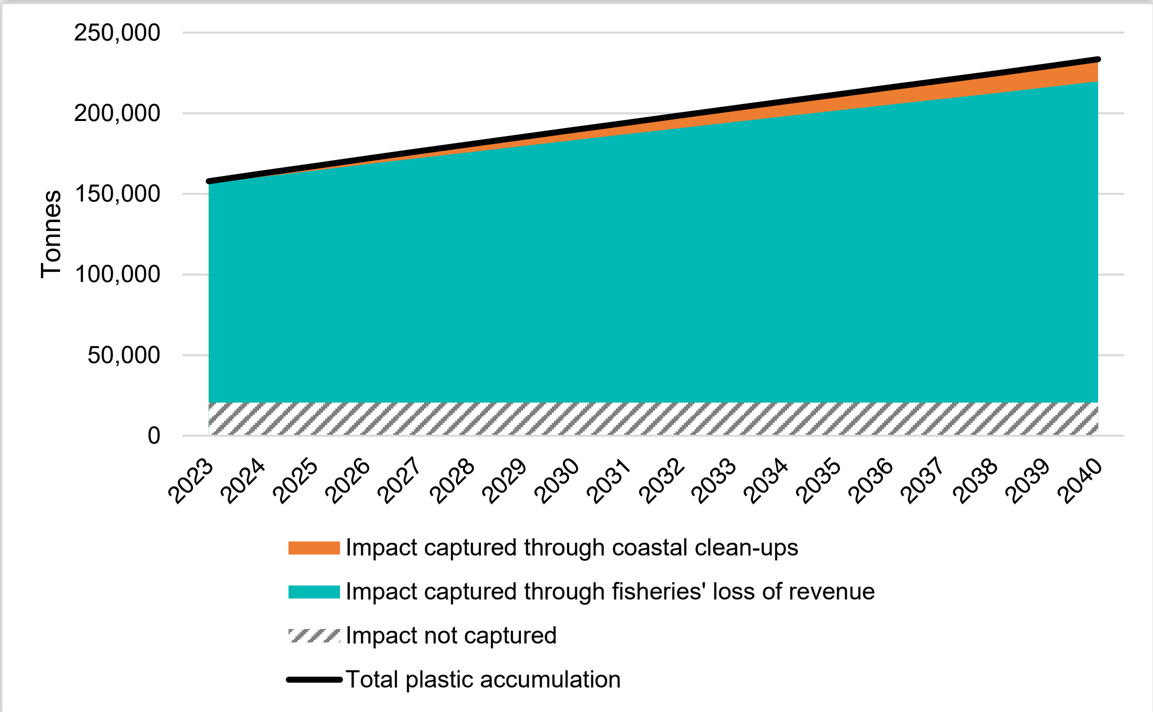


Figure 10 – Future plastic accumulation under plastic accumulation scenario 1, BaU

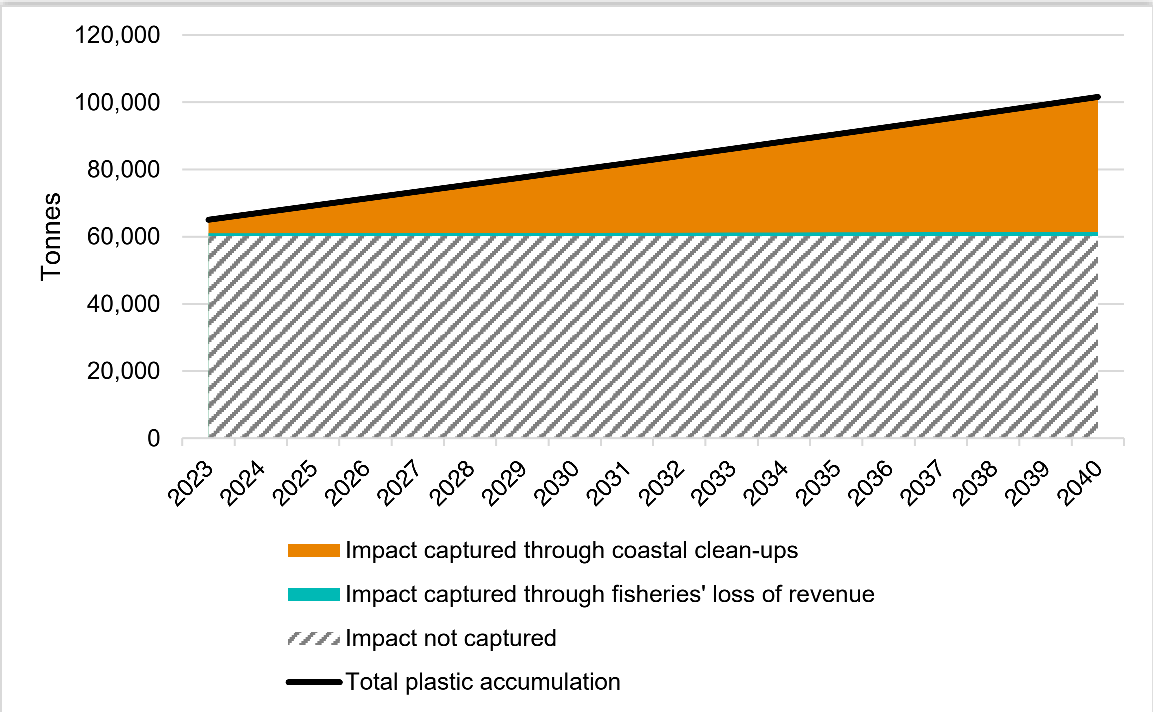


Figure 11 – Plastic accumulation under plastic accumulation scenario 2

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

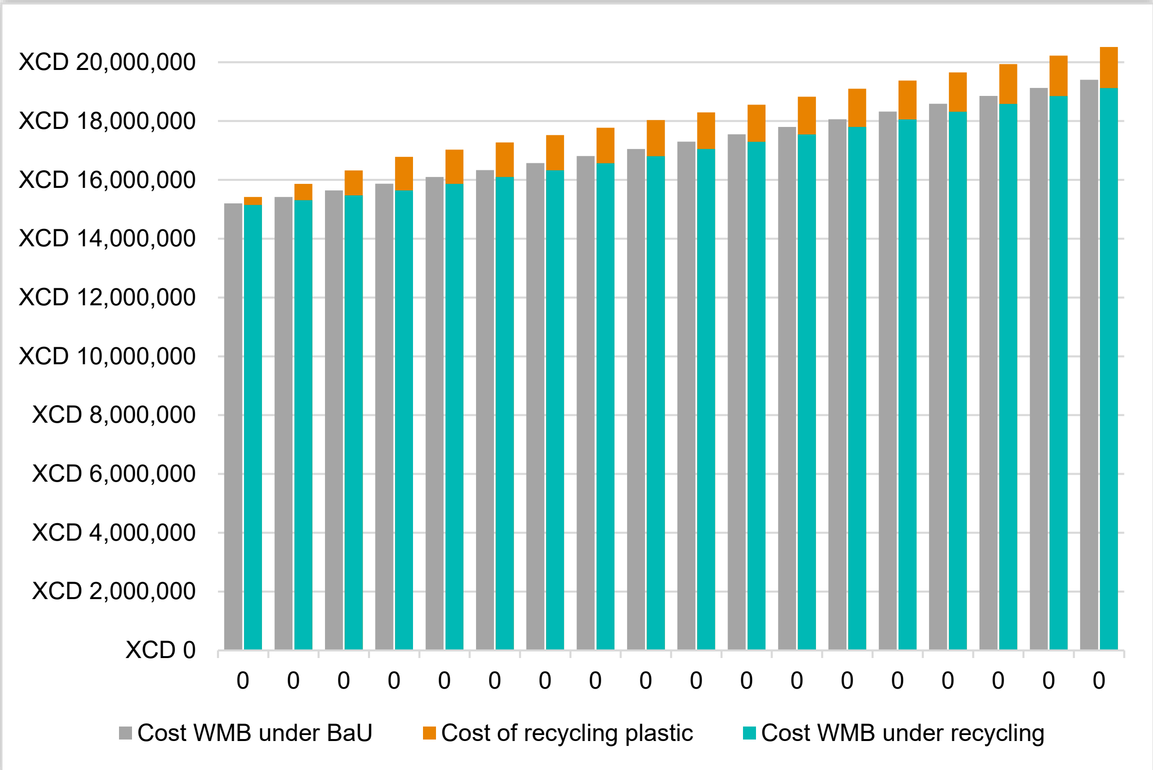


Figure 12 – Estimated cost of recycling, and the waste management budget under BaU scenario and the national recycling scenario (XCD/year)

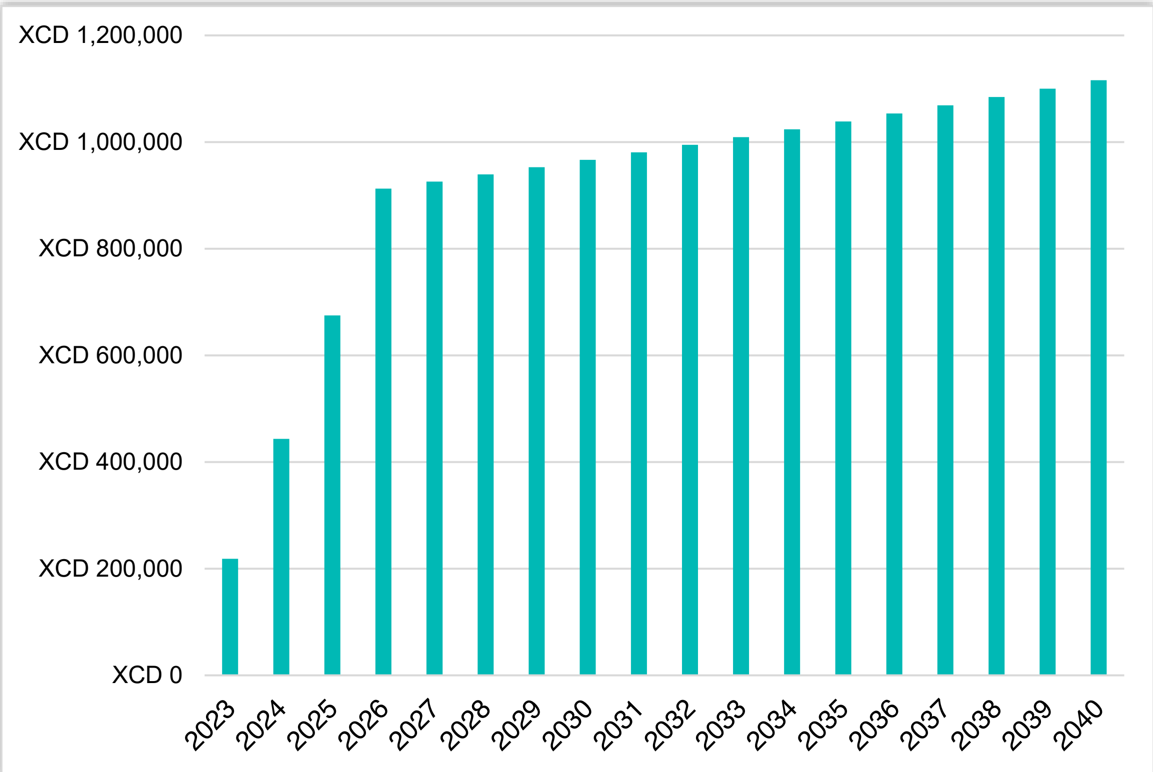


Figure 13 – Actual cost of recycling (XCD/year)

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).

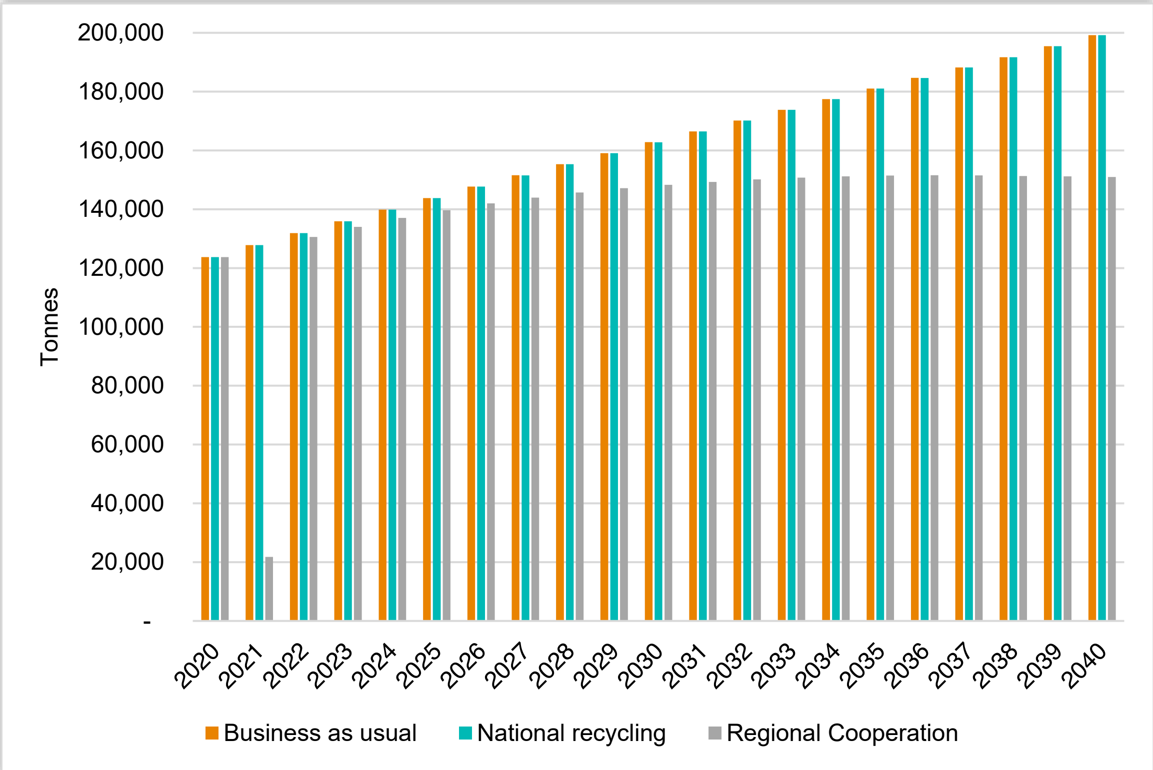


Figure 14 – Estimated tonnes of plastics in Antigua and Barbuda's waters under the three future plastic management scenarios

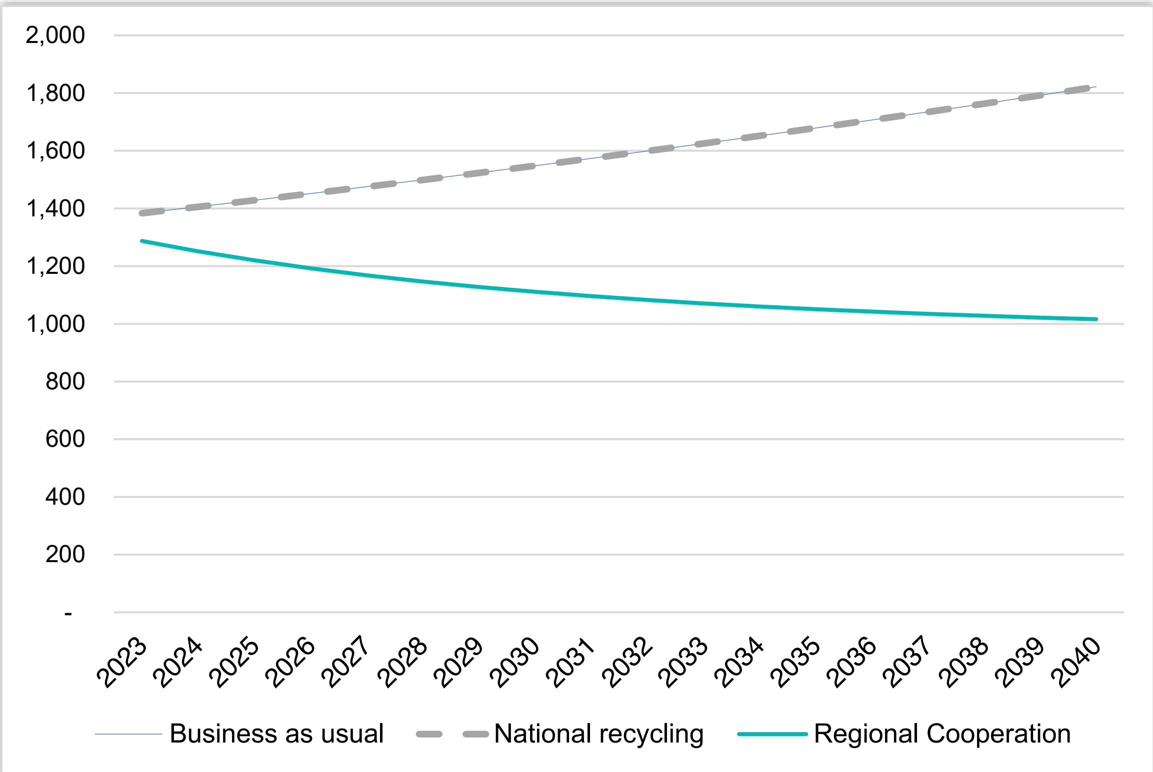


Figure 15 – Estimated tonnes of plastics ending up on Antigua and Barbuda's shoreline each year under the three future plastic management scenarios

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.

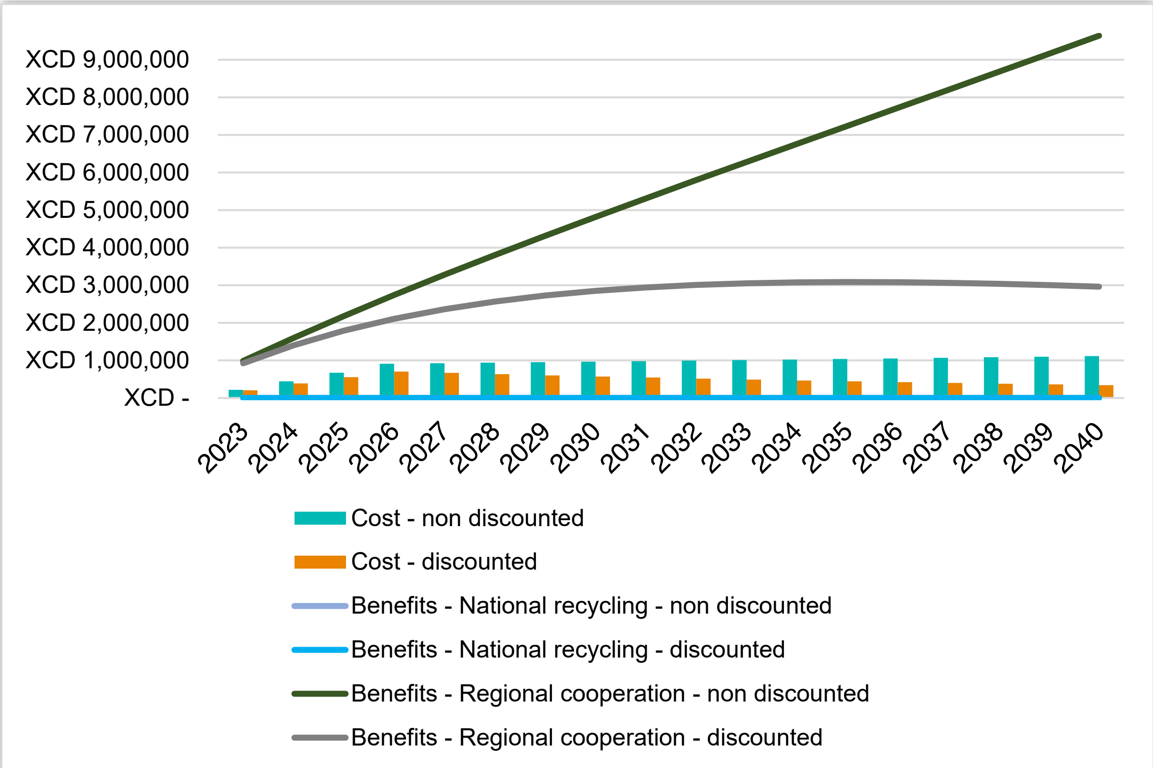


Figure 16 – Cost of recycling plastics for Antigua and Barbuda (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 1 (future and present values) (discount rate: 6.35%)

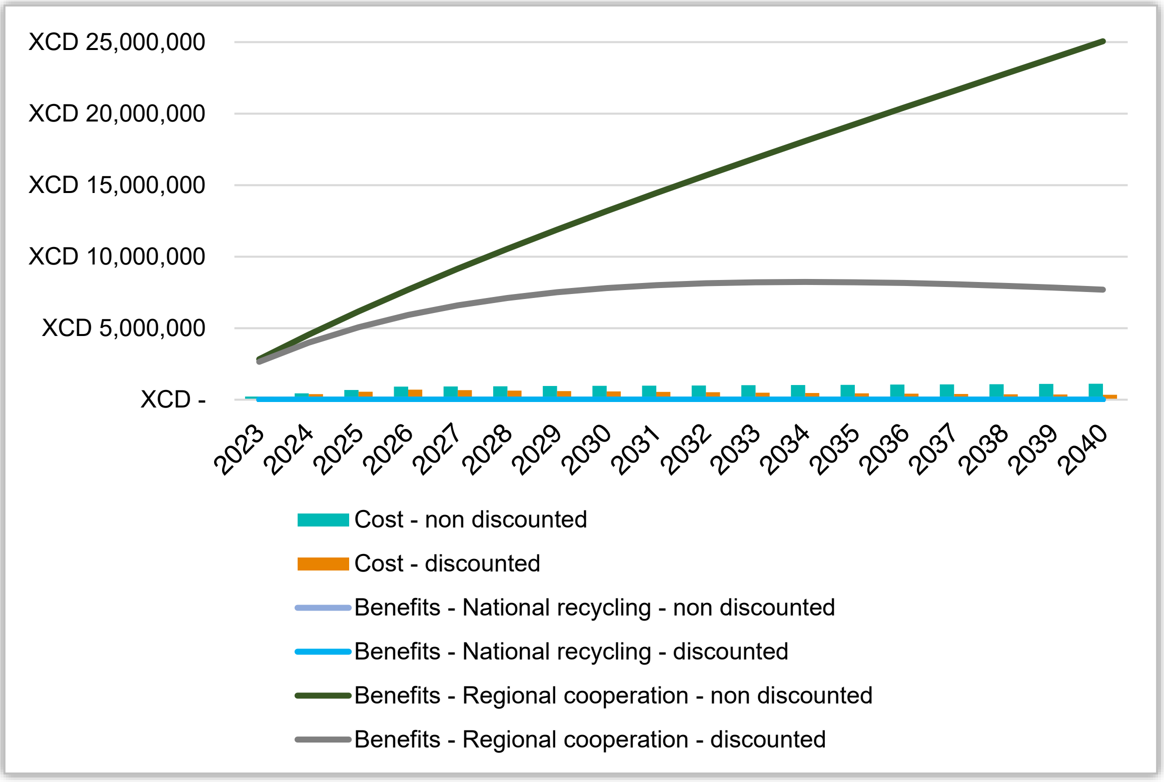


Figure 17 – Cost of recycling plastics for Antigua and Barbuda (future and present values); benefits of the national recycling and regional cooperation scenario under plastic accumulation scenario 2 (future and present values) (discount rate: 6.35%)

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

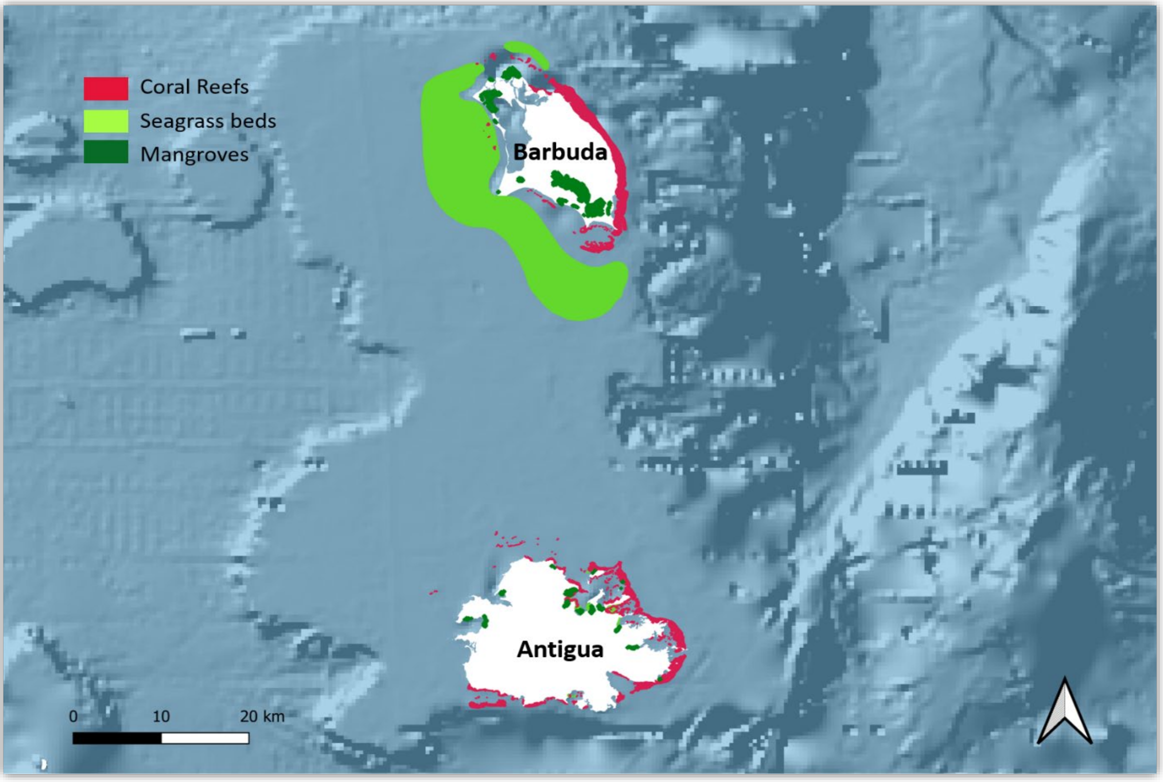
Although the aim of this study was to analyse the direct cost of marine plastics on the fisheries and tourism sectors, and the potential effects from activities to reduce this, marine plastics is not the only problem affecting these sectors and the economy of Antigua and Barbuda in general. the biggest 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

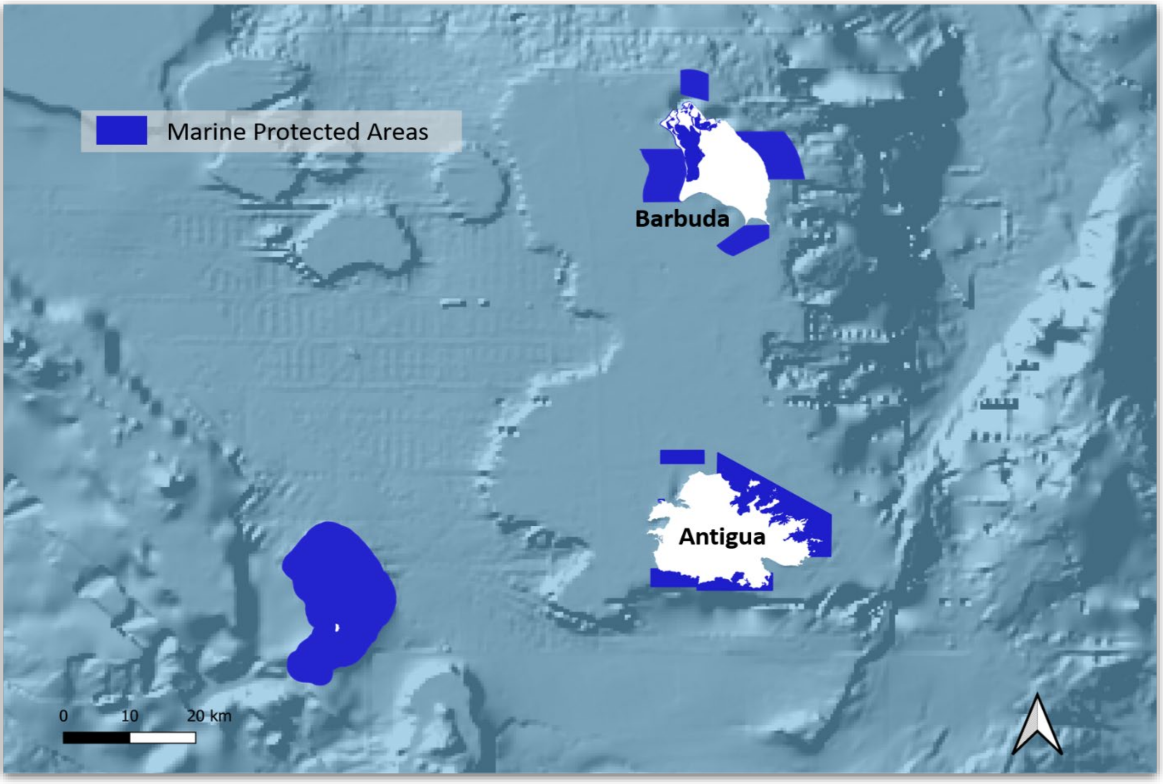
[19] https://litterbase.awi.de/.

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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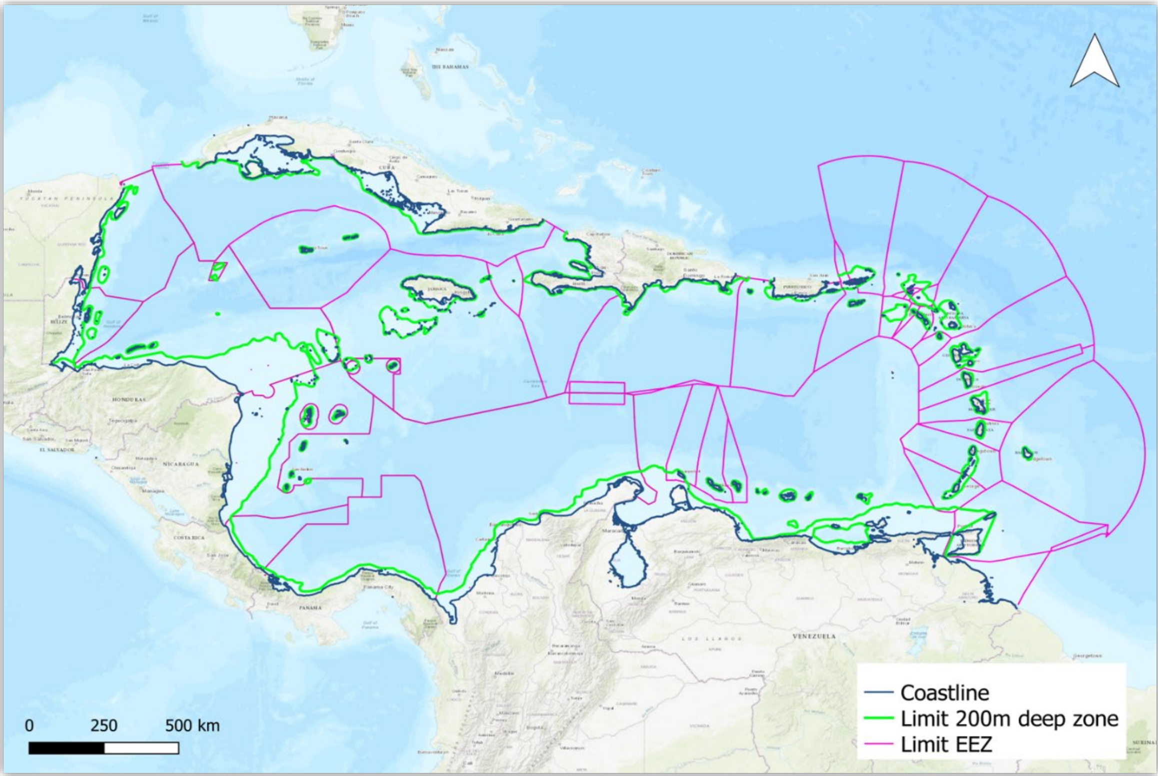
Annexes

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]

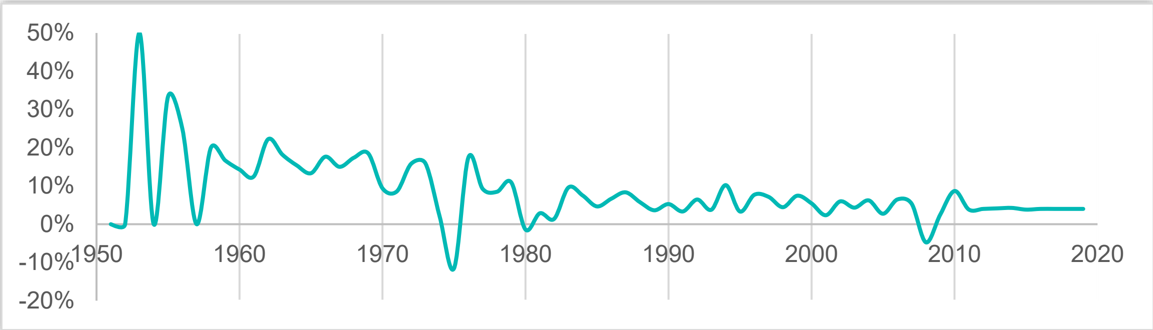

Figure A1 – Plastic growth used for each year (1950-2019)

- 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.

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[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

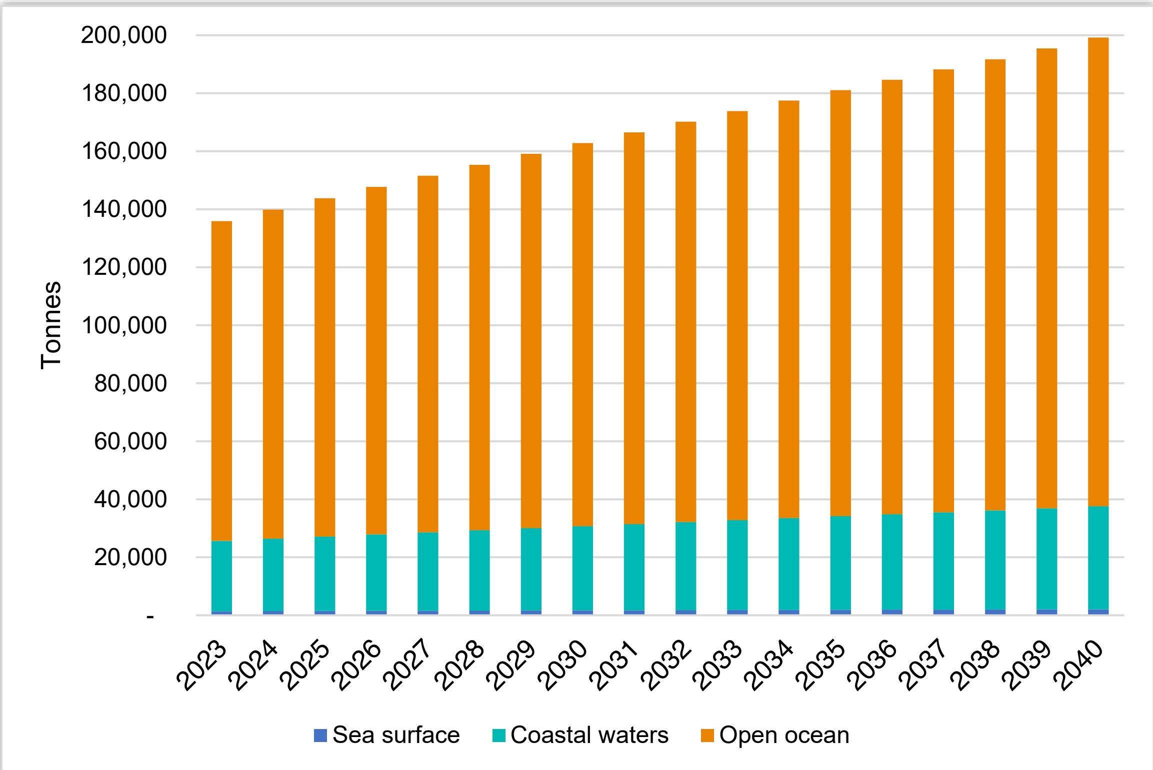
Country	Discount Rate
European Union	4
Norway	4
UK	3.5
France	4.5
USA (CBO)	2
USA (OMB)	5
USA (EPA)	5
USA (GAO)	0.1
IDB	12
World Bank	11
Colombia	12
Costa Rica	12
Mexico	10
Calculated LA	3.77

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".

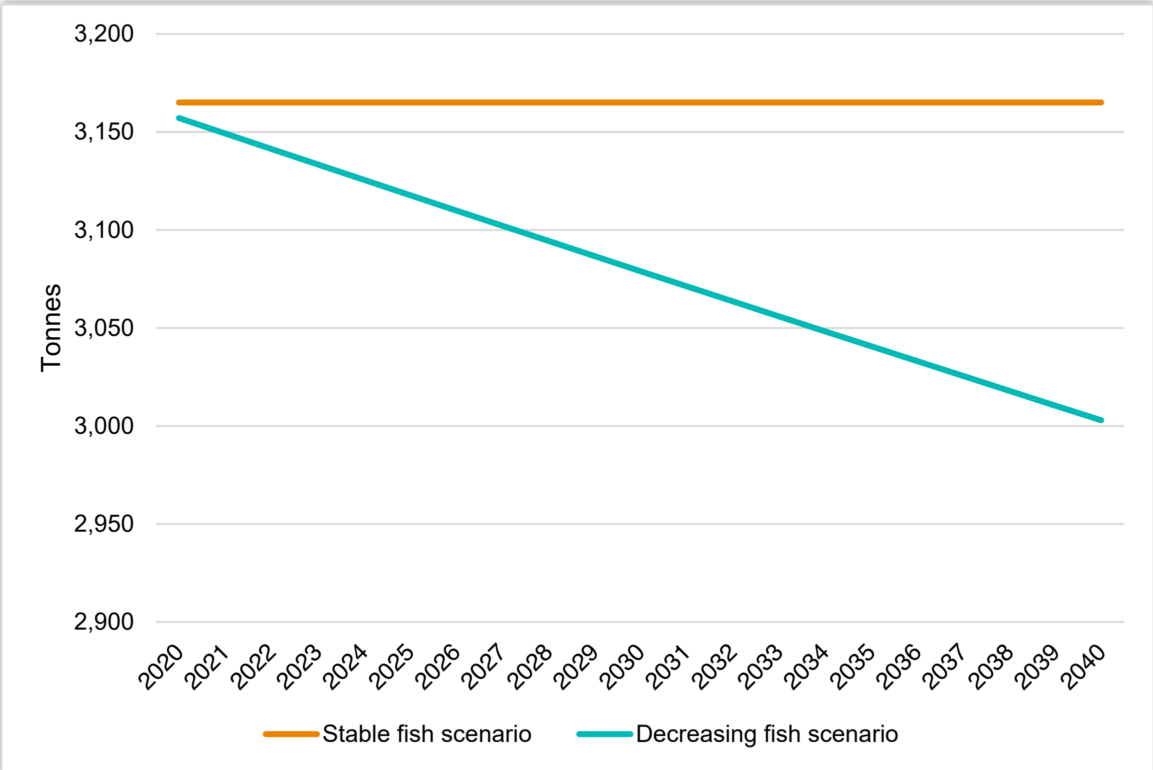


Figure A3 – Evolution of fish catch for different fish scenarios (tonnes/year)

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.

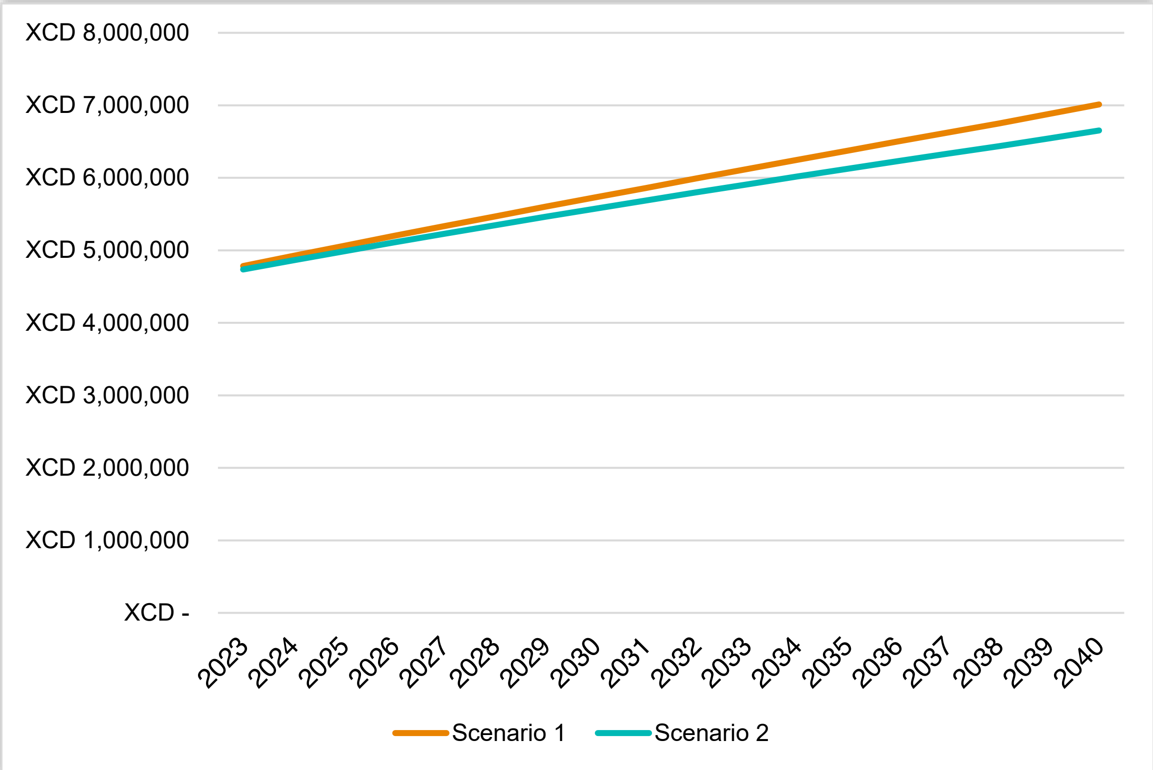


Figure A4 – The estimated losses to the fisheries sector according to both fish scenarios (non-discounted values)

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%

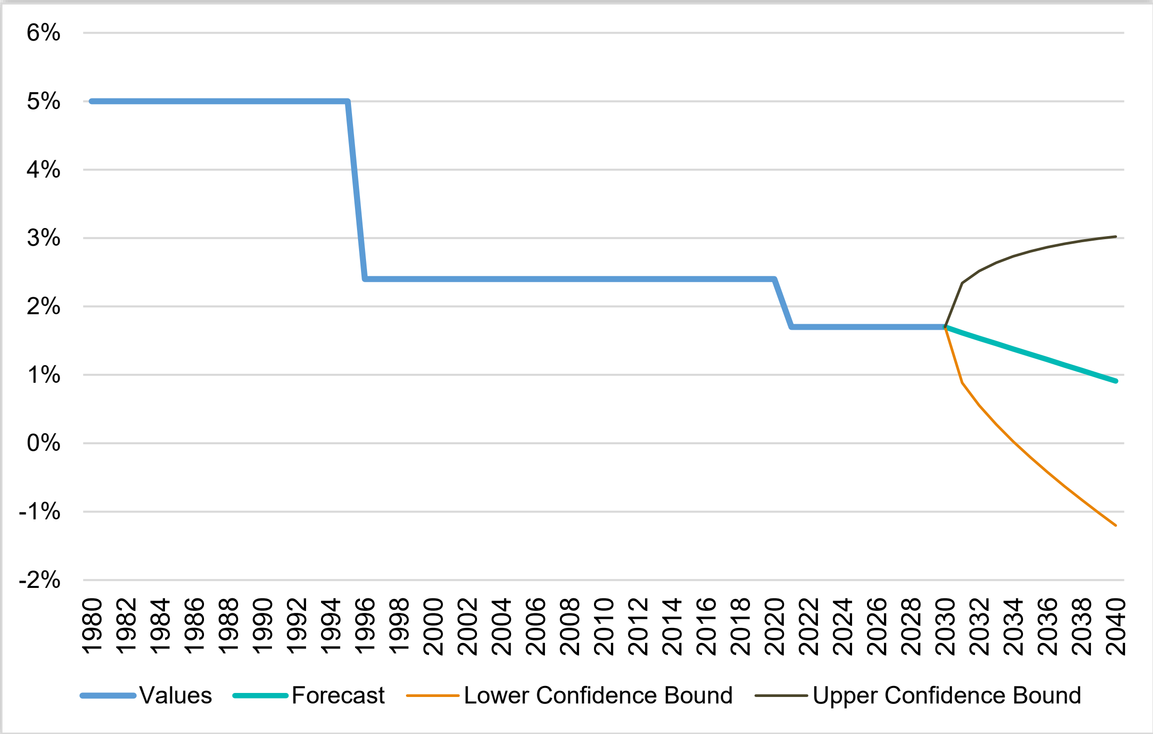


Figure A5 – Estimated annual growth rate of the tourism sector and forecast for the years 2031 to 2040, 95% CI

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**.

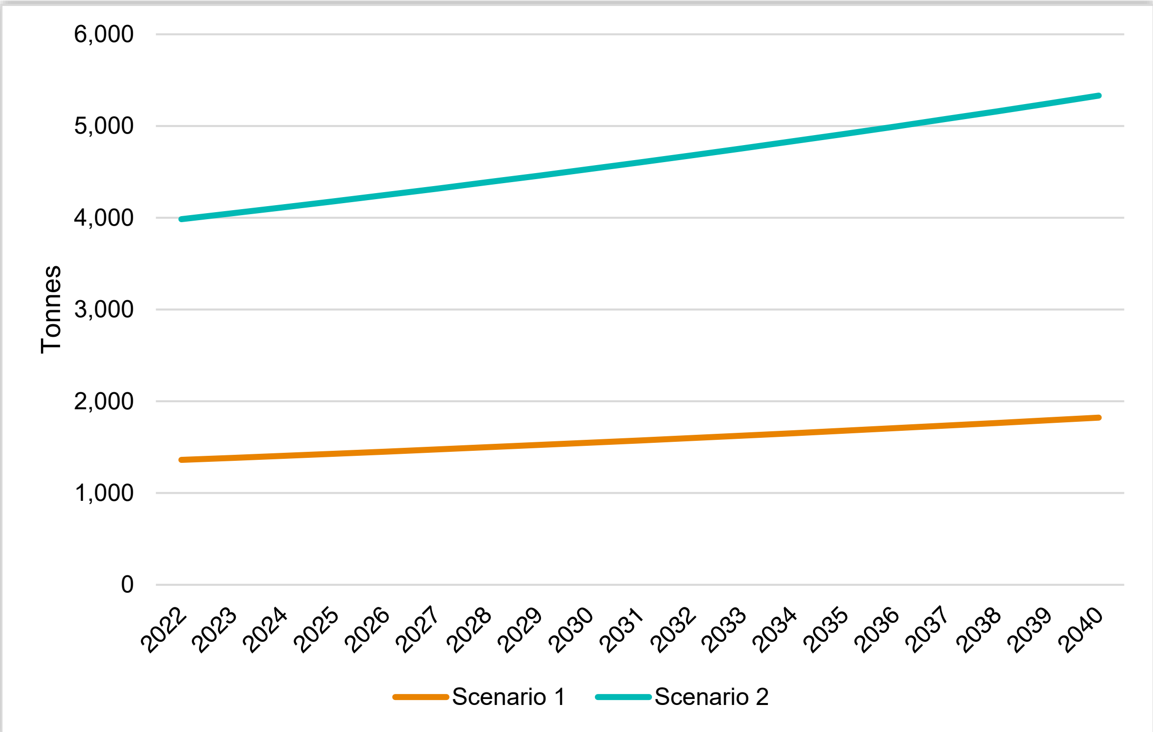


Figure A6 – Estimated amount of plastics ending up on Antigua and Barbuda's coastline under BaU scenario (tonnes/year)

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.

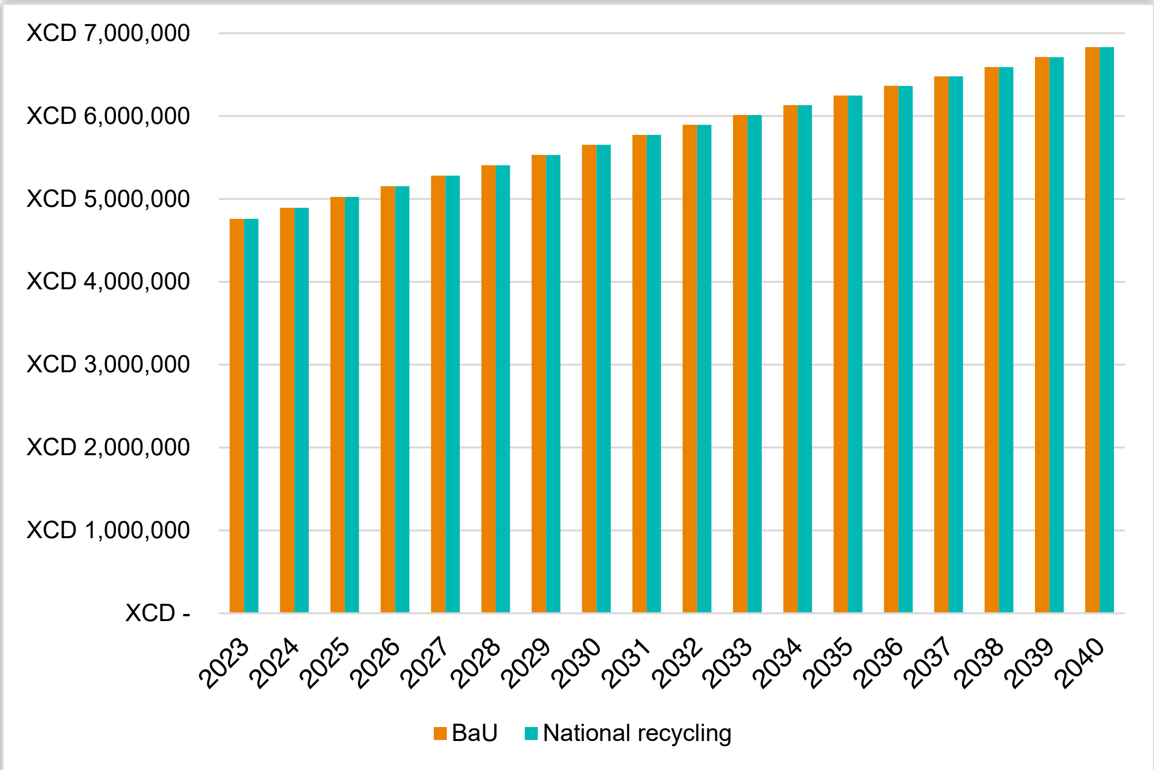


Figure A7 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and national recycling scenarios

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.

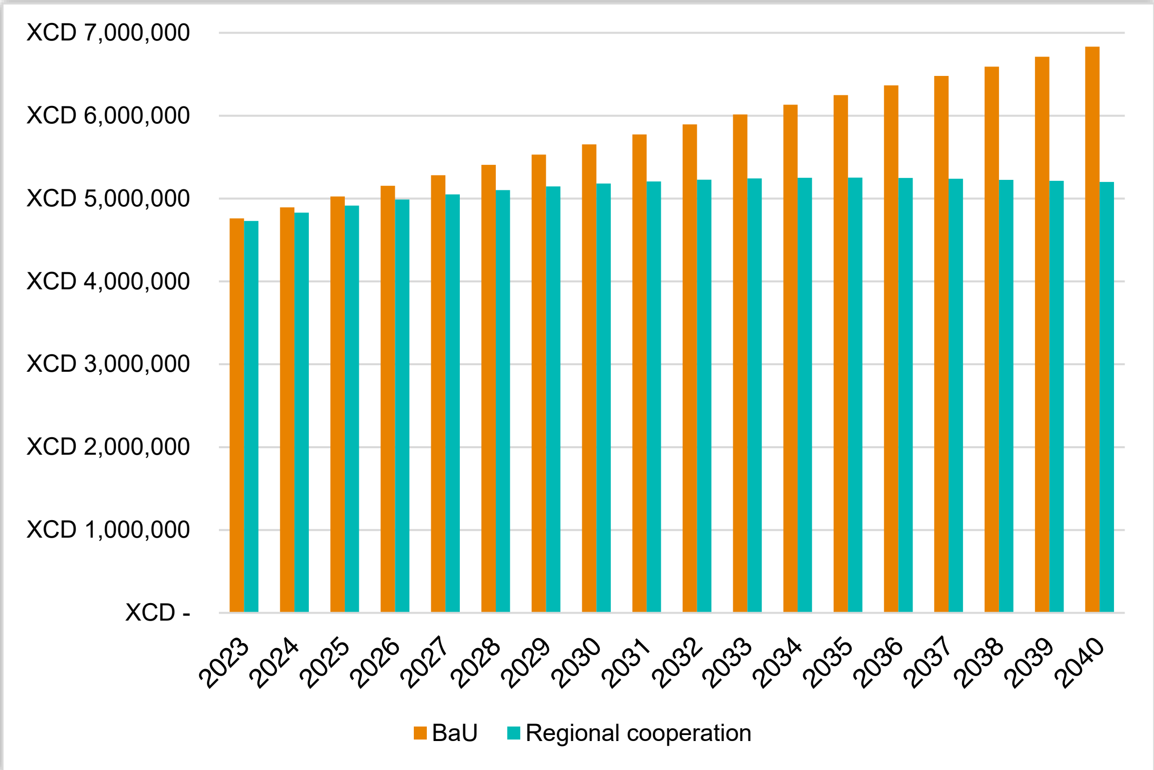


Figure A8 – Impact of marine plastics on fisheries according to the average results of fisheries' scenarios 1 and 2 (XCD/year, non-discounted) for BaU and regional cooperation scenarios

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.

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[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).

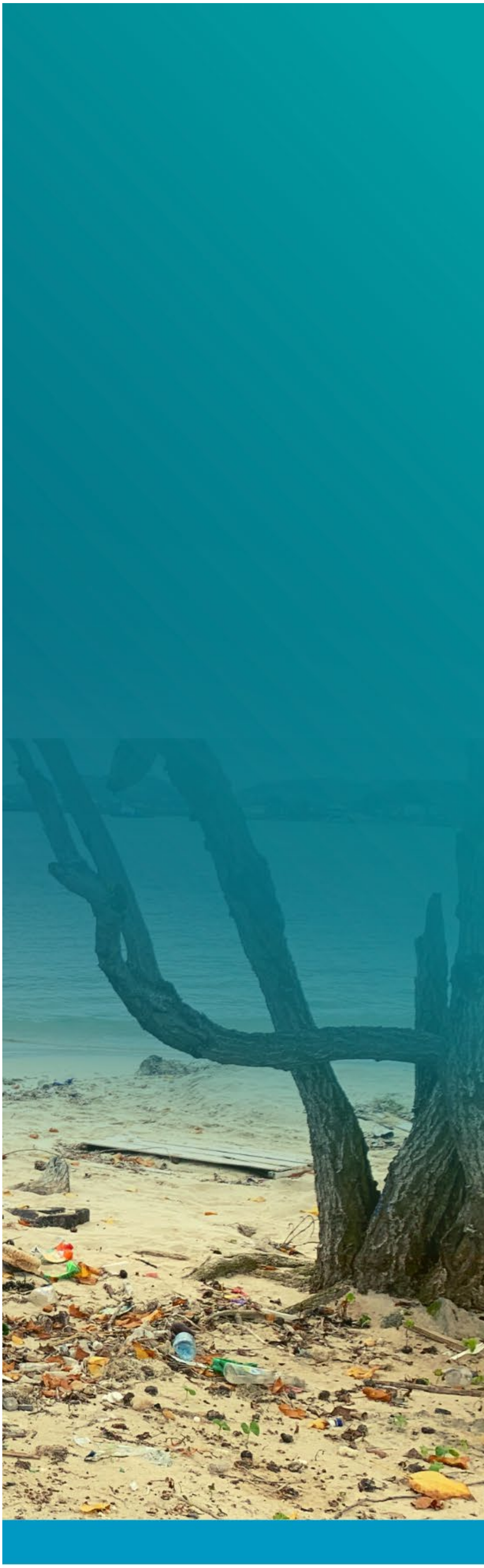
Table A23 – Data to estimate average density of one tonne of plastics in Antigua and Barbuda (2019)

	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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