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The marine litter issue in the Windward Islands- a pathway to responses using the DPSIR framework

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Marine litter is an important and worldwide concern that should be deeper analysed. It also requires information from all over the world and especially in less studied areas like small islands developing states, e.g., the Windward Islands of the Eastern Caribbean. This study analyses the issue of marine litter in the English-speaking Windward Islands using the Driver-Pressure-State-Impact-Response (DPSIR) framework. The research is based on a bibliographical review and analysis of scientific and grey literature regarding these islands and the Wider Caribbean Region at large. The Windward Islands present a unique situation because of their geographic location in the south-eastern Caribbean, socio-economic status, and strong external influences. The DPSIR Framework was used to frame and assess the major types, causes and effects of marine litter for the Windward Islands by reviewing current scientific and grey literature. The major solid waste item retrieved from the coastal and marine environment is fishing gear in the case of Dominica and plastic waste for the other islands. The challenges in current and proposed management measures were identified. Proposed solutions in the form of responses were tailored to meet each casual and effect component of the DPSIR framework. The study strongly recommends that the islands make use of their existing participation in global agreements and initiatives, participate more actively in the negotiations for the upcoming Global Plastics Treaty set to launch in 2024, and tackle their mutual need for effective solid waste management systems and infrastructure and increased recycling efforts or opportunities. These measures could undoubtedly pave a way to the achieving a cleaner and healthier ocean.

KEYWORDS

Windward Islands, marine litter, DPSIR, solid waste management, tourism, global plastics treaty

1 Introduction

Marine litter, also referred to as marine debris, has been a major threat to coastal and marine ecosystems worldwide. Marine litter has been generally defined as any persistent manufactured or processed solid material that is discarded or lost into the marine environment, thus being anthropogenic in nature ([United Nations Environment Programme \[UNEP\], 2012](https://www.unep.org/press-releases/unep-2012-03-29)). It is generally known that marine litter comes from both land (e.g., rivers, stormwater, tourism) and at sea-based sources (e.g., commercial shipping, fishing) ([Ryan et al., 2009](#); [Browne et al., 2011](#); [Hardesty et al., 2014](#)) and can travel long distances across the world ([Hardesty et al., 2014](#)).

Marine litter threatens marine species and ecosystems as well as poses various risks to human health and has had significant implications to human welfare. The impacts of marine litter on the marine environment can be summarised to include endangerment and death of marine animals which eat marine litter or are smothered or entangled by it (Gregory, 2009; Sheavly, 2010; Trouwborst, 2011; Alimba and Faggio, 2019; Galgani et al., 2019; Zhongmin et al., 2020; Woods et al., 2021); endangerment to human health through the occurrence of microplastics and nanoplastics in biological chains (Galloway, 2015; Galgani et al., 2019; Hahladakis, 2020); transportation and introduction of invasive alien species (i.e., bio-invasions) which can have a host of separate consequences on an ecosystem (Gregory, 2009; Trouwborst, 2011; Woods et al., 2021); damage to habitats often *via* heavy duty beach clean-ups (Trouwborst, 2011), navigational interferences and increased safety risks (Sheavly, 2010; Galgani et al., 2019; Luo and Deng, 2021).

These host of impacts consequently have chain reactions affecting the socio-economic fabric of a country (Galgani et al., 2019), especially small island developing states (SIDS) like those of the Wider Caribbean Region (WCR), which have several geographical vulnerabilities and unique circumstances that challenges their ability to prevent and reduce marine litter.

1.1 Overview of geographical vulnerabilities

Understanding the geographical significance and vulnerabilities of SIDS of the WCR provides some important context to the circumstances of the region that warrants immediate action to deal with marine litter. The research focuses on the English-speaking Windward Islands located south of the Eastern Caribbean and includes Barbados, Dominica, Grenada, St. Lucia and St. Vincent and the Grenadines (SVG). (Matthews, 2018; National Trust for Historic Preservation, 2021). The Windwards Islands are challenged with issues associated with domestic sources of marine litter (de Scisciolo et al., 2016) as well as transboundary debris that washes ashore originating from multiple regions. They are affected by debris that comes from the North Atlantic Gyre and its prevailing currents (World Bank, 2019), as well as immediately affected by debris that comes with the south equatorial currents above Venezuela, extending into the North Atlantic gyre (Hurley et al., 2019). Most freshwater inflow from the Orinoco, Venezuela occurs through the Windward Islands passages, mainly through the Grenada Passage located south of the island Grenada (i.e., near 11.5°N) (Johns et al., 2002; Chérubin and Richardson, 2007), forming one of the main Caribbean Currents (Diez et al., 2019). Everything that reaches the Orinoco River affects the water quality and species of the Caribbean Sea and the Atlantic Ocean (Rivero and Liu, 2020) including marine litter. According to Hardesty et al. (2021), Venezuela (Orinoco), is ranked eighth in the list of topmost polluted countries globally.

Further, the islands' coastlines and associated activities are exposed to hurricanes and storm surges (Ferdinand, 2013) among other climatic hazards. The Windward Islands are historically among the first to receive storms, hurricanes (Blanc and Carson, 1948; Walker et al., 1991) and sargassum influxes (Webster and Linton, 2013; Putman et al., 2018) in the region,

often originating from Western Africa. These natural events also contribute to marine litter. Marine litter is known to be exacerbated by hurricane-driven input (Pelamatti et al., 2019; Alvarez-Zeferino et al., 2020). This is a cause for concern as the occurrence and intensity of hurricanes are expected to increase (Cambers, 1997; Knutson et al., 2015; Reyer et al., 2017; Zhongming et al., 2020; Knutson, 2022).

Marine litter in turn also compromises climate resilience of marine ecosystems. Although it is generally recognised that the projected changes in the global climate will have serious negative consequences for the Caribbean as a whole, it is important to note that it is becoming more and more evident that the impacts of climate change will not be uniformly felt across the region (Nurse et al., 2014). This is partly due to the diverse geophysical composition and topography of the islands as well as the dissimilarities in the degree of vulnerability and adaptive capacities that exist among socio-economic groups within the region itself. These are crucial factors for consideration when designing regional level strategies.

In addition to the diversity in geophysical composition, WCR also consists of culturally distinct states whereby the activities and actions that exist in one or few states may not be representative of the entire Caribbean. Hence integration and collaboration as a region can be quite challenging.

It is also well known that geography and colonialism has somehow greatly influenced the socio-historic developments of the region in which separatism is embedded. There is strong evidence of intra-regional comparison and competition within WCR, which also plays crucial roles in hindering regional integration (Bishop, 2014; Bishop et al., 2021).

Competing priorities in combination with the lack of political support (on all levels) are among the challenges countries in WCR face when it comes to dealing with the specific issue of marine litter (Graham, 2022). According to Corbin (2020), the absence of political motivation and support serves as an obstacle to achieving an integrated, long-term plan for managing and safeguarding the Caribbean Sea as a whole.

1.2 Coastal and marine socio-economic considerations

For WCR, approximately 70% of the Caribbean population lives in coastal areas (United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, 2015). Basically, this percentage provides an idea of how much in demand coastal and marine resources have been and continue to be. Research would show that the rate of the Wider Caribbean economies' dependence on coastal and marine resources is among the highest in the world (see Corbin, 2013; Cannonier and Burk, 2019; Leotaud et al., 2020). The region relies on their coastal and marine resources mainly for tourism, fishing (Clegg et al., 2020; Courtene-Jones et al., 2021) and shipping and transport (Clegg et al., 2020).

The Caribbean Sea is estimated to account for 14%–27% of the Global Ocean Economy with a value of US\$ 407 billion (Patil et al., 2018). However, this is being compromised by the chronic impacts of marine litter (Linton and Warner, 2003; Suchley and Alvarez-Filip, 2018; Cabral et al., 2019; Clayton et al., 2021). Further, this percentage

could be even higher should there be fewer impacts of marine litter in the region. The extent in which the economic impacts marine litter have on WCR is generally unknown (Lachmann et al., 2017), however it is certain that their dependence on natural resources through maritime industries especially ocean-based tourism, make them economically vulnerable to marine litter (Lachmann et al., 2017; Ambrose et al., 2019; Diez et al., 2019).

For these WCR SIDS, their high dependency on the coast and oceans only means that they are at equally high risks to the threats of marine litter. Unfortunately, their development challenges possibly turn a *blind eye* to the situation. Major development challenges include limited capital, economies which are highly exposed to global markets, being largely import dependent, extremely high levels of national debt, poverty, healthcare issues, and inequalities (Caribbean Community [CARICOM], 2013; Scobie, 2019). With limited human resources, financial, and technical resources (Mycoo, 2018; Scobie, 2019), these islands are expected to tackle all these issues including marine litter.

Marine litter is an important and worldwide concern that should be analysed more thoroughly. Unfortunately, there is a relatively low number of published empirical research on marine litter issues specific to WCR including the Windward Islands (Schmuck et al., 2017). Given the magnitude of the marine litter crisis, it also requires information from all over the world and especially in less studied areas like the Windward Islands. Given the unique situation of the Windward Islands, this paper uses a DPSIR analysis to organise key information on marine litter, reviewing literature on the current knowledge on the driving forces, pressures, states, and impacts specific to the islands. It also provides a review of current and potential responses to the problem of marine debris in the Windward Islands. Furthermore, as noted by Graham (2022), the majority of WCR SIDS have not officially published national policies on marine litter. Although there exists a Regional Action Plan for Marine Litter (RAPMaLi) developed in 2014 for the WCR, and an updated version, the Regional Marine Litter Management Strategy for the Wider Caribbean Region was published in 2020 (UNEP, 2019a), neither plan has a set implementation timeline. Consequently, this research may provide more targeted suggestions and feasible action items that account for the islands' unique circumstances and can be accomplished within a reasonable timeframe.

2 Methodology

A bibliographical review of documents, including scientific papers and grey literature (i.e., national documents, documents related to projects and programs, other relevant files) with relevance to the Windward Islands was conducted to obtain a representative number of documents on marine litter, issues and management approaches for the region. The DPSIR Framework was used as an analysis tool to understand the casual factors and issues that surrounds marine litter and current response mechanisms. According to Mateus and Campuzano (2008), the DPSIR framework states that factors that motivate human activities for economic and social development are often driving forces (D) which exert pressure (P) on the environment affecting its state (S). These changes in the environmental state tend to have impacts (I) on the

ecosystems or human health and wellbeing and due to these impacts, society can respond to the driving forces, the pressure, state or impacts through preventive, adaptive or curative measures.

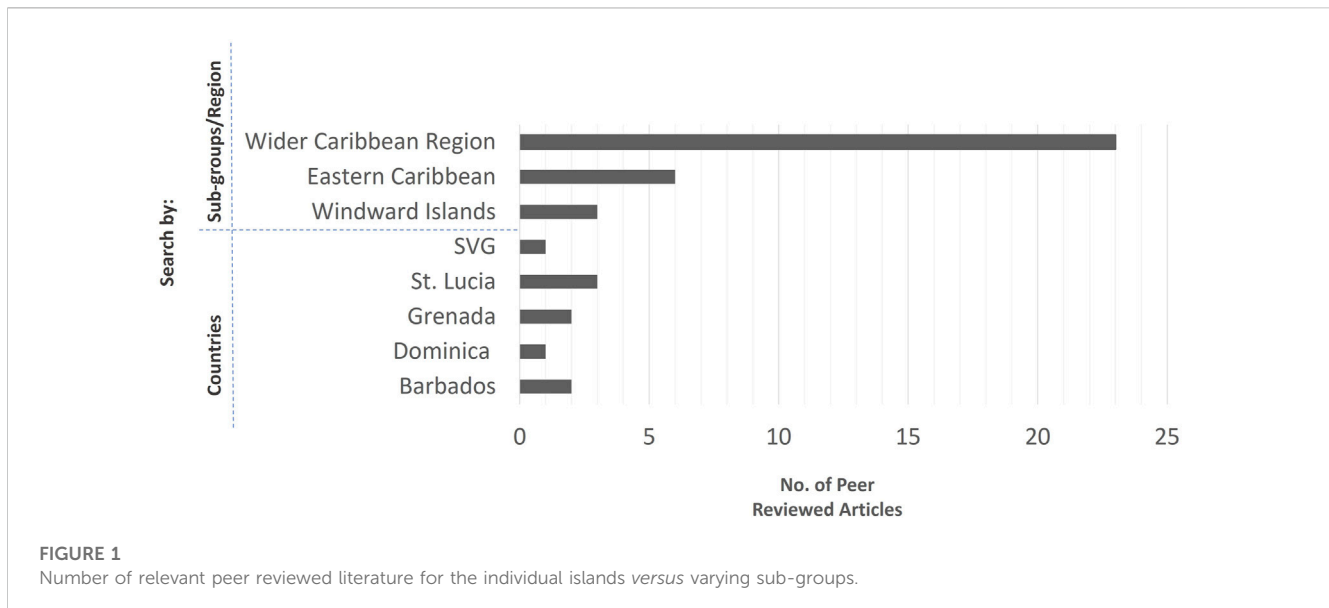
Peer-reviewed scientific papers (in English) were retrieved through OneSearch platform and Google Scholar using different combinations of key terms and phrases including “marine debris,” “marine litter,” “plastics,” “marine pollution,” “sources,” “management,” “approaches,” “regional plans,” “global initiatives,” “international agreements,” “impacts,” “ocean governance,” “policy effectiveness” and “DPSIR.” These keywords were entered with relevance to the individual English-speaking Windward Islands, and where information was limited, extended toward the general Windward Islands, Eastern Caribbean and WCR. The same was applied to retrieve grey literature from Google. Further, grey literature was also selected on the basis of the accessibility and availability of country documents. Grey literature included documents published online by local governments, NGOs and regional organisations on coastal and marine related issues and management that include action for marine litter or debris and solid waste. Grey literature is also necessary to include in the study due to the lack of country-specific publications and to gain a more comprehensive examination of country specific issues, goals, and current and planned response mechanisms and activities.

The general characteristics of the overall bibliographical review of the literature were tabulated and included in the Supplementary Material.

3 Results and discussion

Data extracted from a literature review yielding 41 peer reviewed articles from 2012 to 2022, specific to marine debris issues and management in the Windward Islands and the larger WCR demonstrated that localised studies are rare (Figure 1), and even less as the geographical scales or reduced to sub-groups of islands and individual islands. Twenty-nine percent (29%) of the articles contained information specific to Windward Islands (i.e., as a sub-group) and even less information available for the individual states (see Supplementary Material S1). Thus, the available grey literature proved more useful in obtaining country-specific details relevant to marine debris causation factors and issues. Table 1 shows the documents which contained information relevant to the Windward Islands including coastal and marine management plans, waste management strategies, marine protected areas or managed areas documents, maritime economy plan, marine economies programmes plan, sustainable development goals (Related to Target 14.1¹) documents, national adaptation plans, and Environmental & Social Management frameworks. It is important to note that the countries do not have published national action plans or policies for marine debris nor drafts that are publicly available to date. All literature (scientific and grey) were included in the DPSIR Analysis.

1 “by 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution” (United Nations, 2015).



3.1 Marine litter in the Windward Islands: A DPSIR analysis

According to Lewison et al. (2016), DPSIR is a theoretical framework used as an ideal management tool as it integrates and provide a comprehensive review from a variety of disciplines and helps provide alternative decisions by considering various perspectives. DPSIR also acts as a bridge between the scientific community and stakeholders involved (Benoît et al., 2012; Lewison et al., 2016). It is important to note that only two peer-reviewed articles (post 2012) that uses DPSIR as an assessment tool for marine litter or marine pollution in the Caribbean, as a region, were identified, (see Supplementary Material). Figure 2 summarises the results of the DPSIR framework analysis for the current situation of marine debris and management for the Windward Islands. This section focuses on the cause-and-effect components of the DPSIR, including drivers to impacts. Since a more extensive literature review was done for the responses to marine debris, this information would be discussed in Section 3.2.

3.1.1 Driving forces

On a global scale, generally economic driven activities (i.e., packaging, shipping, fishing, tourism and aquaculture) are the key drivers responsible for increasing amounts of marine litter (Löhr et al., 2017; Watkins and ten Brink, 2017; Abalansa et al., 2020). The peer-reviewed articles from 2012 to 2022 revealed that in the context of the Windward Islands, marine litter are driven not only by fulfilling fundamental human economic needs but a number of social issues as well.

Over, thirty per cent (30%) of the peer reviewed articles generalised national socio-economic driven activities (namely, fisheries, tourism, recreational, construction, packaging) associated with improper waste disposal as the major source of marine litter in the Windward Islands. More than half of the grey literature reviewed specifically highlighted tourism as a shared and major contributor of marine litter throughout all the islands.

The economic contribution of the tourism industry has been arguably recognised as the most important and valuable industry for WCR over the years (Zappino, 2005; Thomas, 2015; Spencer, 2019). Further, the region is known as the most tourism-dependent region of the world (Phillips, 2014; Peterson, 2020; Mahon et al., 2021; Walker et al., 2021; Spencer and Spencer, 2022). Tourism contributes significantly to employment, foreign exchange, and national income. Although other industries make significant economic contributions, the region is highly identified internationally in terms of its tourist destination image (Thomas, 2015; Liao and Sánchez Aguilera, 2020). Moreover, the tourism economy also has a co-dependent and mutually beneficial relationship with other economic sectors including agriculture, transportation, construction, and Information Technology (Spencer, 2019). These sectors benefit directly from tourism and in turn provide valuable inputs to tourism (Spencer, 2019).

Nautical and coastal tourism play key roles in terms of contribution to general tourism and the overall economy in WCR and even more so, the Windward Islands. WCR is a renowned destination for nautical tourism with more than thirty million (30,000,000) cruise ship visits in 2019 (Caribbean Tourism Organisation, 2020). Cruising is the Caribbean represents 38.9% of total global itineraries (da Silva, 2021). Also, approximately ten million yachting holidays are taken in the Caribbean every year (Ajagunna and Casanova, 2022). Moreover, it is well known that the convenient archipelago passage of the Windward Islands encourages yachting tourism (Bankoff, 2017).

As for coastal tourism, according to Mendoza-Gonzalez et al. (2018), the majority of Caribbean tourism is coastal tourism, which credits the use and availability of beaches and ocean views. Using the data available for St. Lucia, it is important to note that St. Lucia's tourism industry accounted for 51% of total domestic employment in 2017 and is projected to be 62.7% in 2028 (World Travel and Tourism Council [WTTC], 2018; Sutton, 2019). Moreover, their tourism industry significantly contributed to their GDP at 41.8% of total contribution in 2017 and is also projected to increase to 54.9%

TABLE 1 Identification of Grey Literature Information is based on documents available online.

Countries	Coastal and marine management plan	Waste management strategy	Marine protected areas (MPAs)	Maritime economy plan	Commonwealth marine economies programme	Sustainable development related to 14.1	National adaptation plan	National biodiversity strategy and action plan	Environmental & social management framework
Barbados	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
Dominica	Light Blue	Light Blue	Light Blue	Light Blue	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue
Grenada	Light Blue	Light Blue	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
St. Lucia	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
SVG	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
	Dark Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue

Note: Specific document details can be found in the Supplementary Material.

by 2028 (WTTC, 2018; Sutton, 2019). Coastal tourism significantly influences these figures, and the preservation of the associated environments are pertinent to facilitate the projections.

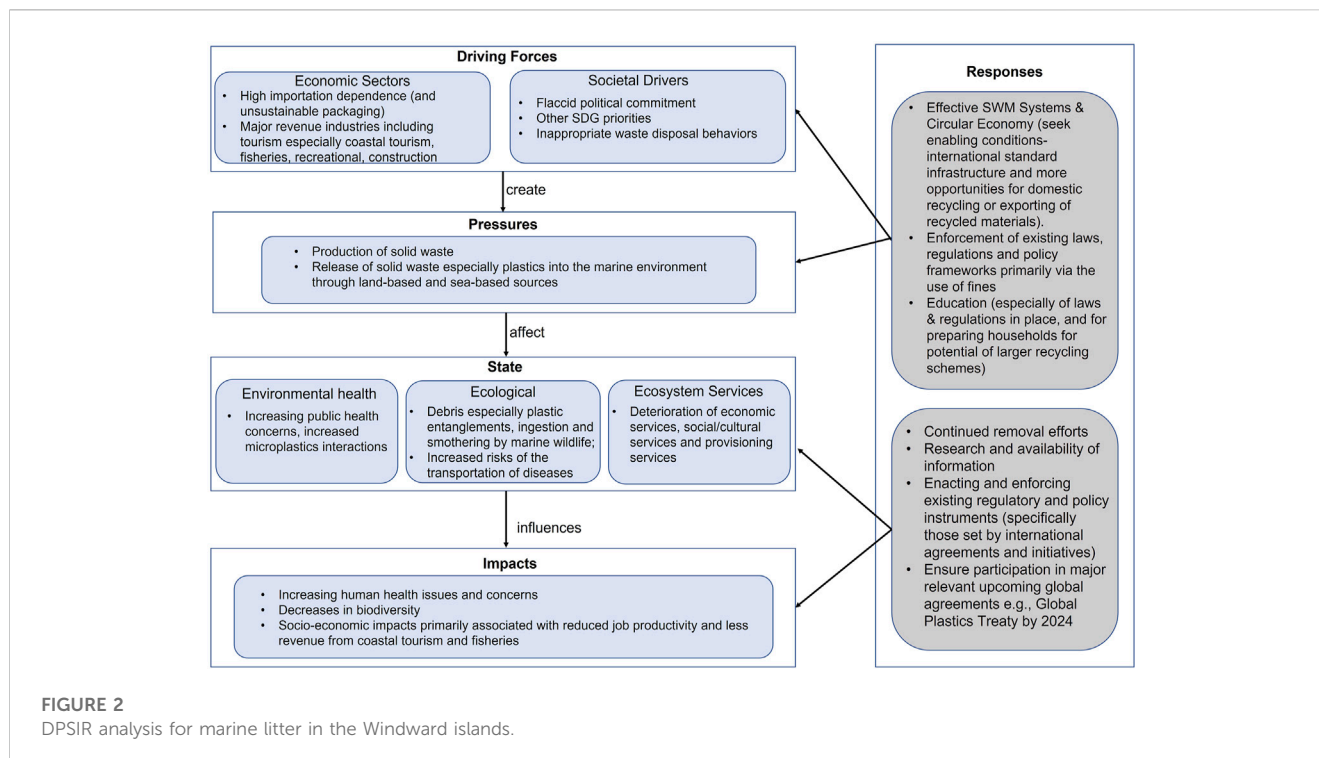
Unfortunately, the same industries that local people depend on for a living, are the same industries that contribute to the marine litter issue in the region. Case in point is the tourism industry in St. Lucia. While the influx of tourists generates income and employment it also threatens St. Lucia’s coastal and marine ecosystems and economy. Harasymiw (2021), describes the litter situation in St Lucia as an “environmental headache” for the country. The author uses cruise lines as an example to portray the connections between tourism and litter in the marine environment. The author stated that even prior to the disembarkment of tourists from their ships, damage is done. Cruise ships not only leak oil residues but various debris into the sea harming ocean ecosystems (Harasymiw, 2021). Additionally, once people get to land more problems arise simply because of the resources “needed-and depleted” in order to host vast amounts of people (Harasymiw, 2021). The generation of excessive waste and increases in marine litter are largely due to overwhelmed local waste management infrastructure. (Gesellschaft für Internationale Zusammenarbeit [GIZ], 2015). Tourists have also known to directly contribute to the problem by littering, as observed in the island of Grenada (GIZ, 2015) and St. Lucia (Harasymiw, 2021). As the Windward Islands’ economies are heavily dependent on beach tourism, this is an impending problem for these nations.

Regarding fisheries as a contributory factor, little information regarding the Windward Islands were available, except for the island of Dominica. The specific mention of abandoned, lost, discarded fishing gear (ALDFG) was absent in 95% of the total literature review. However, Dominica has been faced with the issue of driftwood debris from abandoned boats and traps since 2008 (UNEP, 2008; Lachmann et al., 2017). According to Lachmann et al. (2017), the debris on Dominica was dominated by driftwood, and plastic pollution was the second most common type of debris.

It is important to note the general inappropriate waste disposal behaviours of people within and outside of the major industries of tourism and fisheries. The grey literature also indicated that in the islands (specifically, Grenada, Dominica and St. Lucia, mismanaged household trash, recreational activities and illegal dumping continues to be major contributors to littering and marine litter. Further, the literature disclosed that a popular habit is the disposing of garbage over coastal cliffs edges which is a direct form of marine littering.

As it pertains to societal drivers, first, socio-politically, the region has different priorities such as pressing Sustainable Development Goals (SDGs) priorities including ending extreme poverty, better healthcare, reducing inequality, promoting economic growth, and developing sustainable cities, while considering climate change, governability and population growth pressure (United Nations Economic Commission for Latin America and the Caribbean [UNECLAC], 2018; Salvia et al., 2019; Mahlkecht et al., 2020). Salvia et al. (2019), states that the SDG 14, Life Below Water, received no expression of interest for research from experts in the Latin America and Caribbean (LACA) region. This can highly likely influence the political will to address marine litter as well.

Overall, there is little scientific research that investigates this and other drivers of marine debris in great detail that is specific to Eastern Caribbean much less its individual nations. Additionally, perhaps SIDS can be reluctant to disclose research data on marine pollution



likely because it can compromise their revenue (particularly linked to tourism). In WCR, there is an unwillingness to share data from environmental and disaster risk management related research (Fanning et al., 2021; Omukuti et al., 2021).

The gaps in the scientific knowledge presents a problem for marine litter management (Schmuck et al., 2017). These gaps compromise the ability to prioritise prevention and other management efforts and to assess progress or effectiveness in implementation of measures. Within the last decade, it has been increasingly recognised that top-down approaches (with little to no local contribution) and generalised recommendations are futile, especially for Small Island Developing States (SIDS). An important first step in tackling several marine ubiquitous problems is conducting investigations at the community and local levels and integrating lessons learnt into discussion forums and policy proposals at higher levels (i.e., regional and then international) (Alexander et al., 2019; Sheridan et al., 2020).

3.1.2 Pressures

In essence, the socio-economic demands create pressures. While the drivers offered insight into major socio-economic factors or forces that influence human activities that eventually perpetuates the issue of marine litter, pressures offer details into the stresses (and associated sources) these human activities place on the islands². Globally, consumer packaging (e.g., single-use bags, bottles, food containers, wrappers) make up a major portion of solid waste and plastics are the most dominant of packaging waste and marine litter (UNEP, 2021). Further, it has also been modelled that almost two-

thirds of plastic waste in 2060 will be from short-lived items such as packaging, low-cost products, and textiles (Organisation for Economic Co-operation and Development [OECD], 2022). Unfortunately for SIDS like the Windward Islands and Caribbean at large which are largely import dependent (CARICOM, 2013; Dorodnykh, 2017; Scobie, 2019), this only leads to pressure of a higher input of plastics and other solid waste into the environment and through a variety of sources. These sources are frequently classified as land-based or sea-based.

Most studies indicate that the main pressures identified are associated with land-based related issues including largely solid waste management stresses such as overwhelmed landfills, unnecessary waste materials, inefficient waste disposal, collection, and processing systems. In the SIDS dynamic, improper waste disposal and ineffective waste management likely has a strong correlation with marine litter. At least 50% of all the literature reviewed addressed plastics as a main waste management issue and linked it with the pressures it exerts on freshwater and marine ecosystems.

Wind and rivers represent a major vector for the introduction of litter particularly plastics to the ocean. Rivers transport 80% (Meijer et al., 2019; Ritchie, 2021) to 83% of the annual plastic debris into the marine environment worldwide (Landrigan et al., 2020; World Bank, 2021). In the case of WCR, up to 85% of marine litter in the Caribbean Sea is from land-based sources of solid waste (UNEP, 2019b). Other sources claim that as much as 90% of all the plastic that reaches the world's oceans get flushed through just 10 rivers mostly located in Asia (Franzen, 2017; Lebreton et al., 2017). Once litter enters lotic freshwater systems, it is important to note there is also a separate set of associated pressures on freshwater ecosystems and the adjusted coastal environment, before it inevitably reaches the wider marine environment.

² It does not include the resultant socio-economic or environmental impacts.

Pressures on solid waste management was further investigated using the grey literature and the biggest contributors to solid waste include organics, paper and plastics in the Windward Islands of Barbados, Grenada, St. Lucia and SVG (Figure 3). Once these and other debris make their way to the coastal or marine environments, they can pose a threat to related ecosystems (especially plastics pollution) and are generally unsightly (Inskipp, 2004; Agamuthu et al., 2019). A list of the wide range of marine litter sources were compiled and listed in Table 2.

3.1.3 State

A state change occurs when the normal state of the marine environment alters with special reference to the physio-chemical parameters (Elliott et al., 2017). The normal biological functioning at individual, population, community, or ecosystem levels has observable changes (Elliott et al., 2017). These changes are indicators of ecosystem quality, reflecting the ecosystem integrity, which may hinder ecosystem services which humans rely on (Mateus and Campuzano, 2008). In the context of solid waste, data on trends can be postulated based on the available literature, however in terms of changes in state of marine litter in the Windward Islands data on trends were unavailable due to lack of scientific research or inconsistencies in monitoring and clean-up activities among the islands. Budget restraints also affect amounts of litter collected per year (Diez et al., 2019).

However, there are two recent studies that may be used to infer on the status of ecosystem quality in the region, and they both involve microplastics (MPs). One study, performed by Bosker et al. (2018), evaluated the presence of MPs in beach sediments in four islands of the Lesser Antilles (i.e., Anguilla, St. Barthelemy, St. Eustatius, and St. Martin), all of which are north of the Windward Islands. All samples collected along the four islands contained MPs, with an average 261 ± 6 items/kg of dry sand. Another study by the Inter-American Development Bank (IDB) (2020) revealed that MPs have been also found in drinking water within the LACA region. Tracking the source and transport of MPs is challenging, however there is documented evidence of MPs sources into water from a range of different activities, infrastructure, and land uses (IDB, 2020). Yet, there is no confirmed evidence that links ingestion of MPs as a current exposure risk through drinking water in the region, likely due to lack of research.

As it pertains specifically to the Windward Islands, examples of state changes were identified and was further categorised into the following based on the literature: environmental health, ecological, and ecosystem services of state. Table 3 illustrates examples of states within the Windward Islands.

3.1.4 Impacts

In the context of marine litter, it is important to define some indicators that can be used to measure and assess the possible impacts of marine litter (Abalansa et al., 2020). Most indicators are associated with impacts on human welfare such as health and socio-economic impacts which are more easily identified (Abalansa et al., 2020; Miranda et al., 2020). This is applicable to the Windward Islands. Socio-economic impacts can include the compromising of leisure and recreational activities (Krelling et al., 2017), the costs associated with removal of coastal and marine debris (Rangel-

Buitrago et al., 2018; National Oceanic and Atmospheric Administration [NOAA], 2020b) and costs to tourism, fisheries and shipping sectors, loss of jobs, and impact on social wellbeing (Krelling et al., 2017; Watkins and ten Brink, 2017; Williams and Rangel-Buitrago, 2019; OECD, 2020; Aretoulaki et al., 2021). Environmental impacts on the other hand are more difficult to assess (Miranda et al., 2020), but tend to comprise the adverse effects directly on biota and on human health in the Windward Island dynamic. In other nations (mostly developed) changes in the ecosystems functioning (biological, geochemical and physical processes and components of the system) can be assessed (Miranda et al., 2020).

In the Windward Island context, it is understood that a growing health hazard and continued potential risk include litter that are considered water holding items (coconut shells, bottles, bags, cups, tires, buckets, tins). These trash items are breeding grounds for mosquitoes, such as *Aedes aegypti* that can transmit dengue fever (Raffoul, et al., 2006). Many of these trash items can be particularly observed along various coastal ecosystems in each island especially where illegal dumping is evident. A compounding factor is the fact that *A. aegypti* not only tolerates freshwater but also brackish water of higher salinity (up to 15 ppt) (Ramasamy et al., 2011; Rao et al., 2011). *Aedes aegypti* has been more problematic with illegal dumping than with littering, because of the quantity of garbage accumulated in one area (Raffoul, et al., 2006).

Along the same context of human health concerns is that of plastic litter various pressures on freshwater and marine ecosystems. This in turn is thought to have an impact on both wildlife and human welfare. There are few papers that suggest the increase in ingestion of MPs by marine and coastal organisms in the Caribbean (Vendel et al., 2017; Morrall et al., 2018; Garcés-Ordóñez et al., 2020). Morrall et al. (2018), found that 97.6% of commercial-fish samples from Grenada contained microplastic particles. Studies have indicated that microplastics entering the human body *via* ingestion or inhalation can lead to various health implications, including inflammation, genotoxicity, oxidative stress, apoptosis, and necrosis (Wright and Kelly, 2017; Koelmans et al., 2019; Hu and Palić, 2020). These are all also linked to an array of negative health outcomes such as cancer, cardiovascular diseases, inflammatory bowel disease, diabetes, rheumatoid arthritis, chronic inflammation, auto-immune conditions, neuro-degenerative diseases, and stroke (Wright and Kelly, 2017; Koelmans et al., 2019; Hu and Palić, 2020). Moreover, a recent study has provided evidence to support that polymers from plastics are now detected in human blood (Leslie et al., 2022).

Regarding the loss of biodiversity, there is insufficient statistical data available that directly links marine litter to reductions and losses in biodiversity through entanglement, ingestion, and smothering. However, the Caribbean islands generally recognize comparable impacts to their coastal and marine ecosystems, human populations, and economic activities as seen in several global case studies (highlighted in Section 1). It is noteworthy that the region's unique aspect is the probable association between marine litter and diseases as well as invasive species.

Marine litter, particularly plastic debris, serve as vectors for diseases and invasive species and can also create a physical environment that favours the growth and spread of pathogens. The presence of plastic debris in the water can provide a

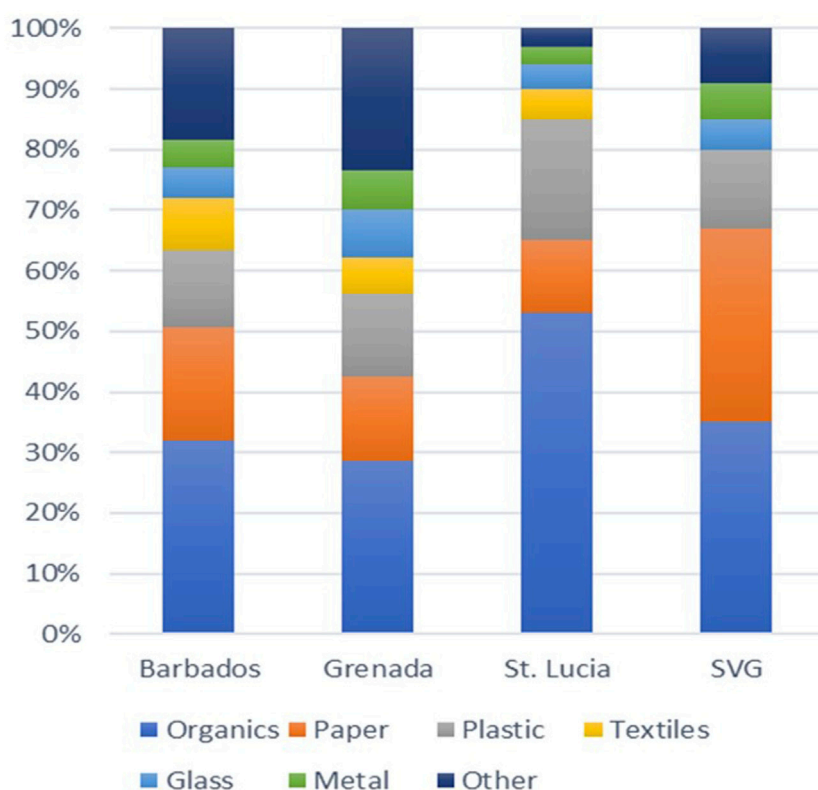


FIGURE 3

Waste Characterisation for Windward Island nations of Barbados (Government of Barbados, 2018), Grenada (Grenada Solid Waste Management Authority, 2019), St. Lucia (St. Lucia Solid Waste Management Authority, 2018) and SVG (Seadon et al., 2019). Percentages are based on the volume of waste (tonnes). Dominica is excluded due to the information being unavailable.

substrate for pathogenic microorganisms, allowing them to colonize and grow. This can lead to an increased likelihood of coral infections and the spread of diseases such as the most recent spread of stony coral tissue loss disease (SCTLD).

SCTLD is a relatively new coral disease that has emerged in the Caribbean basin in recent years and has rapidly spread across the region, affecting nearly thirty (30) different coral species (Camacho-Vite et al., 2022). Several factors have been proposed as possible contributors to the outbreak of SCTLD, including changes in ocean temperature, water quality, and the introduction of pathogenic microorganisms (Estrada-Saldívar et al., 2021).

Marine debris may serve as a potential vector for the proliferation of SCTLD in the Caribbean, and this is gaining traction within the scientific community. It is postulated that the presence of bacterial-causing pathogens in the litter may facilitate their dissemination to coral colonies, while simultaneously compromising the structural integrity of the corals, which may exacerbate the incidence and severity of the disease. This emerging line of inquiry underscores the need for further investigation into the relationship between marine litter and coral health, as well as the imperative for effective management of waste in marine ecosystems.

In terms of bio-invasions, there is a lack of recent observations and published studies that would indicate a correlation between marine litter and bio-invasions specific to WCR. However historical data would show that it has been the reason for introduction of new

species into the region, which has the potential to proliferate and become harmful in the marine environment, in which then it will be termed an invasive species. Bryozoan (*Membranipora tuberculata* originally the Tasman Sea and *Electra tenella*) for instance, were found on plastics washed ashore on the Florida coast, USA, the Caribbean Sea. The findings are supported by earlier research by Winston (1982) and Winston et al. (1997). Moreover, Minchin (1996), documented the transportation of barnacles across the North Atlantic Ocean by attaching to plastic debris. The results underscore the potential role of plastic debris in the long-distance dispersal of marine organisms, which has important implications for marine ecology and conservation.

In the context of socio-economic impacts, the literature revealed that the industries that are impacted by marine litter mainly include tourism and fisheries. The same industries that are also listed as drivers to the problem of marine litter. Religion and culture are other topics identified as being impacted by marine litter. Marine litter impacts the economies in a few ways. One, in terms of tourism, it impacts the chances of tourists returning to an area. Studies show that if debris were to reach a significant amount on beaches—usually more than 15 items/m², more than 85% of tourist beachgoers would look elsewhere when searching for a coastal region to vacation (Williams et al., 2016; Krelling et al., 2017). In the Windward Islands dynamics marine litter may have directly or indirectly affected job productivity. Two, in terms of fisheries, main issues described were

TABLE 2 Main sources of marine litter.

Source classification	Sources/Activities ^a
Land-based (>85%) UNEP, (2019b)	Mismanagement of solid waste (in terms of disposal, treatment, collection and landfill activities) ^b
	Illegal dumping (from typical solid waste materials, to increasing roadside abandonment of vehicles, many of which are located close to rivers and coastal environments)
	Construction sites, demolitions, and abandoned buildings
	Discharge from storm water drains
	Untreated or insufficiently treated wastewater
	Bad agriculture practices
	Annual carnival or crop-over events ^c
	Freshwater activities (domestic, recreational) ^d
	Medical waste, drug paraphernalia and personal hygiene debris
Sea-based ^e (<15%)	Coastal and ocean leisure activity and recreational boating
	Fisheries
	Cruise and Shipping
	Illegal dumping at sea
	Offshore fossil fuel platforms and transportation

^aDerived from the grey literature review.

^bFurther investigation also revealed the overlooked issues for controls in medical waste, drug paraphernalia and personal hygiene debris for WCR ([UNEP, 2022](#)).

^cThis specifically applies to the islands of Grenada and Barbados. Further investigation reveals that national news reports indicate that both countries tend to have excessive amounts of garbage left behind usually near coasts after their carnival or crop-over events respectively ([Evanson, 2017](#); [Joseph, 2018](#)).

^dIn terms of domestic, it is important to note this as an origin of microplastics directly entering rivers from direction human interaction-including use of personal care products and textile fibres from bathing, washing clothes, etc. in rivers.

^eEstimated contribution based on information from [UNEP, 2019b](#).

TABLE 3 Levels of state changes in the environment.

Level	Examples of state change
Environmental health	Prevalence of mosquito-borne public health concern
	Possibility of microplastic (MPs) interaction with biota and adverse implications (through different exposure pathways)
Ecological	Ingestion of microplastics by marine organisms
	Smothering of coral reefs by plastics
	Entanglement of marine organisms in discarded fishing lines
	A likely correlation between the abundance of plastic debris and the prevalence of stony coral tissue loss disease (SCTLD)
Ecosystem services	Deterioration of economic services (tourism)
	Deterioration in social/cultural services (baptism) or loss or less quality in provisioning services (foodP)

reduced fishery yields and decrease revenues from fishing industries due to a combination of impacts of marine litter on fishermen resources including impacts such as propeller entanglements, foulings of gill nets and hooks, damage to the fishing gear ([Lachman et al., 2017](#); [Diez et al., 2019](#)). These problems tend to modify their fishing behaviour such as avoidance of some fishing areas, and use of different types of gear. This sometimes goes against fishers' best economic interest. In terms of social dynamics and specific to the region of the Windward Islands, there were concerns related to small beaches and bay often used for baptism becoming dump sites and polluted ([Garcia et al., 2019](#)).

3.2 Responses to marine litter in the Windward Islands

The issue of marine litter is cross-sectoral and has an overwhelming amount of dynamics to consider in management ([Galloway et al., 2020](#)) hence, the responses section have been tailored in this direction to facilitate decision making. It first acknowledges the challenges of current responses; second, discusses current strategies while recommending appropriate measures based on the driver and its associated pressures and then on the changes in state and consequent impacts.

3.2.1 The challenges with current responses and recommendations

Four major challenges with current responses and recommendations were identified in the review. First, dealing with marine litter in the Windward Islands is not a high priority for the islands especially when compared to the issues concerning poverty, public health, inequalities, etc (UN-ECLAC, 2018; Salvia et al., 2019; Mahlkecht et al., 2020). Thus, responses to this issue have been mostly acknowledged in the various plans (i.e., grey literature) with generic recommendations and very little management activity occurring. The main management activities over the years include removal and monitoring chiefly *via* the International Coastal Cleanup (ICC) Day, which typically occurs once a year and is highly dependent on donations (Graham, 2022). Also, Governments tend to fund street sweeping especially after festivities. Street sweeping is a common means in the region of preventing litter from entering waterways but the service has limited coverage (Diez et al., 2019). The challenge however is that the data collected by the varying entities, is often improperly stored or speculated for inaccuracy or currency unfortunately (GIZ, 2015). This lower level of priority for marine litter certainly challenges the way forward.

Second, as it relates to the Windward Islands vulnerability to the impacts of global climate change (particularly exposure to increasing hurricanes and storms) and strong influence on marine debris, a managerial problem arises. The main agencies with responsibility for natural disasters rarely place emphasis on the topic of marine debris in its plan or assessment. Case in point, in 2020, the United States Agency for International Development- Eastern and Southern Caribbean (USAID/ESC) conducted a resilience assessment for the ESC region to better understand the interplay of the region's socioeconomic, environmental, and institutional context with regards to natural hazards and human-induced stressors among other factors (Hansen and Hellmuth, 2020). The Grenada Resilience Profile Report by USAID (2021) has no information of issues or plans surrounding marine debris, pollution or waste management.

An additional challenge to consider are the modern and common issues associated with debris entrapped in *Sargassum* influx on beaches within the region. *Sargassum* is a genus of brown macro-algae that clusters into long algal mats that drift on the ocean surface and move along with ocean currents (Thompson et al., 2020). While it is a natural and important habitat for over 127 species of fish and 145 invertebrates, several of which are threatened and endangered, excessive blooms of *Sargassum* can become a problem for coastal communities (Thompson et al., 2020). One issue is that these mats can trap and bring in marine litter, which can have negative impacts on both the marine environment and local economies.

A fourth challenge is related to the influence of international initiatives to help tackle marine litter.

Exhaustive overviews and analysis of all applicable initiatives for marine litter has been conducted (Jeftic et al., 2009; Chen, 2015; Carlini and Kleine, 2018; Frantzi et al., 2021) and specifically for WCR as well (UNEP, 2014; Graham, 2022). The varying options in this respective of global governance has resulted in fragmentation, with uneven regulations in different countries and uncoordinated policies (Dauvergne, 2018; Frantzi et al., 2021). Moreover, meeting

the terms of some of these initiatives can be difficult as WCR are challenged by their unique situations. When it comes to recommendations derived from a top-down approach, it is pertinent that policymakers ensure that their island, first have the capacity (or pre-requisites) to tackle the global and regional initiatives and recommendations that come down or, accommodate plans for achieving the pre-requisites first.

Lack of the pre-requisites is a subsequent and fifth challenge. For instance, the review revealed that consumption pressures placed on the environment are a consequent of ineffective and overwhelmed solid waste management systems and infrastructure. Additionally, recycling opportunities are rare. Yet, a major suggestion coming out from the literature for WCR is adopting the circular economy approach. The circular economy model is one that has seen success in developed nations, however according to Graham (2022), WCR cannot afford to transition to circular economy at the moment. Graham (2022) also states that in order to accommodate circular economy in its entirety and capitalise on profitable chain opportunities, there is a clear need to first make SWM disposal, collection and infrastructure improvements top priorities. A key prerequisite to the circular economy is having effective waste management processes and infrastructure (Fedotkina et al., 2019; Luttenberger, 2020; Di Foggia and Beccarello, 2021; Graham, 2022).

The circular economy concept also largely involves changes in manufacturing and production to a more sustainable form (Global Environmental Facility [GEF], 2020; Velenturf and Purnell, 2021), an aspect which is currently inapplicable to the Windward Islands which mostly imports rather than manufacture its own products. Henceforth, recommendations from studies carried out in developed nations that have functioning waste management systems and product recyclability may serve as a point of reference or guide for lesser developed regions, e.g., WCR, but their conclusions cannot be directly inferred (Orona-Návar et al., 2022); at least not until SWM infrastructure has improved and there is opportunity and incentive to recycle. Moreover, there is a lack of empirical studies that investigates the profitability of adopting circular economy concepts for waste processing (Zaleski and Chawla, 2020). According to Zaleski and Chawla (2020), one of the primary reasons for this is the inaccessibility to market data used by waste management companies.

SWM inefficiency is clearly the common denominator for many marine litter issues and circular economy impracticalities for SIDS. Moreover, even islands classified as developed nations, e.g., the Greek islands, are faced with marine litter issues and solid waste management problems; especially given the increasing refugee crisis and consequently increasing amounts of solid waste (Skanavis and Kounani, 2016; Kounani and Skanavis, 2018). Yet, funding opportunities (both grants and even loans) are quite scarce in addressing this global need, and if available are often followed by one or a combination of complex environmental to socio-political factors. For the Windward Islands, these factors include adverse natural and weather conditions (World Bank, 2003), lack of sustainable operational funds like in the case of Dominica (World Bank, 2003), underestimation of actual construction costs like in the case of Grenada (World Bank, 2003), and may also include lack of appropriate planning, poor allocation or mismanagement of available funds or help, political issues or

change in funding commitments. For instance, in Grenada, the island's construction of their new landfill began since 2001 and was at first funded by the World Bank (World Bank, 2003; Mike, 2009). Two decades later, likely due to a combination of these complex factors, construction remains incomplete and according to HYDEA (2022), the new landfill is currently funded by the Caribbean Development Bank.

3.2.2 Responses to the D-P-S-I components

3.2.2.1 Responses- drivers and pressures

Three main types of response were found to be appropriate for addressing the driver or specific human activities that cause marine litter, including significant improvement of current SWM processes and infrastructure, enforcement of legislation and regulations, and education. These three can positively impact the individual to national level (Hemidat et al., 2022) and also prevent the corresponding pressures. However, awaiting short incremental progresses over a long period of time is necessary with such recommendations.

Developing SWM infrastructure requires a huge investment and would eventually need to be coupled with circular economy to promote sustainability and profitability. Although the islands may be making progress in SWM, waste collection alone in some islands is unprofitable. Case in point is Grenada. Solid waste collection rate in the island was once 50% (World Bank, 2003). Yet, the island saw increases in waste collection to above 98%, but the cost of their collection system is much greater than the income the waste collection fees generate (GIZ, 2015). This is unprofitable and potentially disincentivising. Hettiarachchi et al. (2018), stated that lack of finances and poor financial planning prohibit necessary waste management infrastructure development and maintenance, in small island developing states. Thus, whilst islands wait on funding to execute such a recommendation, ways to lessen the amount of trash in the environment is key. Additional preventive measures include increasing recycling and re-using opportunities.

Re-using and recyclability is a challenging transformation for several islands across WCR (Ali et al., 2021), but it is often a recommendation identified in the literature for the Caribbean. There are few businesses across the islands that have already started recycling and re-using on a small scale. It would be valuable to know what works, what does not, transfer the knowledge and pursue potential collaborations within the region. Case in point is the effort by a local bottled water supplier in Grenada. The local supplier dedicated to recycling its water bottles post-consumer use, and placed bins throughout the island for collection of its water bottles (Glenelg Natural Spring Water [Glenelg], 2019). This pilot initiative sold its plastic bottles to a recycler in Trinidad and since had intentions of collaborating with other bottling companies in the country (Glenelg Natural Spring Water [Glenelg], 2019). An operation like this throughout the islands can mean an increase in recycling of plastics and a decrease in input of marine plastic litter over time. Another example identified was Sustainable Barbados Recycling Centre Inc (SBRC). SBRC receives and processes the island of Barbados' household waste and predicts that this diversion of waste from the landfill will lessen the chances of an overwhelmed landfill (SBRC, 2019). SBRC recycles the organic waste to create various mulches while the other solid waste materials (i.e., plastics,

cardboard, paper, scrap metal and glass) are exported internationally (SBRC, 2019).

As it pertains to enforcement of legislation and regulations, this is a repeated recommendation throughout the literature specifically within the policies and frameworks. Thus, policymakers and governments understand that this is needed. The implementation of such a recommendation can make significant changes not only in current behaviours that encourage marine litter and illegal dumping but also positively influence ecosystem valuation (Kushner et al., 2012). Enforcement of regulations *via* use of fines have proven to be successful in other Caribbean islands especially concerning societal and health issues (Kushner et al., 2012; Clayton et al., 2021). Further, minimization of *red tape* seems to be an essential component in enforcing regulations.

The major bureaucratic obstacle appears to be within the government and its agencies. In the Windward Island's case, varying ministries and its agencies have responsibility for enforcing regulations related to waste management. For example, in the case of Grenada, the National Waste Management Strategy for Grenada revealed that GSWMA, the Ministry of Health and the Environment³ and the Royal Grenada Police Force share responsibility for ensuring enforcement of legislations and compliance to regulations related to waste management. This is excellent for sharing resources and maximizing efficiencies among other benefits. However, oftentimes the prosecution of offenders (e.g., persons who illegally dump) does not occur, because of the ambiguity on entities responsible for filing initial reports of illegal dumping incidences, investigating, and pressing of charges.

The literature also revealed that the common and most prominent legislation or form of policy control within the Windward Islands are the current plastic and Styrofoam bans that are well in effect in 4/5 of the Windward Islands. According to UNEP (2019b), the ban has been suspended in St. Vincent and the Grenadines for allowing the depletion of current business' stocks of plastic bags and because of the challenges associated with COVID-19 pandemic. Maintenance of bans are projected to see a reduction of the use of plastic bags and Styrofoams and subsequently a less percentage contribution in landfills (UNEP, 2018). Prior to the ban, Grenada saw a reduction in its plastic composition in the waste characterisation moving from 16.4% in 2009% to 13.7% in 2018 (Grenada Solid Waste Management Authority [GSWMA], 2019). This is likely because a number of local companies and small businesses were engaged in profitable re-use and recycling of plastic bottles among other products (GIZ, 2015). Thus, plastic is expected to decrease even further with these bans and initiatives in place.

As it pertains to education and awareness, this is a response mechanism that has been in place for many years within the islands and continues to expand. The bibliographical review would suggest frequent awareness approaches include educational campaigns to the general public about the problems of dumping and littering, using litter bins, coastal clean-up campaigns and on a smaller scale education on port reception for waste from ships. However, the ever-

³ Now two separate ministries: Ministry of Health, Wellness and Religious Affairs and the Ministry of Climate Resilience, The Environment & Renewable Energy (Government of Grenada, 2022).

increasing global and regional trends in the quantity of marine litter particular plastic waste (Galgani et al., 2021) may require a more strategic approach to education and enforcement of anti-litter laws and regulations within the current infrastructural capacity. Also, as islands strive toward circularity, steps towards educating and eventually getting the general public into the habit of assorting household waste can be useful if waste management and larger recycling opportunities become a reality for these nations. Include info on current stakeholders and their involvement. Suggestion that an up-to-date analysis would be valuable.

Continuous intervention is needed across the ever-changing relevant sectors and its actors (i.e., distributors, retailers, consumers) and the general public. As a recommendation, it may be appropriate that countries first conduct a stakeholder analysis on a national level and create a network on inter-country scale (Keijser et al., 2018; Kandziora et al., 2019; Dimitrovski et al., 2021). Moreover, the grey literature revealed that involving those with different roles (i.e., communication specialist, graphic artist, health and wellness representative, Professional Association of Diving Instructors [PADI], product officers) meant that common issues, relevant strategies and appropriate visuals are injected into projects, programmes and even policies.

3.2.2.2 Responses- states and impacts

States and impacts are commonly regarded as the effects of the drivers and pressures (Eastwood et al., 2007). Four main appropriate management measures were identified for addressing the effects including continued removal, research, dissemination of information and enabling compliance by enacting and enforcing existing regulatory and policy instruments especially those influenced by international agreements and initiatives.

Removal efforts has been expensive in the region not only because of the finances needed for the resources to clean but also because the Caribbean is within a storm and hurricane zone that poses additional budget strains when an event occurs (NOAA, 2020a). In general, removal is also very time-consuming and only captures a fraction of the overall litter (Williams and Rangel-Buitrago, 2019). As long as governments do not make marine litter a priority in the countries, dealing with marine litter will remain unfunded and dependent on donations by non-governmental organisations in and outside of the country for removal, among other management activities (e.g., monitoring, research, disposal incentivisation or compliance mechanisms, awareness raising). Hence, why investment in prevention (tackling the drivers and pressures) are so important to stop or reduce the input of marine litter in future.

With regards to research, there are several key research areas that arose from the grey literature available and are deemed necessary for answering so that appropriate measures for dealing with marine litter can be applied. In order to adopt functioning systems that address marine litter locally, research needs to be conducted to fill the knowledge gaps. The knowledge gaps and needs identified include.

- i) Consistent data collection for the removal and monitoring of marine debris and development of trend analysis stating all possible influential drivers, subsequent pressures and identifying indicators for monitoring change in state.

- ii) Standard methods for data collection and common housing for information and exchange
- iii) Documentation of marine and coastal users' behaviour and adaptation.
- iv) Research in governance mode assessment (i.e., comparing the effectiveness of existing bottom-up approaches with top-down approach in the current realm of marine protected areas management, coastal zone management and other relevant fields.)
- v) Tourism and Fisheries litter management capacities and assessment
- vi) Need for information on hotspots, patterns and trends especially of foreign litter
- vii) Biodiversity monitoring and marine environmental toxicology

Further, based on the potentiality of bio-invasions and diseases, this study calls for further research in the region to better understand and mitigate the ecological impacts of bio-invasion and diseases *via* plastic pollution.

Additionally, the dissemination or accessibility of research results is needed in the region, but not in a parachuting science sense (Stöfen-O'Brien et al., 2022) nor in a *keep the results shelved and undisclosed* sense either (Fanning et al., 2021; Omukuti, et al., 2021). This suggestion also simultaneously targets one of the drivers—flaccid political commitment and its connection with not disclosing results as it can affect economies linked to marine resources. Accessibility of research information is of fundamental importance so that relevant scientists, policymakers and even innovators can use the information to path best ways forward (Kleppner, 2010; Crippa et al., 2019).

The enactment and enforcement of existing regulatory and policy instruments were discussed in Section 3.2.2.1. Enforcement of these instruments are meant to both prevent undesired acts (i.e., casual factors contributing to marine litter) and guide prosecution after an undesired act by an individual or entity is committed (which in turn also helps to encourage future prevention by others). An important recommendation would be for policymakers and decision makers of the islands to explore or assess how their local actions feed into global agreements and initiatives and *vice versa*.

3.2.3 External responses *via* global ambitions

Countries increasingly use international agreements and initiatives to address common problems. The Windward Islands are signatory to a growing list of global agreements and other initiatives (see Table 4). Despite their supposed usefulness and increasing numbers, little is known about the effectiveness of these instruments in achieving their intended goals. Thus, it is essential to conduct investigations on how international agreements and initiatives impact national legislation, enactment, and compliance, especially in the context of global issues such as plastic debris to (Lambert and Wagner, 2018). For the Windwards Islands, investigating their implementation and compliance is crucial to identifying areas of improvement and guiding the development of future agreements and initiatives. This also ultimately ensures that the efforts to address global problems are more effective.

TABLE 4 International instruments most frequently acknowledged in the literature likely influencing the Windward Islands journey to preventing and reducing marine litter.

International initiative	Intentions	Legally Binding/Non-Binding	Recognised or ratified (or acceded)
Protocol concerning Pollution from Land-Based Sources and Activities (LBS Protocol)	The LBS Protocol was adopted in 1999 and entered into force in 2010. It is Protocol under the UNEP- Cartagena Convention. According to Ali et al. (2021) , this legal instrument consists of obligations to reduce the negative environmental and human health impacts of land-based pollution in the Wider Caribbean Region (WCR)	Binding	Barbados, Grenada & St. Lucia has ratified St. Vincent is currently in the process of ratifying
UNCLOS (part XII)	Aims to provide a legally binding instrument to regulate activities on the oceans and seas, for the protection and preservation of marine environments. UNCLOS (part XII) requires member states to take steps to avoid, decrease, and take charge of marine pollution from any source; including land-based sources of pollution, pollution from vessels, seabed activities, and dumping (UNEP and GRID-Arendal, 2016)	Binding Note: Each state has considerable discretion to decide how its national measures conform to international requirements	All Windward Islands Ratified
MARPOL Annex V (2013 Revision)	This annex advocates for the complete ban on any type of plastics that litter the sea and advocates for the inclusiveness of Garbage Record Book for ships above a tonnage of 400 (gross) or certified to carry more than 15 persons Chen, (2015)	Binding Note: penalties “may” be set by each state domestically	All Windward Islands Ratified except Grenada *Grenada has since established new and larger Port Facilities and can consider ratifying
London Convention (and London Protocol)	The London Convention and the London Protocol came into effect in 1975 and 2006 respectively and play major role in controlling marine pollution. The unregulated dumping and incineration activities that developed in the late 1960s and early 1970s have since halted International Maritime Organization [IMO], 2012 . The protocol continues to deliver practical solutions towards the stoppage of pollution by waste dumping at sea. The conventions prohibit dumping plastic and other synthetic material that are persistent at sea. Under these provisions, sewage sludge and dredged materials as the sources of marine plastics are also being considered for inclusion UNEP and GRID-Arendal, (2016) . Currently few Caribbean States are parties to the Convention and the protocol, and several others (approximately 14) are currently in discussions on ratifying IMO, (2022)	Binding Note: no compliance mechanisms, however recent establishment of a “compliance group IMO, (2017)	Only Barbados has acceded
Global Partnership on Marine Litter (GPML)	Launched at the United Nations Conference on Sustainable Development (Rio+20) in June 2012 in response to a request set out in the Manila Declaration on Furthering the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities UNEP, (2011) ; Chen, (2015) . It functions as a multi-stakeholder partnership that brings together all actors working to prevent marine litter and plastic pollution. It does so by providing unique global and regional platforms to share knowledge and experience and to create and advance appropriate solutions Chen, (2015) ; UNEP, (2019b)	Non-binding Note: lacks a functioning compliance mechanism Meier-Wehren, (2013)	All Windward Islands Recognise
SDG (Target 14.1)	Focuses on the prevention and reduction of marine pollution, such as marine debris resulting from land-based activities Patwa et al, (2015) . Part of SDG 14 (target 14.2) also seeks the judicial use of and protection of marine ecosystems from marine debris and actions for their recuperation UNEP and GRID-Arendal, (2016)	Non-binding	All Windward Islands Recognise

The effectiveness of global initiatives comes into question also, when lack of sufficient resources exist among SIDS to implement global agreements they have adopted. This is a pressing issue that requires attention from relevant responsible global entities. One way for global agreements to make more significant strides in a region like the Caribbean is to consider providing more support to the island nations in the implementation of these agreements. This could involve providing financial resources, technical expertise, and capacity-building programs that are tailored to the specific needs of each island. Unique island issues and needs have a tendency to get lost in translation or generalisations in the process of negotiations for global agreements and initiatives.

Furthermore, the responsible global entities should work closely with small island nations to ensure that these agreements are effectively enforced and monitored. This could involve setting up mechanisms for regular reporting and review, as well as providing technical support for compliance monitoring and reporting. In cases where small island nations lack the necessary human resources to monitor and implement global agreements, alternative approaches can be explored such as leveraging technology with the responsible global bodies to automate reporting and monitoring. Also, the islands could work together to jointly report on the implementation of global agreements, sharing resources and expertise to reduce the burden on individual countries. Regional organizations could also play a role in supporting monitoring and reporting efforts by providing technical assistance and training to member states.

This paper also suggests that islands should exhibit solidarity by jointly accepting, enforcing, or even declining global demands, particularly in situations where resources for implementation are deficient. In instances where adoption is under consideration, it is imperative that assurances of assistance in implementation be secured before proceeding. With regards to solidarity as a recommendation, it is crucial that the Windward Islands and WCR at large prioritize their objectives and work together to push for effective solutions. One important step in this process is to demand greater transparency, disclosure, and collaboration among the global network of lead countries and stakeholders involved in international agreements and initiatives. However, the Windward Islands should not limit their efforts to their immediate geographic region alone. Instead, they should start considering transnational activism and solidarity going forward. Transnational activism among SIDS of the global south has in the past successfully raised their issues and suggestions related to oceans to the highest levels of global discussions, resulting in real local differences (Bueger and Wivel, 2018; Mead, 2021). By joining forces and building coalitions with other SIDS, the Windward Islands can amplify their voices and influence on the global stage, ultimately leading to more effective solutions for their circumstances.

One pressing matter that needs to be addressed thoroughly on the global stage, is how do SIDS deal with local and transboundary plastics? Many developed countries in the Global North have been exporting their plastic products as well as plastic waste to developing countries in the Global South for many years (Wang et al., 2020; Bergmann et al., 2022). Since, developing countries like SIDS of the WCR, lack the resources and infrastructure to safely manage plastic waste, it is imperative for both developed and developing countries to work together to create sustainable solutions for managing debris especially plastic waste. This could involve investing in waste

management infrastructure and technology needed in developing countries, enforcing international regulations on plastic waste exports and increasing recycling and waste reduction efforts in all countries particularly those with large-scale manufacturers. Simon et al. (2021) argues that to fully prevent plastic pollution for instance, it is essential to phase out the production of virgin plastic by 2040. Virgin plastic refers to newly produced plastic, rather than recycled plastic. The authors point out that despite efforts to increase recycling and reduce plastic waste, the production of plastic has continued to grow, and plastic pollution remains a major problem.

The timing of the Global Plastics Treaty (GPT) also known as the Global Treaty on Plastic Pollution is therefore very crucial. In March 2022, the United Nations Environmental Assembly adopted a resolution to address plastic pollution, which entails the establishment of a comprehensive and legally binding global treaty on plastics in 2024 (UNEP, 2022a). WCR was represented at the initial Intergovernmental Negotiating Committee session that aimed to develop the GPT (UNEP, 2022b; Ambrose and Hassanali, 2023), but participation was relatively low. With forthcoming sessions, it is imperative for more WCR nations to capitalize on their presence in the ongoing discussions to tackle plastic pollution in the oceans. This presents an opening for the region to reinforce international collaboration aimed at mitigating plastic usage. Further, based on the results of this study the GPT could support WCR SIDS by.

- 1) Enabling sustainable tourism: As mentioned in Section 1.2 Caribbean islands rely heavily on tourism, which can contribute to plastic pollution. The GPT could encourage the development of sustainable tourism practices that reduce plastic waste, such as eco-friendly packaging and the use of reusable containers.
- 2) Increasing recycling infrastructure: Since the Windward Islands lack the infrastructure to properly manage plastic waste, making it more difficult to recycle, GPT could provide funding opportunities and support for the development of recycling infrastructure in these countries.
- 3) Encouraging sustainable product design from local to global scales: The treaty could incentivize businesses to design products and packaging that are biodegradable or more easily recyclable and overall, less harmful to the environment. This could help reduce the amount of solid waste generated in the first place.

4 Conclusion

In conclusion, this study focused on identifying measures that can be taken by the Windward Islands to prevent or reduce their domestic marine litter, as well as the litter arriving from transboundary circumstances, given that external factors such as transboundary debris, possibility of entrapped debris in Sargassum influx, and unpredictable storms and hurricanes are uncontrollable circumstances. Using a DPSIR analysis, the study identified the driving forces and pressures of marine litter, characterized based on available literature, and revealed a lack of quantitative data on inputs and fluxes. The DPSIR identified the consistent economic (chiefly tourism, fisheries, recreational, construction and packaging) and societal (flaccid political commitment and inappropriate waste disposal behaviors) DRIVERS relevant to the Windward Islands.

The primary PESSURES were determined to be linked to solid waste management stresses and overwhelmed landfills. Additionally, the research identified three distinct levels of STATE change, including environmental health, ecological parameters, and ecosystem services. Notably, there exists a hypothesis that marine debris may serve as a possible mechanism for the spread of SCTLTD in WCR including the Windward Islands. Thus, more research is needed to fully understand the link between marine litter and coral disease outbreaks. Ultimately, a host of IMPACTS occur, primarily including increased human health issues, reduced biodiversity, and declining job productivity, leading to decreased revenue particularly from coastal tourism and fisheries.

RESPONSES took into account current recommendations, and new suggestions were proposed for each component of the DPSIR framework. The responses to the marine litter problem have been mainly top-down approaches, with several new regulatory and policy initiatives coming into force from across the world. Unfortunately, SIDS often lack the capacity to implement or enforce global reforms. Sometimes they are even unable to make the best possible use of foreign assistance. As such, it is crucial for the Windward Islands to leverage their representation at international forums, especially the proposed Global Plastics Treaty, to advocate for actions to address plastic pollution in their region. Moreover, while global industries focus on circular economy and looks at alternatives to replace the conventional package material especially plastics, the same alternatives (e.g., recyclable plastics) will continue to gather in open air landfills of the Windward Islands. Hence, it is imperative to first and foremost consider the challenges faced by the Windward Islands and ensure that their needs are taken into account. The major necessity in which the islands need to push going forward in international forums is their need for effective solid waste disposal, collection, sorting, processing and overall management systems and infrastructure, opportunities to increase recycling efforts, education to enable a circular economy, and ongoing scientific research to enable better decision making.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2023.1150722/full#supplementary-material>

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