STATE OF THE CARTAGENA CONVENTION AREA

An Assessment of Marine Pollution from Land-Based Sources and Activities in the Wider Caribbean Region

JULY 2019

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ACRONYMS AND ABBREVIATIONS

BCRC	Basel Convention Regional Centre
BOD	Biological Oxygen Demand
CARPHA	Caribbean Public Health Agency
CATHALAC	Centro del Agua del Trópico Húmedo para América Latina y el Caribe
CEP	Caribbean Environment Programme
CFP	Ciguatera Fish Poisoning
Chl-a	Chlorophyll-a
CLME+	Catalysing implementation of the Strategic Action Programme for the sustainable management of shared Living Marine Resources in the Caribbean and North Brazil Shelf Large Marine Ecosystems
COD	Chemical Oxygen Demand
COP	Conference of Parties
CReW	Caribbean Regional Fund for Wastewater Management
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
DPSIR	Driver-Pressure-State-Impact-Response
EPA	Environmental Protection Agency (USA)
GDP	Gross Domestic Product
GEAF	Governance Effectiveness Assessment Framework
GEF	Global Environment Facility
HAB	Harmful Algal Bloom
HDI	Human Development Index
ICEP	Index of Coastal Eutrophication Potential
IWCAM	Integrating Watershed and Coastal Area Management in the Small Island Development States of the Caribbean
IWEco	Integrating Water, Land, and Ecosystems Management in Caribbean Small Island Developing States
JCEF	Jamaica Credit Enhancement Facility
LBS	Land-Based Sources
LME	Large Marine Ecosystem
MAR	Mesoamerican Reef
MARB	Mississippi-Atchafalaya River Basin
MARPOL	International Convention for the Prevention of Pollution from Ships
N	Nitrogen
NEWS	Nutrient Export from Watersheds Model
NWC	National Water Commission (Jamaica)
OECS	Organisation of Eastern Caribbean States
P	Phosphorus
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PSP	Paralytic shellfish poisoning
RAC	Regional Activity Centre
RAN	Regional Activity Network
RAPMaLi	Regional Action Plan for Marine Litter
REPCar	Reducing Pesticide Run-off to the Caribbean Sea
ROLAC	Regional Office for Latin America and the Caribbean
SAP	Strategic Action Programme
SDG	Sustainable Development Goal
Si	Silica
SIDS	Small Island Developing States
SOCAR	State of the Convention Area
SOMEE	State of the Marine Environment and Associated Economies
STAC	Scientific and Technical Advisory Committee
TSS	Total Suspended Solids
TWAP	Transboundary Waters Assessment Programme
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WCR	Wider Caribbean Region
WHO	World Health Organization
WTTC	World Tourism and Travel Council

EXECUTIVE SUMMARY

Land-based pollution: what's at stake

Countries bordering the Wider Caribbean Sea, particularly the Small Island Developing States and Island Territories, are heavily dependent on the ocean for socioeconomic prosperity and human well-being. Thriving marine-based economic sectors such as fisheries, tourism, shipping, and petroleum provide employment and livelihoods for millions across the region and generate vast revenues for the countries. Fisheries and marine-based tourism in particular are critical pillars of the economies of the Small Island Developing States and territories. Moreover, governments in the region have begun to recognize the immense potential of this natural capital for development of the blue economy, and are increasingly re-aligning their national development paradigm with this concept.

Concern over pollution is reflected in every international framework related to the environment and sustainable development that has been developed. For example:

- At least six Sustainable Development Goals and Targets, notably SDG 14.1:
- By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. The Cartagena Convention and its Protocol on Land-based Sources of Marine Pollution.
- Aichi Target 8:
  By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
- The Barbados Declaration and SAMOA Pathway related to SIDS

- **US$407 billion:** conservative estimate of the gross revenues generated in 2012 by the ocean economy in the Caribbean Sea alonei[1]
- **US$53 billion:** estimate of the gross revenues generated in 2012 by the ocean economy for the Island States and Territories[1]
- **US$7.9 billion:** recent estimated value of coral reef-associated tourism in the Caribbean[2]

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[1] Patil et al. 2016

[2] Spalding et al. 2018

Despite the vital benefits we derive from marine ecosystems, increasing human populations, poorly planned urbanization, and harmful production and consumption patterns are generating unprecedented pressures on the marine environment. There is undisputed evidence that pollution, particularly from land-based sources, has become a serious and pervasive threat to marine ecosystems as well as to human health, livelihoods, and economies in the region. Concern over pollution is reflected in every international framework related to the environment and sustainable development that has been developed. That countries across the globe have committed to such frameworks in recent decades attests to the level of concern across the world. These impacts hinder progress towards achievement of the Sustainable Development Goals (SDG) and the other goals and targets to which countries have committed or aspire.

The Cartagena Convention

The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention) remains to date the only regional legally binding agreement for the protection, sustainable development, and use of the region's coastal and marine resources. The geographic extent of the Cartagena Convention is shown in Figure ES 1. It is supported by three technical Protocols (Land-Based Sources of Pollution, Oil Spills, and Specially Protected Areas and Wildlife).

Figure ES 1. The Cartagena Convention Area.

State of the Convention Area (SOCAR) report

In 2010, the Contracting Parties to the Land-based Sources (LBS) Protocol decided to produce the first State of the Convention Area (SOCAR) report on land-based pollution. The objectives include assisting the Contracting Parties of the Land-Based Sources Protocol to fulfil their reporting obligations by:

- providing a quantitative baseline for monitoring and assessment of the state of the marine environment with respect to LBS pollution; and
- supporting Wider Caribbean Region (WCR) Governments in assessing progress towards relevant goals and targets including the SDGs, particularly SDG 14.1.

This assessment will also help to inform regional or country-level decisions on addressing land-based sources of pollution, including the development of a regional strategy and investment/action plan for nutrient reduction in the WCR.

This SOCAR report is the first of its kind for this region. The report combines empirical water quality data sets from several WCR countries and territories with global data sets, mathematical models, and information from published sources to produce an assessment of land-based pollution and its impact for the Cartagena Convention area. Eight water quality indicators were assessed based on relevance to the LBS Protocol, SDG 14.1, and Regional Seas indicators, using data submitted by countries. These indicators are: dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), chlorophyll-a, dissolved oxygen, turbidity, pH, and *Escherichia* coli and *Enterococcus* species. A brief review of marine litter/plastic and mercury is also included owing to increasing concern over their impacts on human health and the environment. The assessment is based on the Driver-Pressure-State-Impact-Response (DPSIR) framework, which describes the interactions between human society and the environment.

The assessment is organized around five sub-regions within the Cartagena Convention Area (Figure ES 2). In response to a request from the Cartagena Convention Secretariat to WCR countries for water quality data, 16 countries (nine of which are Parties to the LBS Protocol) in all the sub-regions except sub-region II submitted data for the assessment.

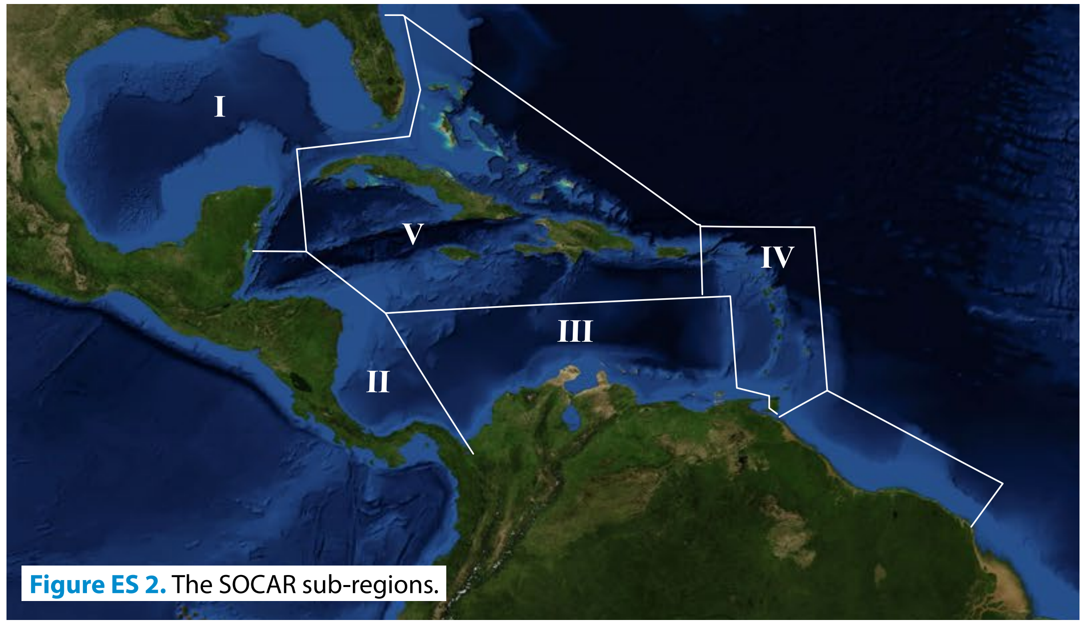

Figure ES 2. The SOCAR sub-regions.

Interaction of humans with marine ecosystems in the Wider Caribbean: drivers of ecological change

Fisheries and marine-based tourism in particular are critical pillars of the economies of the Island States and Territories. Human population, urbanization, economic development, and production and consumption patterns are major drivers of change in the condition of marine ecosystems. The WCR's total population, which was 132 million in 2010, is projected to grow to 149 million by 2020. This region, along with the rest of Latin America, has the highest rates of urbanization on the planet. These trends will be accompanied by concomitant increase in the production of solid and liquid waste under the 'business as usual scenario' of poor urban planning and inadequate wastewater treatment facilities and solid waste management in many of the countries. Added to this is pollution from both land-and marine-based economic sectors such as fishing, tourism, agriculture, manufacturing, shipping, and petroleum industries, which are also expanding in the region.

Population and urban centres as well as major agricultural and industrial activities are concentrated in coastal areas and within extensive watersheds. As a result, significant loads of untreated wastewater and agricultural run-off are introduced to coastal waters through point and non-point sources, and distributed by ocean currents over large areas of the Wider Caribbean Sea.

Land-based pressures on the marine environment

Untreated domestic wastewater/sewage and nutrient loads are the major anthropogenic pressures from land-based sources and activities that are considered in this assessment owing to their potentially severe impacts on the marine environment and ecosystems, and on human health and economies.

Domestic (municipal) wastewater loads

Despite significant progress in sanitation coverage in recent years, most of the countries are still plagued by insufficient and poorly functioning wastewater treatment infrastructure. An estimated 15 x 10^9 cubic meters of domestic municipal wastewater[3] was generated in the Wider Caribbean Region in 2015, of which only 37% reached treatment plants and 63% presumably discharged in untreated form. The latter is lower than the claim of 85% presumably discharged without treatment, which is widely used in other reports. The highest volume of untreated domestic wastewater comes from sub-region III, followed by sub-regions I, V, II, and IV (descending order).

Discharges of untreated or inadequately treated domestic wastewater are major sources of bacterial loads, nutrients, and other contaminants to coastal waters. At the current level of technology, only post-secondary treatment methods can rid wastewater of nutrients, pathogens, heavy metals, and toxins.

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[3] "Domestic wastewater" means all discharges from households, commercial facilities, hotels, septage, and any other entity whose discharge includes the following: (a) toilet flushing (black water); (b) discharges from showers, wash basins, kitchens, and laundries (grey water); or (c) discharges from small industries, provided their composition and quantity are compatible with treatment in a domestic wastewater system (LBS Protocol Annex III). A similar definition is used by FAO Aquastat, which was the main input data source for empirically assessing municipal wastewater discharge in the WCR. (http://www.fao.org/nr/water/aquastat/data/query/results.html)

Nutrient loads from watersheds to coastal areas

Concern over nutrients is explicitly expressed in SDG 14.1. The over-enrichment of water by nutrients such as nitrogen and phosphorus (eutrophication) is one of the leading causes of coastal water quality impairment. Estimates of total nitrogen and total phosphorus loads discharged from untreated domestic wastewater and from agricultural fertilizers were produced in this assessment. About 610,000 tonnes of nitrogen and 100,000 tonnes of phosphorus were contained in the estimated volume of untreated domestic wastewater released in 2015. A coarse inventory of agricultural fertilizer use in the WCR countries, expressed in the weight of total nitrogen and total phosphorus for year 2002, showed that fertilizer use in the WCR region in 2002 amounted to 6.44 Tg total nitrogen and 2.34 Tg total phosphorus.

Over the 20th century, the total nitrogen load for the region delivered from river basins to coastal areas almost doubled (Figure ES 3), attributed mainly to sub-region I (Gulf of Mexico). Total phosphorus load also increased over the same time period (Figure ES 4).

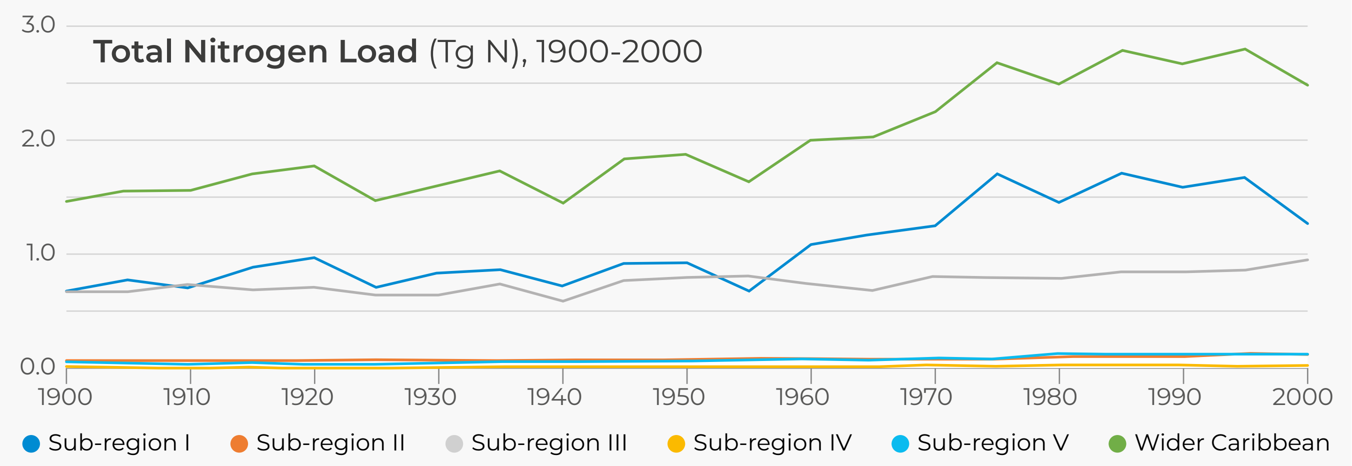


Figure ES 3. Modelled annual nitrogen load in each sub-region and the WCR for the 20th century. Total Nitrogen Load, Tg N, Wider Caribbean Region,1900-2000

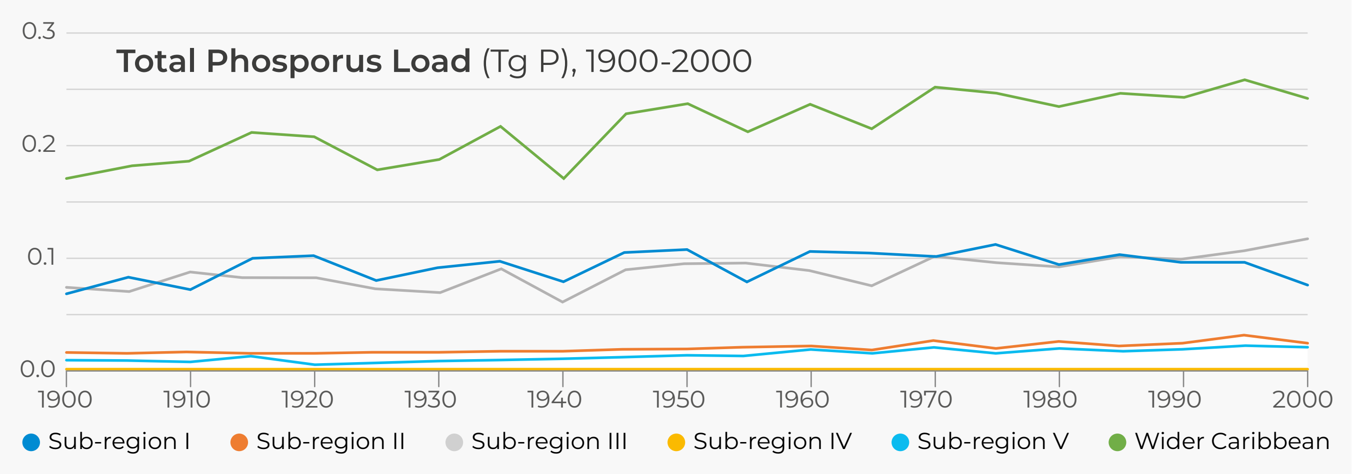


Figure ES 4. Modelled annual phosphorus loads in each sub-region and the WCR for the 20th century. Total Phosphorus Load, Tg P, Wider Caribbean,1900-2000.

Model-based assessment of major sources of nutrients to coastal areas

At the regional scale, agriculture is the most important anthropogenic nutrient source in coastal waters, with the combined contribution of nitrogen from agricultural surface and groundwater run-off greatly exceeding that from sewage. Moreover, groundwater impacted by agricultural fertilizers, rather than surface agricultural run-off and domestic sewage, has emerged as the biggest anthropogenic source of nitrogen to coastal waters, particularly in sub-regions I and V (Figure ES 5). The finding underscores the need for increased attention to non-point sources of land-based pollution from nutrients under Annex IV of the LBS Protocol on Agricultural Non-Point Sources, and to protecting groundwater resources.

Surface agricultural run-off is the major anthropogenic source of phosphorus inputs in all sub-regions except sub-region IV where sewage dominates (Figure ES 6). Weathering makes an important contribution of phosphorous particularly in sub-regions II, III, and IV, which must be taken into account when assessing nutrient inputs to coastal waters. There is need to estimate nutrient inputs from industrial sources in the WCR.

Knowledge of the relative contribution of different sources of nutrients to the marine environment will be valuable for the development of a nutrient reduction strategy and investment/action plan for the region.

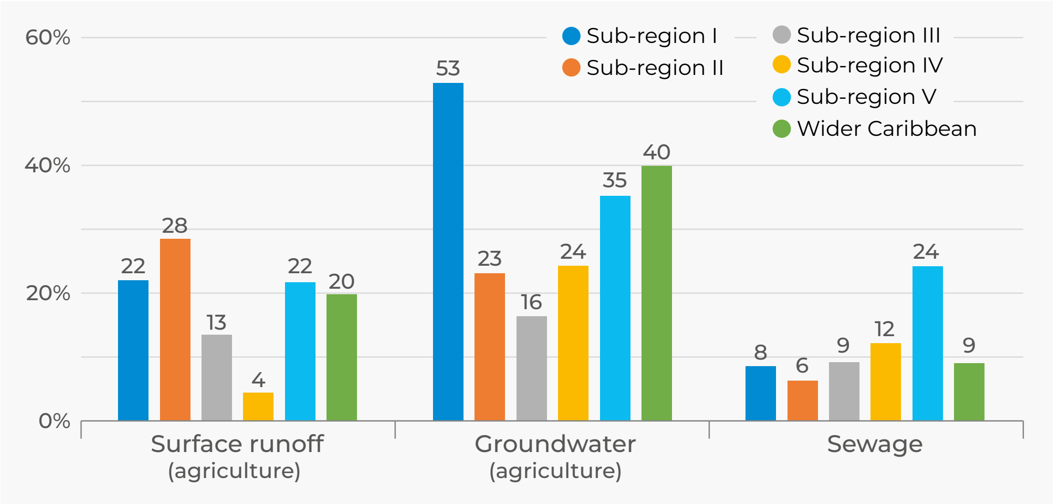


Figure ES 5. Nitrogen (N) contribution by major anthropogenic sources for each sub-region as a proportion of the sub-regional total N source loads.
(data from Beusen et al, 2016)

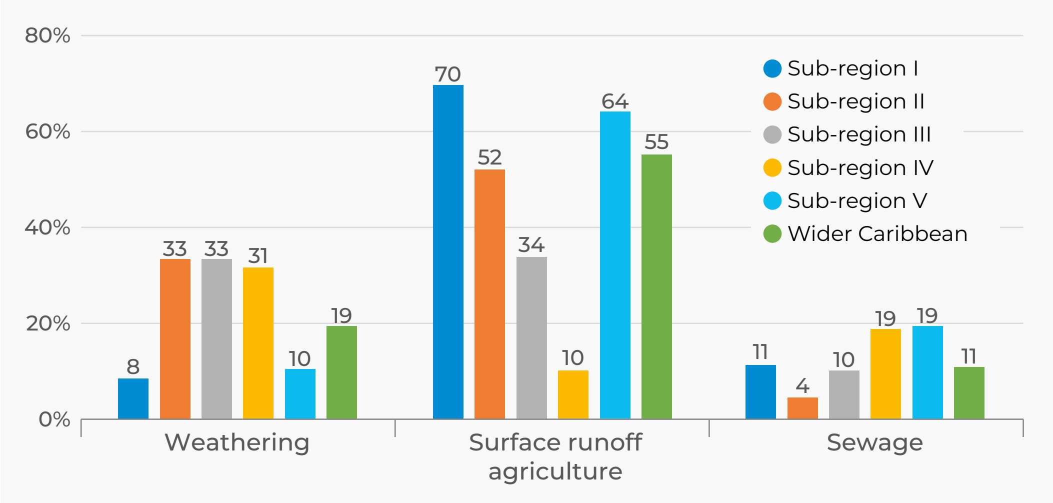


Figure ES 6. Phosphorus (P) contribution by major anthropogenic source (and weathering) for each sub-region, as a proportion of the sub-regional total P source loads.
(data from Beusen et al, 2016)

Model-based assessment of DIN and DIP loads from watersheds to coastal areas

Model-based assessment of DIN and DIP loads from watersheds to coastal areas

Dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) are the forms of nutrients that are directly utilizable by marine plants and hence of most relevance to the process of eutrophication. Therefore, they are the two core LBS nutrient indicators for this assessment. Inputs of DIN and DIP from watersheds to coastal areas for each of the five sub-regions were assessed by E. Mayorga (University of Washington) using the Global Nutrient Export from Watersheds Model (Beusen et al. 2009, Mayorga et al. 2010, Seitzinger et al. 2010). The highest exports of DIN to coastal areas (Figure ES 7) are in the sub-regions along the continental margins of the WCR: I, III, and II (descending order). These areas receive discharges from continental watersheds (with intense agricultural activities and large urban centres) via rivers such as the Mississippi/Atchafalaya Rivers of the USA; Magdalena River of Colombia and Orinoco River of Venezuela; and Central American Rivers such as the Motaqua and Chamelecon, respectively. It must be noted that the Amazon Basin is not included in this analysis.

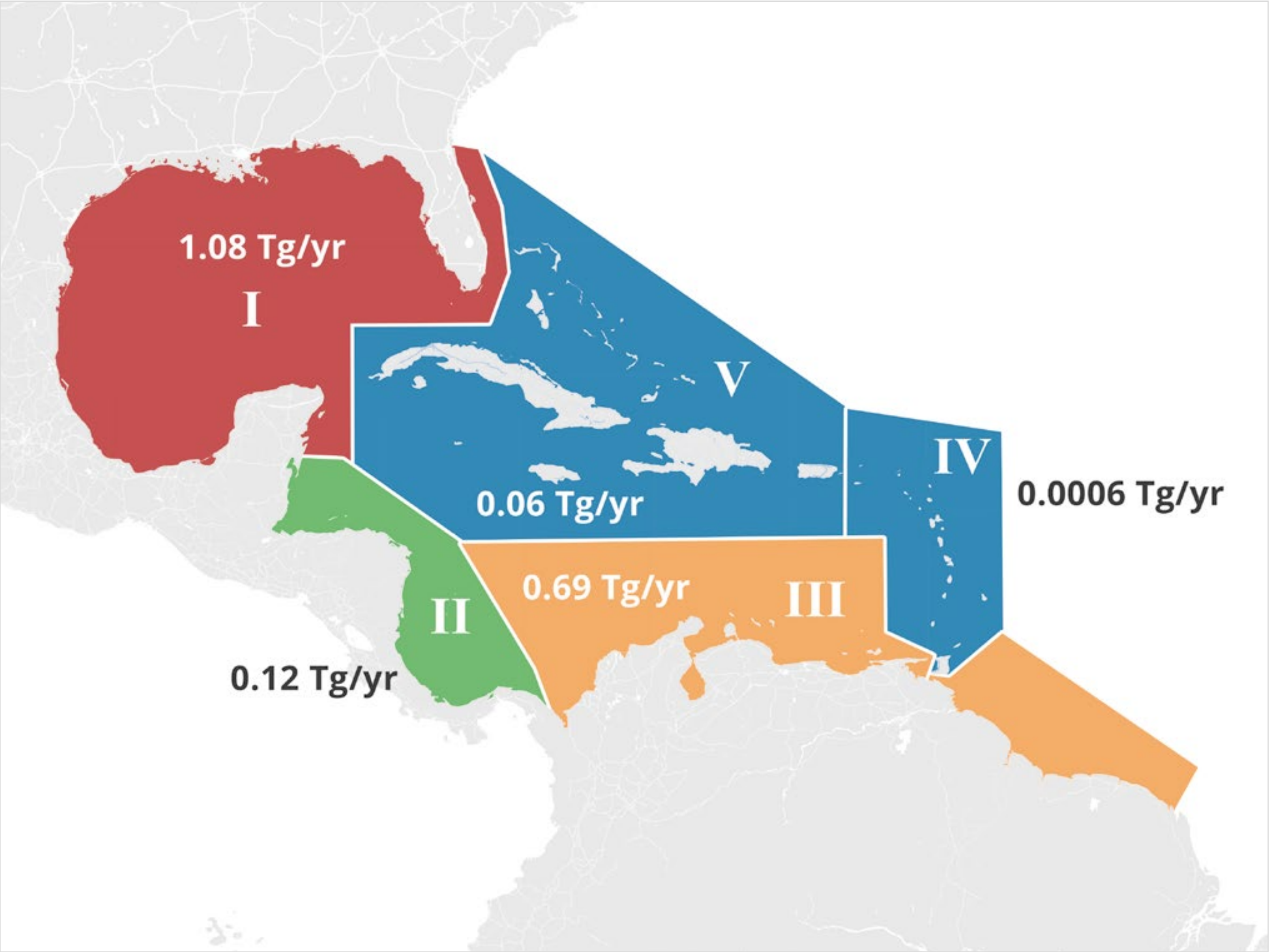


Figure ES 7. Dissolved inorganic nitrogen (DIN) inputs (Tg) from watersheds to coastal areas in the five sub-regions, in model year 2000. Colours represent the range of values (red = highest; orange = high; green = medium; blue = lowest).

State of the marine environment with respect to land-based pollution

The impact of land-based pollution on the quality of coastal waters was assessed with the eight core LBS water quality indicators using the national water quality data. Colour-coded assessment ranges or cut values representing 'good', 'fair', and 'poor' status for each of the indicators except turbidity, pH, *E. coli*, and *Enterococcus* species, where an assessment range denoting 'acceptable' status was applied. These assessment ranges, which are taken from the US Coastal Condition Report (2008) and Annex III of the LBS Protocol (for *E.coli* and *Enterococcus*), were approved by the LBS Protocol Scientific and Technical Advisory Committee in 2014. The assessment ranges are given in Chapter 6 of this report.

For each country/territory and indicator for which data was available, the average value of the indicator for each sampling site was computed across all years, for the wet and dry seasons. Based on the site averages, the proportion of sampling sites in each assessment range was determined for each season. Results for seven of the eight indicators are presented in Figures ES 8-ES 14 for the wet season only, when land-based impacts intensify. In these figures, the status corresponding to each assessment range is denoted by different colours: green=good; yellow=fair; red=poor. The number preceding the country and 1st level administrative unit is the SOCAR sub-region, and the number in brackets is the number of sampling sites.

For DIN, all the countries and territories showed sampling sites with poor status except Guadeloupe (Figure ES 8). In some cases, all or most of the sites showed poor status.

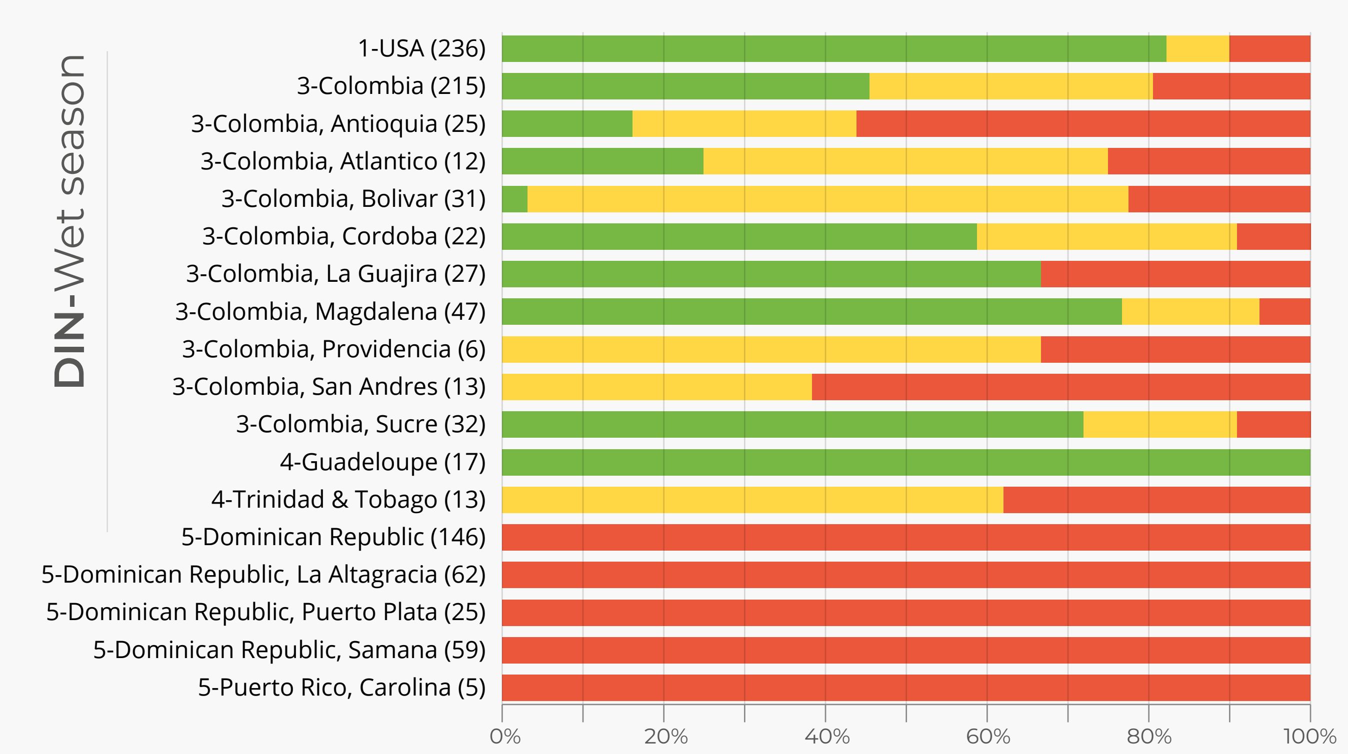


Figure ES 8. Proportion of sampling sites showing good, fair, and poor status in the wet season for dissolved inorganic nitrogen (DIN).

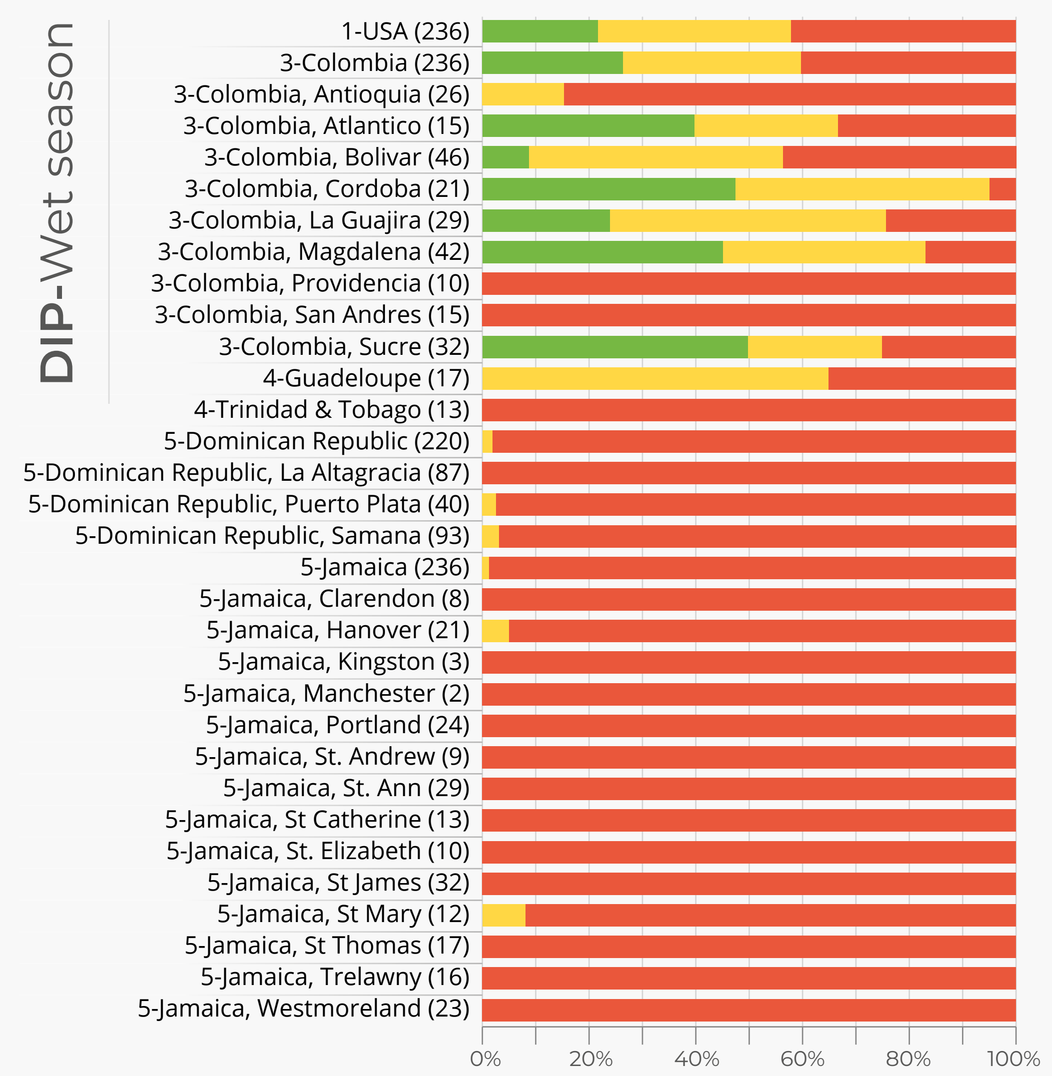


Figure ES 9. Proportion of sampling sites showing good, fair, and poor status in the wet season for dissolved inorganic phosphorus (DIP).

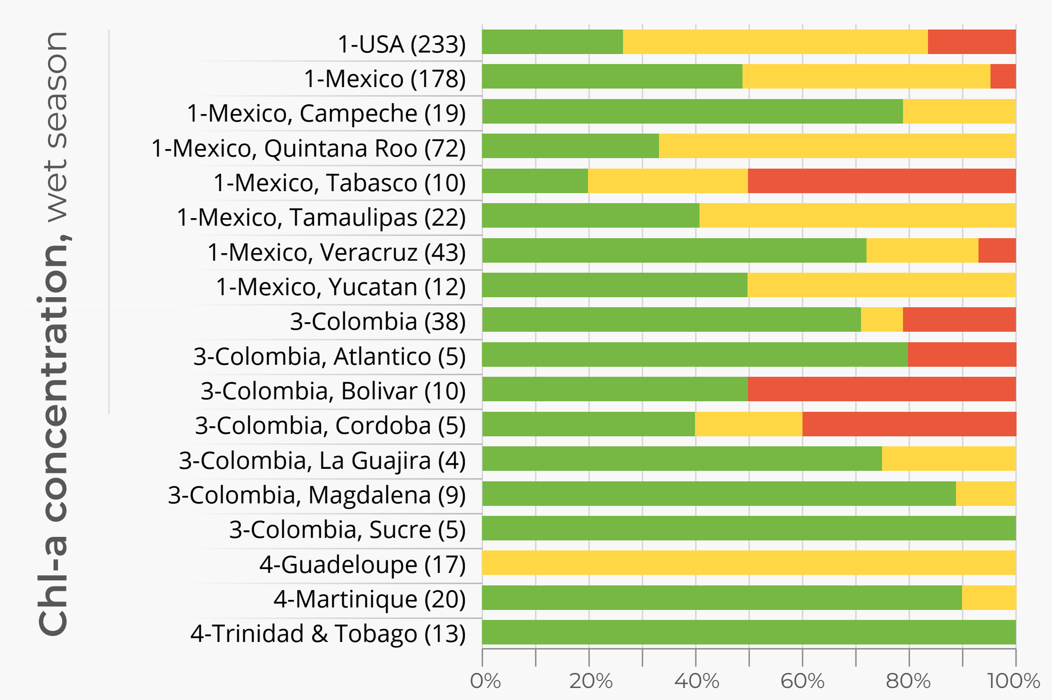


Figure ES 10. Proportion of sampling sites showing good, fair, and poor status in the wet season for chlorophyll-a (Chl-a).

Figure ES 11. Proportion of sampling sites within (green) and outside (red) the acceptable range in the wet season for turbidity

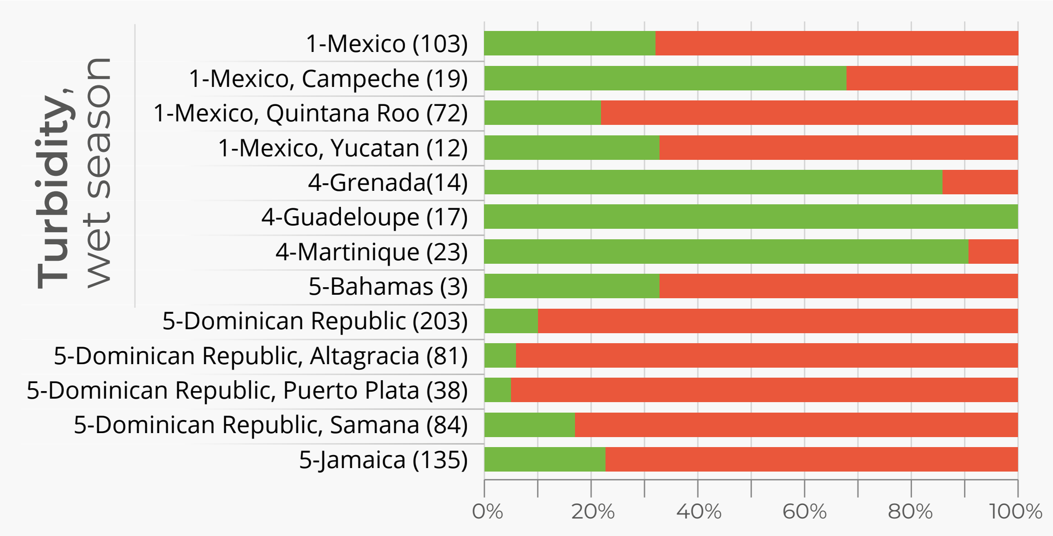
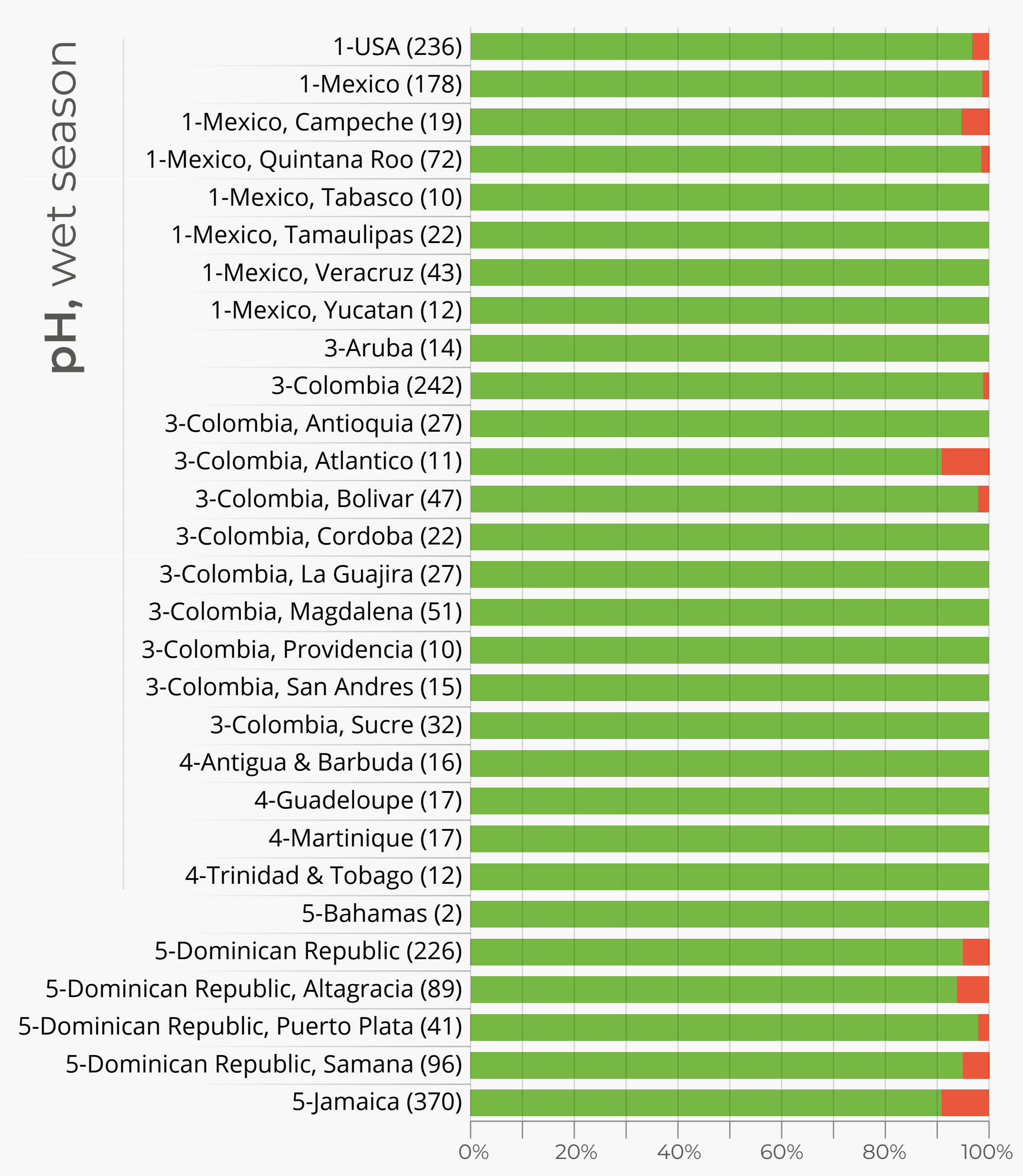


Figure ES 12. Proportion of sampling sites within (green) and outside (red) the acceptable range in the wet season for pH.



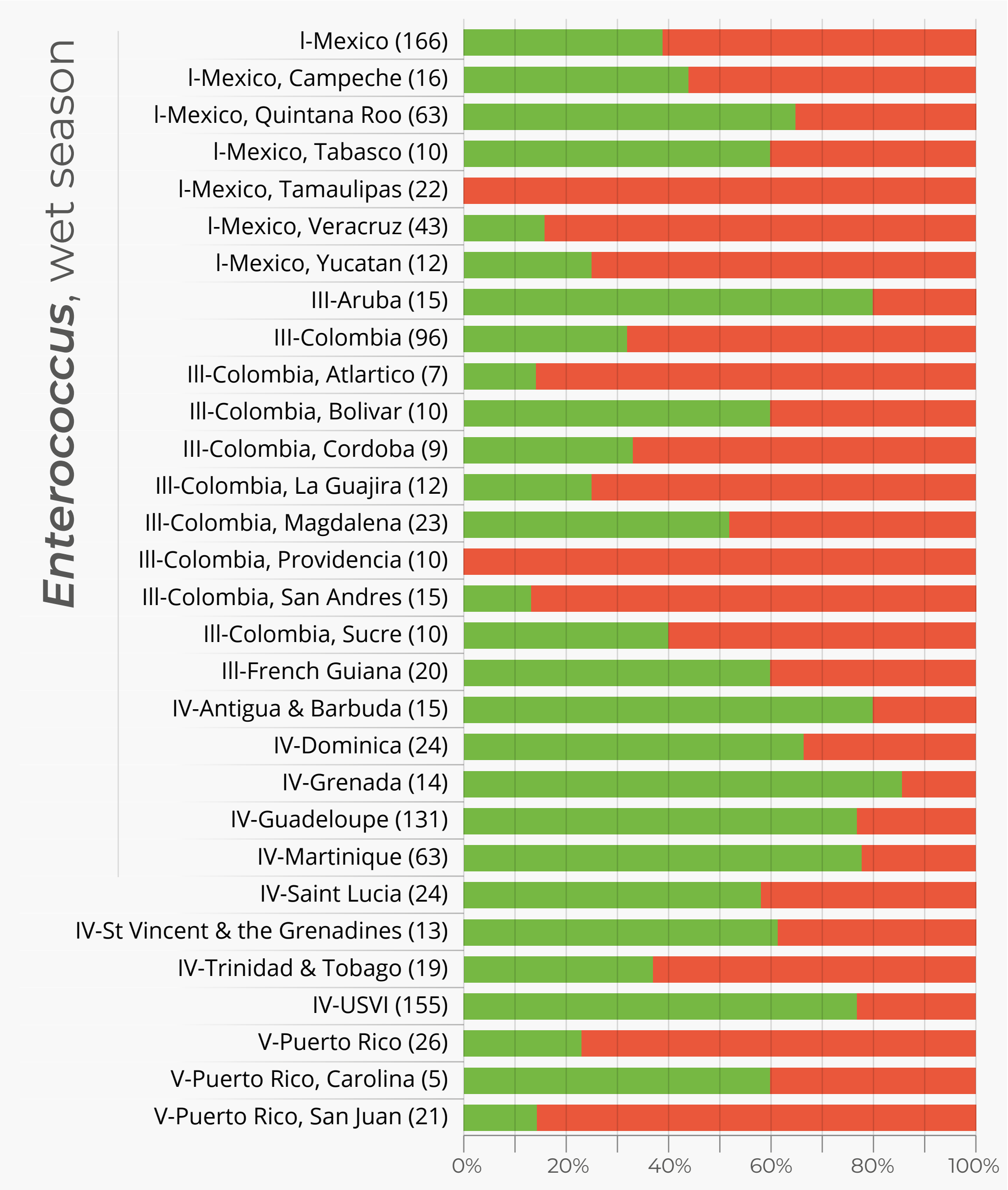


Figure ES 13. Percentage of sampling sites within (green) and outside (red) the acceptable range in the wet season for *Enterococcus*.

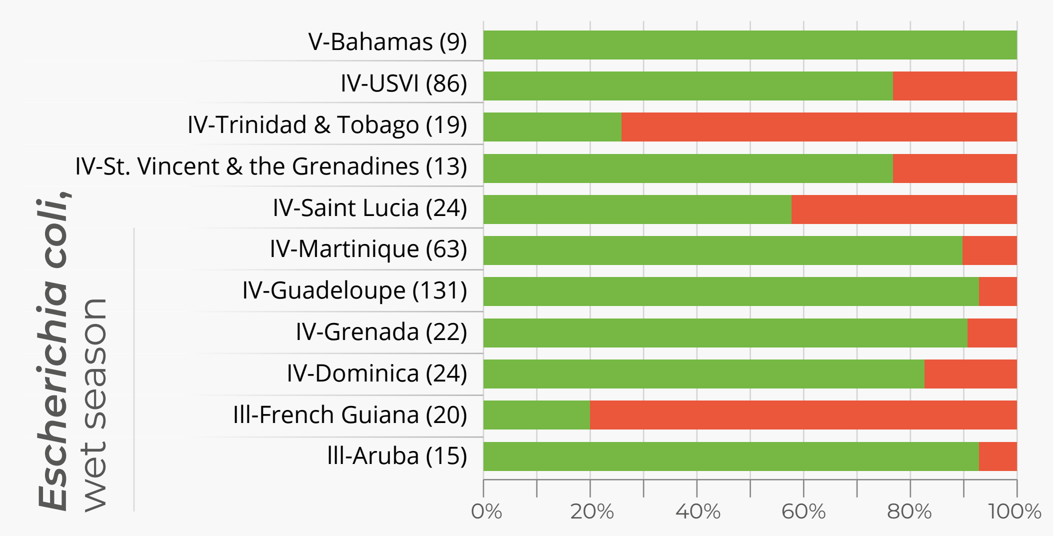


Figure ES 14. Percentage of sampling sites within (green) and outside (red) the acceptable range in the wet season for *E. coli*.

The following is a summary of the major results of the water quality assessment:

- For all the indicators except dissolved oxygen and pH, nearly all the countries/territories (with one or two exceptions depending on the indicator) had sampling sites showing poor status or being outside of the acceptable range. In some cases, the majority of the sites were in these categories, which provides empirical evidence that the marine environment in the region continues to be acutely polluted from land-based sources.
- For *E. coli* and *Enterococcus*, all the countries and territories showed sampling sites with status outside of the acceptable range, indicating faecal contamination (ES 13 and ES 14). In some cases, all or most of the sites were in this range. In the dry season the condition improved due to reduced run-off.
- The proportion of sites with poor status or outside of the acceptable range increased in the wet season as a result of intensification of run-off from land during this period.
- In general, areas with an elevated proportion of sites in these categories were associated with river run-off. However, some exceptions were noted where high proportions of sites in these categories occurred in areas with little riverine influence, such as in some island settings. This may be linked to local conditions such as the high influx of tourists, inadequate wastewater treatment infrastructure, or discharge of contaminated groundwater.
- For dissolved oxygen (DO), only five countries/territories that submitted DO data explicitly reported the sampling depth, with four sampling in bottom waters and one in surface waters. DO should be measured in bottom waters, since this is where its depletion is more likely to occur. A number of sites in the northern Gulf of Mexico showed poor status, linked to the extensive low oxygen (hypoxic) zone in this area.

Ecological impacts of land-based pollution

The combined impact of the multiple stressors acting on marine ecosystems is still largely unknown, and requires further investigation. However, there is documented evidence in the region of the occurrence of certain phenomena (such as harmful algal blooms, low oxygen zones, and coral reef degradation) that are linked to pollution from nutrients and domestic wastewater. These can be exacerbated by increasing sea surface temperatures, storms, and hurricanes. Scientists have cautioned that multiple and unrelenting stressors may push marine ecosystems towards an ecological tipping point, which occurs when small shifts in human pressures or environmental conditions bring about large, sometimes abrupt and irreversible changes in a system. Land-based pollution could potentially lead to such tipping points, which, in fact, may already be evident in localized areas.

Eutrophication

The Index of Coastal Eutrophication Potential (*ICEP*) is an indicator under SDG 14.1. Eutrophication (nutrient enrichment) of coastal waters is manifested by the proliferation of marine algae (algal blooms) triggered by excessive loads of nutrients in coastal areas. This phenomenon in turn leads to other changes in the marine environment, some of which can be devastating to marine life as well as to human health and economies. Many eutrophic zones have been recorded across the region. In addition, it is suspected that increased nutrients could be contributing to the ongoing Sargassum blooms. According to Seitzinger and Mayorga (2016), if current trends continue, the risk of eutrophication will increase from medium to high in years 2030 and 2050 for the Caribbean Large Marine Ecosystem (LME) while it will remain at very high risk for the Gulf of Mexico and North Brazil Shelf LMEs by year 2050.

Harmful algal blooms (HABs)

In recent years the occurrence of HABs in the Latin America and Caribbean region has been increasing. The most conspicuous effects of HABs are mass mortality of marine fauna such as fish and sea turtles, and reduction in the quality of recreational and shellfish harvesting areas, all of which have been documented in the region. In 2018, HAB (red tide) outbreaks in Florida led the authorities to declare a state of emergency in some counties and having had to remove thousands of tons of dead fish. HABs pose a potentially severe threat to human health.

Low oxygen (hypoxic) and dead zones

Algal blooms can result in oxygen depletion and associated 'dead zones' (devoid of macrofauna) near the sea floor caused when dead algal masses sink and oxygen in the bottom water is used up in the decomposition process. Low oxygen concentration (hypoxic) and 'dead zones' have been documented in the WCR, with the most persistent being the extensive zone in the northern Gulf of Mexico. In July 2017, this zone covered 22,720 km^2, the largest ever measured in this location. In 2018 the extent of this zone decreased to 7,040 km^2 due to variability in coastal conditions and rainfall/snowfall melt in the upper watershed.

Degradation of marine habitats

Land-based pollution is among the many stressors affecting the region's ecologically and economically important marine habitats particularly coral reefs and seagrass beds. Numerous cases have been documented throughout the region where nutrients, sewage, and sediments have contributed to coral reef degradation and loss of live coral cover. Pollution coupled with the impacts of climate change and coral diseases as well as other stressors that the region's reefs are currently experiencing may represent an 'existential threat' to the region's coral reefs. However, local stressors, as opposed to ocean warming, diseases, and hurricanes, may have played a bigger role in degrading coral reefs in the Caribbean. Hence, land- and marine-based stressors should be simultaneously mitigated, especially in areas heavily influenced by continental fluxes. The associated losses can be enormous in terms of livelihoods and revenue, considering that coral reefs underpin vital economic sectors such as fisheries and tourism in the region.

Impacts of land-based pollution on human health and economies

Marine pollution poses a substantial threat to human health and causes billions of dollars in economic losses annually. Data for the WCR is limited, but it has been estimated that globally, each year there are millions of cases of diseases such as gastrointestinal and severe respiratory diseases as well as hepatitis A and E, which is often linked to direct contact with polluted waters or consuming contaminated raw or partially cooked shellfish. Associated economic losses have been estimated at about US$12 billion per year globally.

Between 1970 and 2007, about 7,800 documented reports of harmful algal bloom toxin-related diseases, including 119 human fatalities, were mainly associated with paralytic shellfish poisoning (PSP) in the Pacific and Atlantic coasts, and ciguatera fish poisoning (CFP) in the Caribbean. PSP is linked to the incidence of HABs. During 2011, 248 cases of clinically diagnosed CFP were reported from six Small Island Developing States (SIDS) in the region. This is likely to be an underestimate at the regional scale.

HABs and hypoxia can cause significant economic losses at local and regional scales. For example, in the USA, a preliminary and highly conservative nationwide estimate of the average annual costs of HABs is approximately US$50 million. Public health is the largest component, representing nearly US$20 million annually or about 42% of the nationwide average cost. The effect on commercial fisheries averages US$18 million annually, followed by US$7 million for recreation and tourism effects, and US$2 million for monitoring and management.

Greater effort is needed in this region to document the impacts of marine pollution on human health and economies. Despite the significant economic losses caused by pollution and its impacts, waste management and control presents many opportunities for generating livelihoods and revenue while reducing pollution, for example by adopting a circular economy approach to waste management.

This assessment corroborates what has been widely known about the impacts of land-based pollution on marine ecosystems and human health, well-being, and economies. It adds value to the existing body of knowledge by providing empirical evidence of land-based impacts on the marine environment across many countries and territories in the region, using a standardized approach. Gaps in data and information have been identified, which must be addressed to improve decision making regarding land-based pollution. Nevertheless, insufficient data and information should not hinder the development and implementation of measures to diminish land-based pollution.

The assessment clearly shows that the region still has a long way to go to achieve the SDGs and Targets related to pollution (particularly nutrients and plastic, which are explicitly addressed in SDG 14.1) and other relevant targets. Moreover, the impacts of land-based pollution on human health and economies will seriously compromise our ability to achieve the remaining SDGs and other societal goals and targets to which we aspire or have committed. Furthermore, land-based pollution of the marine environment will undermine opportunities for development of the blue economy in the region.

Marine litter and plastics

Concern over plastic pollution of the ocean is explicitly expressed in SDG 14.1. In this assessment, it was estimated that in 2015 the resident population of the WCR generated 79 million tonnes of solid waste, which is projected to increase to 84 million in 2020. From this, 1.3 million tonnes of plastics were introduced to coastal waters of the WCR in 2015. The highest volume of municipal waste is produced in sub-regions I and V, while the highest volume of mismanaged plastic waste is produced in sub-regions V. First estimates of solid waste generated by the combined resident populations and by tourists in the Eastern Caribbean Currency Union member countries in 2015 amounted to 663,000 tonnes and 49,000 tonnes, respectively.

The WCR is among world regions with the highest floating microplastic and macroplastic concentrations. Microplastic adsorbs organic pollutants from the surrounding seawater and when ingested, can deliver harmful chemicals to marine fauna and humans. In Grenada, for example, in a recent study, microplastic particles were found in 41 of the 42 digestive tracts of seven species of commercially exploited marine fish analyzed.

While bans of single-use plastic bags and polystyrene foam products have swept across the region in the last year, solid waste management improvements continue to be a major challenge for the countries. While addressing plastic pollution using the circular economy approach is gaining momentum in the region, the by-products of plastic recycling can be just as or even more harmful than the uncycled plastic itself. There is a growing recognition of the need to reduce the production of new plastic.

Mercury

Mercury is considered by the World Health Organization (WHO) as one of the top ten chemicals or groups of chemicals of major public health concern owing to its high toxicity. In 2015, about 495 tonnes of mercury (amounting to about 22% of global emissions) were emitted to the atmosphere by countries in the Americas, with South America accounting for over 80%, mainly from artisanal and small-scale gold mining. Bio-accumulation and bio-magnification in the marine food chain, and consumption of tainted seafood by humans is a major pathway for exposure of humans to mercury compounds. A recent study in a number of Caribbean SIDS found high concentrations of mercury in human hair samples from most of the Caribbean locations. This was attributed to the consumption of predatory fish, which may bio-accumulate mercury in their tissues. According to the study, distant air emissions of mercury from industrial sources such as coal-fired power plants, mercury use in small-scale gold mining, and emissions from other sources contaminate ocean fish that serve as a primary protein source for SIDS populations. Further investigations are needed, however, to correlate potential mercury sources with fish contamination levels, and mercury body burden with dietary habits in the region.

Responses

Responses are actions taken by society to address land-based pollution and its impacts. These include multilateral environmental agreements; institutional, legal, and policy frameworks; projects and programmes; and on-the-ground actions to reduce land-based pollution (stress reduction measures).

While demonstrated progress is being made on several fronts in the countries and in the region as a whole, the approach to addressing land-based pollution remains generally inadequate, uncoordinated, and fragmented. Many of the same challenges that countries identified decades ago when the Cartagena Convention was being developed, persist to this day. Among these are inadequate (and sometimes uncoordinated) policy, legislative, and institutional frameworks; lack of human, financial and technical resources; inadequate wastewater management systems; and challenges in accessing and adopting more appropriate and cost-effective technologies.

There is an urgent need for WCR governments to adapt and scale up existing experiences, best practices, and technologies, and undertake the required institutional, policy, legislative, and budgetary reforms to address land-based pollution, particularly at its source. It has been demonstrated that preventing pollution at its source is more cost-effective than addressing its impacts. Furthermore, the complex and multifaceted nature of land-based pollution means that an integrated, cross-sectoral approach (including private sector engagement) is required to effectively tackle land-based pollution.

A wide range of recommendations targeted to the Contracting Parties to the Land-Based Sources Protocol and to the Cartagena Convention Secretariat are included in the report. These are arranged according to the following themes: Technical/Monitoring and assessment; Capacity building and training; Institutional, policy and legal frameworks; Knowledge management, communication, and stakeholder engagement; and Sustainability.

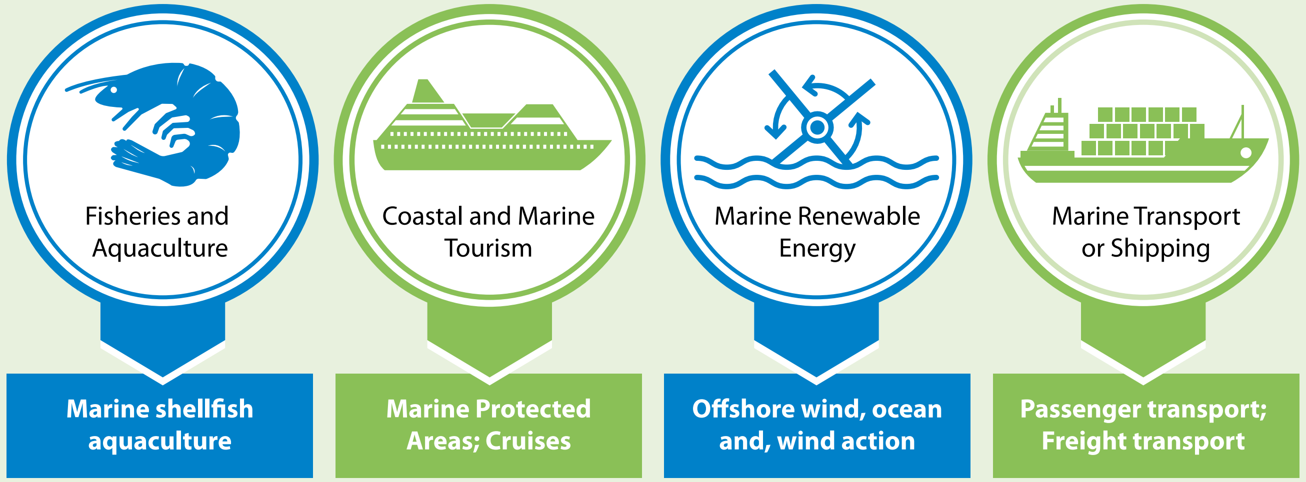
1. INTRODUCTION AND BACKGROUND

INTRODUCTION
AND
BACKGROUND

1.1. Land-based pollution: what's at stake

Coastal and marine ecosystems are not receptacles for our waste products, even though they are often viewed as such by some. On the contrary, these fragile but immensely productive ecosystems are the source of an enormous array of vital goods and services. We enjoy them for their aesthetic value (e.g., tranquil beaches and fascinating coral reefs), depend on them for socioeconomic prosperity (e.g., fish stocks, clear blue waters and coral reefs for tourism and recreation, non-living resources such as oil and gas, and a medium for international shipping), and—in the case of coastal communities—depend on them for protection from extreme weather events. Furthermore, many of these "eco-services" are of fundamental importance to the functioning of Earth's life-support system and for human survival (such as oxygen production and climate regulation).

To put this in an economic context, the global value of marine ecosystem goods and services has been estimated at US$49.7 trillion per year, about 56% of which is attributed to coastal ecosystems (Costanza et al. 2014). It must be noted that coastal ecosystems are the most heavily impacted by land-based activities and pollution. Across the countries and territories of the Wider Caribbean Region (WCR), marine ecosystem goods and services underpin thriving economic sectors that support socio-economic development and human well-being. A conservative estimate of the gross revenues generated in 2012 by the ocean economy in the Caribbean Sea alone (which comprises only about 1% of the global ocean) is US$407 billion—equivalent to 14–27% of the estimated value of the global ocean economy—and some US$53 billion for the Caribbean Island States and Territories (Patil et. al. 2016). Marine ecosystems also provide employment and livelihoods, and ensure food security for millions of people across the region. This natural capital represents a significant potential for development of the blue economy (Box 1.1), a concept with which WCR countries are increasingly re-aligning their national development paradigms.



Box 1.1. Blue economy concept

The blue economy concept was first introduced at the Rio+20 Conference in 2012 and later at the 2014 SIDS conference. The World Bank defines blue economy as "the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, while preserving the health of marine and coastal ecosystems". Major sectors with opportunities for developing the blue economy are presented below (Caribbean Development Bank)

However, these ecosystems and associated living marine resources are being degraded by the production and consumption patterns of a burgeoning human population and its activities, both on land and in the sea, compounded by the impacts of a changing climate. Degradation of marine ecosystems and the loss of biodiversity undermines ecosystem functioning and resilience, and threatens the ability of ecosystems to sustain the flow of goods and services for present and future generations. There is undisputed evidence that pollution, including that from land-based sources, is a serious and pervasive threat to the marine environment and human health. Concern over pollution is so significant and widespread that the issue is reflected in every international environment and sustainable development framework that has been developed and to which countries across the globe have committed to in recent decades (Box 1.2). Notable among these in the WCR is the Cartagena Convention and its three Protocols.

Box 1.2. Examples of international goals and targets related to pollution

- Cartagena Convention and its Oil Spill and LBS Protocols.
- SDG 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
- SDG 9.4: By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
- SDG 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
- SDG 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
- SDG 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.
- SDG 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.
- Aichi Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
- Small Island Developing States Accelerated Modalities of Action (Samoa Pathway) calls for support for actions by SIDS to address marine pollution and other related issues.
- Barbados Declaration 1994: Affirms that 'Small Island Developing States share with all nations a critical interest in the protection of coastal zones and oceans against the effects of land-based sources of pollution'.
- Strategic Approach to International Chemicals Management: Overall objective is the achievement of the sound management of chemicals throughout their life cycle so that by the year 2020, chemicals are produced and used in ways that minimize significant adverse impacts on the environment and human health.

It is within this context and in compliance with the obligation under the Cartagena Convention Land-Based Sources Protocol to monitor and report on the state of the marine environment with respect to land-based pollution, that the Contracting Parties took a decision in 2010 to produce the first *State of the Convention Area* (SOCAR) report on land-based pollution.

1.2. The Cartagena Convention Area

The Wider Caribbean Region (WCR) consists of the insular and coastal states and overseas territories with coasts on the Caribbean Sea and Gulf of Mexico as well as waters of the Atlantic Ocean adjacent to these states and territories. It includes 28 island and continental countries and 19 overseas territories of four States (Figure 1.1).[4] The Cartagena Convention area encompasses four large marine ecosystems[5] (LMEs): Gulf of Mexico, Caribbean Sea, North Brazil Shelf, and Southeast US Continental Shelf. See Chapters 2 and 4, respectively, for a description of the main physical and socio-economic features of the Wider Caribbean Sea pertinent to land-based.

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[4] https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/wider.

[5] Coastal regions of 200,000 km^2 or greater, extending from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major ocean current systems.

Figure 1.1. The Wider Caribbean Region (WCR) showing the Cartagena Convention area.
(Source: UNDP/GEF CLME+ Project)

1.3. The Caribbean Environment Programme and the Cartagena Convention

In 1976, UNEP launched the Caribbean Environment Programme (CEP),[6] which embraces the region's diversity in its efforts to advance economic prosperity and environmental health. In laying the groundwork for the CEP, the governments of the WCR identified several pressing issues, including:

- Land-based sources of municipal, industrial, and agricultural wastes and run-off;
- Over-exploitation of resources such as fish, molluscs, and crustaceans;
- Increasing urbanization and coastal development as populations and economies expand; and
- Unsustainable agricultural and forestry practices, and a profound need to strengthen government and institutional capacity to address environmental problems.

The Caribbean Action Plan was adopted in 1981 by 22 States, and led to the adoption of a legal framework in 1983, known as the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region or **Cartagena Convention**[7] (Figure 1.2). The Convention, which to date remains the only legally binding regional agreement for the protection, sustainable development, and use of the region's coastal and marine resources, is supported by three technical agreements or protocols:

- The Protocol Concerning Cooperation in Combating Oil Spills in the Wider Caribbean Region
- The Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region
- The Protocol Concerning Pollution from Land-Based Sources and Activities (LBS Protocol)

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[6] www.unenvironment.org/cep.

[7] Descriptions of the obligations under the Convention and the three Protocols are available at http:// https://www.unenvironment.org/cep/who-we-are/cartagena-convention

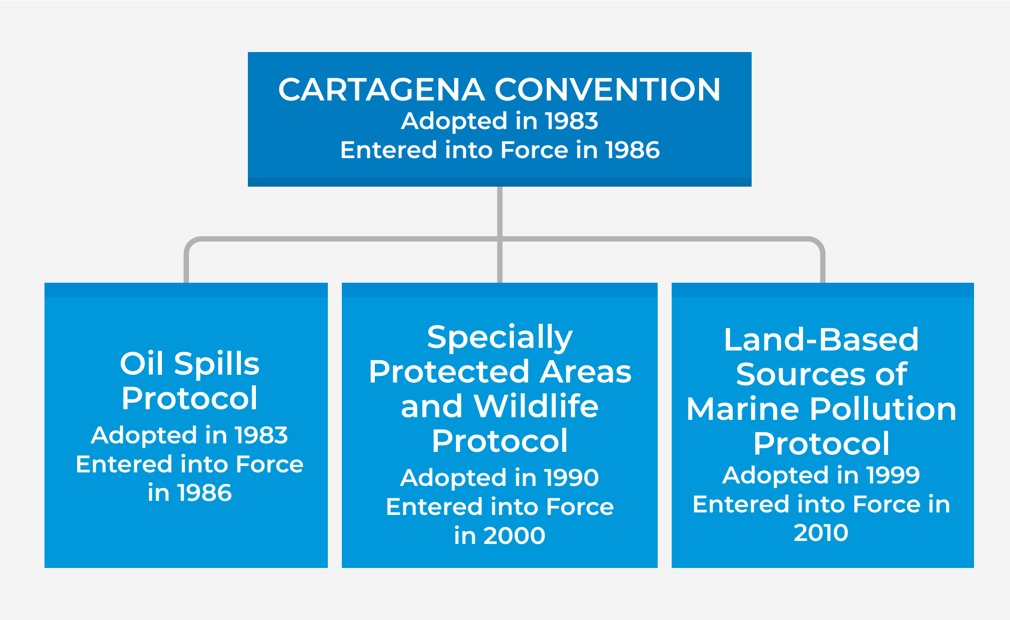

Figure 1.2. The Cartagena Convention and its three Protocols being prepared by UNEP-CEP under the SPAW Protocol.

These two reports will feed into the State of the Marine Environment and Associated Economies (SOMEE) report being prepared by regional partners under the UNDP/GEF CLME+ Project, which has contributed financial support for the development of the SOCAR and marine habitats reports.

Figure 1.3. Status of ratification of the Cartagena Convention and LBS Protocol (April 2019).

The Caribbean Regional Coordinating Unit (UN Environment–CAR/RCU) was established in 1986 in Kingston, Jamaica, and serves as the Secretariat to the Cartagena Convention and its Protocols. Currently, the activities of the Secretariat focus mainly on supporting governments in meeting their obligations under the Convention and its Protocols through capacity building, technology transfer, policy, legislative and institutional reforms, information management and exchange, and environmental education and training.

1.4. The State of the Convention Area Report

The SOCAR report is the culmination of a series of events and activities that date back to 1987. This first report is preceded by two landmark technical reports that were produced by the Cartagena Convention Secretariat in 1994 and 2010: the UNEP-CEP Technical Report 33[8] and the UNEP-CEP Technical Report 52.[9]

Several other reports that cover marine pollution in the region have been produced by various organizations. A recent report is the World Bank Marine Pollution in the Caribbean: Not a Minute to Waste report (Diez et al. 2019), which addresses both land-based and marine-based pollution in the Caribbean.

While these reports were major achievements, they do not allow governments to fully comply with their reporting obligations under the

Cartagena Convention and specifically the LBS Protocol. The 14th Intergovernmental Meeting (IGM) on the Action Plan for the Caribbean Environment Programme and 11th Conference of Parties (COP) to the Cartagena Convention decided to: Establish an Interim Working Group to continue work related to monitoring and assessment that could use Technical Report No.33 as a baseline document with the goal to improve effluent reporting and assessment of water quality conditions throughout the Convention Area, under the LBS Protocol (Decision 3). In response to this decision, the Secretariat requested country nominations from all Contracting Parties for participation in the Interim Working Group (Annex 1.1). The Working Group was later tasked with developing an outline for the first SOCAR report on land-based pollution. Based on a recommendation of the 1st LBS Scientific and Technical Advisory Committee (STAC), the Working Group's mandate was later extended by the 1st LBS COP and the 15th IGM to develop the SOCAR report.

1.4.1. SOCAR vision and objectives

The SOCAR is the first such region-wide assessment undertaken by the Secretariat, and is a baseline assessment of the state of the WCR coastal and marine environment with respect to land-based sources of pollution. SOCAR's vision is to be "A major periodic and authoritative regional assessment of the state of the WCR marine environment with respect to LBS (and their ecological and human impacts) that will inform decision-making and stimulate actions and investments to reduce and eliminate land-based sources of pollution in the WCR on the longer term."

In essence, the SOCAR assessment is also a call to action for the States and Territories of the WCR to reduce and eliminate land-based pollution, in keeping with commitments under the LBS Protocol, SDGs, Aichi Targets, and Barbados Programme of Action, among others.

Box 1.3. SOCAR aims to:

- Assist Contracting Parties to fulfil their reporting obligations, as mandated under the Convention and LBS Protocol (main objective).
- Provide a quantitative baseline for monitoring and assessing the state of the marine environment with respect to LBS pollution.
- Increase awareness and understanding of LBS pollution, its sources, and environmental and human impacts.
- Trigger action at all levels and facilitate improved decision-making and enforcement.
- Promote and inform the development of legislative and policy initiatives and action plans for pollution prevention, reduction, and control. This includes a regional strategy and investment/action plan for nutrient reduction being developed by UN Environment CEP.
- Help mobilize and better target resources for national interventions to address LBS pollution.
- Strengthen national and regional systems for monitoring environmental status with respect to key international agreements, including Multilateral Environmental Agreements, and facilitate monitoring and evaluation of the Strategic Action Programme (SAP) for the Caribbean and North Brazil Shelf LMEs.
- Support Governments in reporting on progress towards achieving relevant SDGs including SDG 6 on Water and Sanitation and SDG 14 on Oceans.
- Contribute to global and regional marine environmental assessments and reporting.
- Contribute to the development of a regional environmental indicators compendium.

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[8] Regional overview of land-based sources of pollution in the Wider Caribbean Region (1994).

[9] Updated CEP technical report No. 33. Land-based sources and activities in the Wider Caribbean Region (2010).

The SOCAR report will be complemented by a report on the The State of Nearshore

Marine Habitats in the Wider Caribbean being prepared by UN Environment-CEP under the SPAW Protocol. These two reports will feed into the State of the Marine Environment and Associated Economies (SOMEE) report being prepared by regional partners under the UNDP/GEF CLME+ Project, which has contributed financial support for the development of the SOCAR and marine habitats reports.

1.4.2. Target audience

The target audience of the SOCAR report (full report and associated information products) includes a wide diversity of stakeholders, ranging from global to regional and local, as shown below.

- Parties to the Cartagena Convention
- UNEP; other UN and Intergovernmental Organizations
- Other WCR Governments
- Donor agencies
- Regional Seas Programmes
- Private sector
- Sub-regional political groupings (CARICOM, OECS, SICA/CCAD)
- Non-governmental Organizations (NGOs)
- Research and academic institutions
- General public and local communities

This diversity reflects the need for collective action at all levels, since everyone benefits from marine ecosystem goods and services while at the same time contributing to pollution of the marine environment at all spatial scales. Therefore, everyone has a responsibility and a role to play in reversing the current worrying trends.

1.4.3. SOCAR development process

The proposed outline for the SOCAR report was approved at the 2nd LBS COP (Decision 5). Following this meeting, the Working Group met via teleconference and in-person at the SOCAR inception workshop held in 2016 (Kingston, Jamaica) to further develop the methodology and approach for developing the report, which included defining the conceptual framework, core LBS parameters, data sources, and the work plan. The Secretariat contracted two consultants to develop the report. They were supported by other experts and the LBS Working Group, as well as by the Data Subgroup that was established following the inception workshop. One-day technical workshops were held in 2017 in Cayenne (French Guiana) prior to the 17th IGM/3rd LBS COP and in July 2018 (Panama) prior to the 4th LBS STAC meeting.

The LBS Protocol STAC, the LBS Regional Activity Centres (RACs), and collaborating agencies and partners that form part of the Regional Activity Network (RAN) and Meetings of Contracting Parties to the Cartagena Convention and LBS Protocol are expected to continue to support the SOCAR process in the future. In addition, the SOCAR process will be an integral part of the institutionalized regional SOMEE mechanism that is being developed under the CLME+ Project.

The SOCAR assessment was supported by a series of Global Environment Facility (GEF) funded projects, including:

- GEF/UNEP: Reducing Pesticide Run-off to the Caribbean Sea (REPCar);
- GEF/UNEP: Integrating Watershed and Coastal Area Management (IWCAM) in the Small Island Development States of the Caribbean;
- GEF/UNEP: Caribbean Regional Fund for Wastewater Management (CReW);
- GEF/UNEP: Integrating Water, Land, and Ecosystems Management in Caribbean Small Island Developing States (IWEco); and
- GEF/UNDP Catalysing implementation of the Strategic Action Programme for the sustainable management of shared Living Marine Resources in the Caribbean and North Brazil Shelf Large Marine Ecosystems (CLME+).

2. THE WIDER CARIBBEAN REGION

THE WIDER CARIBBEAN REGION

Comprehensive descriptions of the biogeophysical and oceanographic features of the WCR are available elsewhere (e.g., Molinari et al. 1981, Müller-Karger et al. 1988, Müller-Karger et al., 1989, Gyory et al., 2013, Miloslavich et al., 2010). This chapter highlights features that are relevant to land-based pollution of the coastal and marine environment in the WCR.

2.1. Countries and territories

The WCR contains 28 independent States and 19 dependent overseas territories (USA, UK, France, and the Netherlands), which range from the largest to the smallest in the world, and from the most developed—USA and European countries—to the least developed (Haiti). A unique feature of the WCR is the presence of 22 Small Island Developing States (SIDS), the largest number of SIDS in any of the world's large marine ecosystems. Another unique feature is that this region has the highest number of maritime boundaries than anywhere else in the world. This means that much of the marine resources, as well as the environmental problems, are shared, which presents a considerable challenge for effectively managing the region's marine environment and living marine resources.

2.2. River basins

A prominent hydrologic feature of the WCR is the immense combined extent of the watersheds that drain into the Wider Caribbean Sea, including the presence of river systems that are among the largest in the world. The proportion of drainage basin area relative to the total national area in the WCR is 57% (see Chapter 5). Figure 2.1 illustrates the coverage of over 3,000 watersheds that drain into the Caribbean Sea and Gulf of Mexico that were used by the World Resources Institute to estimate relative erosion rate and sediment delivery to marine areas. The Amazon Basin is not included, but this system also exerts a strong influence in this region's marine area (see below).

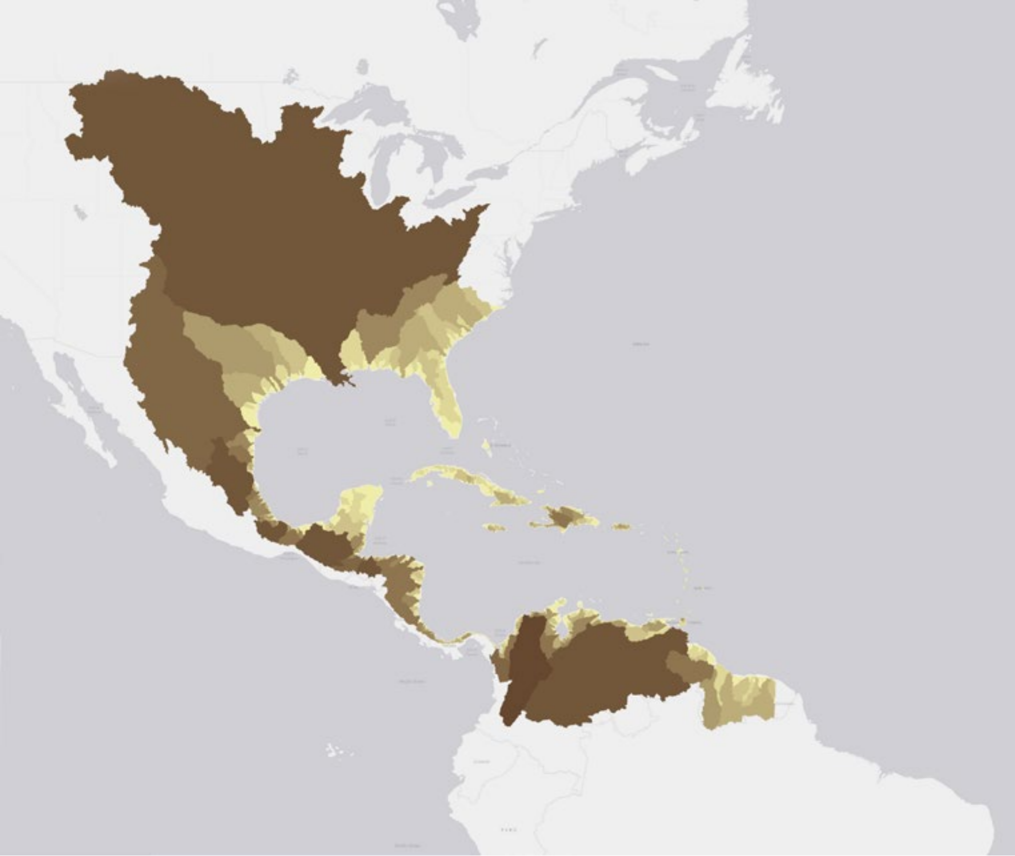

Figure 2.1. Extent of watersheds draining into the Caribbean Sea and Gulf of Mexico

(Burke and Maidens 2004; https://databasin.org/datasets/b4467d4d168b4876bb2eee4ee6061a80)

Notable among the river basins are:

- **_Orinoco, Venezuela:_** A watershed area of about 990,000 km² (covering most of Venezuela and the eastern part of Colombia) makes this the third largest in South America.
- **_Amazon, Brazil:_** The Amazon River is the largest point source of freshwater entering the southwestern Atlantic Ocean. It adds a vast surface plume that extends hundreds of kilometres to the northwest (Müller-Karger et al. 1988).
- **_Magdalena, Colombia:_** This is Colombia's largest river basin, which covers a surface of 273,000 km² (24% of Colombia's total area) and where 66% of its population lives. The Magdalena is the fifth largest river basin in South America and is the largest river discharging directly into the Caribbean Sea (Restrepo et al., 2006). In the Western Caribbean Sea, the plume of the Magdalena River extends north and eastward under the influence of an ocean current called the Colombia-Panama Gyre.
- **_Mississippi, USA:_** At 3.2 million km² in area, this is the largest drainage basin in North America, and the third largest in the world.

Other major rivers systems influencing the WCR include the Rio Grande (Mexico), Usumacinta/Grijalva (Mexico), Artibonito (Dominican Republic/Haiti), and Motagua (Guatemala).

The region's watersheds are generally associated with intense agricultural production and large population centres, which represent demonstrated risks for the marine environment and living marine resources. River outflow introduces massive quantities of freshwater and sediments (Table 2.1) as well as nutrients, sewage, agricultural chemicals, and urban and industrial wastes, and other pollutants, to coastal waters. However, these materials of riverine origin are not just retained near the river mouths and along the coast, but are transported by ocean currents across the entire region. For example, outflow from the Amazon and Orinoco Rivers creates plumes of freshwater across wide stretches of the Caribbean Sea (Müller-Karger et al. 1988, 1989).

Table 2.1. Drainage basin, water discharge, sediment and dissolved loads, calculated yields, and receiving basin for some major rivers influencing the WCR.

River	Basin area (x10^6 km^2)	Water discharge (km^3 yr^{-1})	Total Suspended Solids (g L^{-1})*	Sediment load (x10^6 t yr^{-1})	Sediment yield (t km^2 yr^{-1})	Total dissolved load (x10^6 t yr^{-1})
Amazon	6.15	6,300	0.19	1,200	190	**290**
Orinoco	0.99	1,100	0.19	150	150	**30**
Magdalena	0.25	228	0.61	144	560	**30**
Atrato	0.035	81		11	315	**1.0**
Mississippi*	3.3	490	0.82	400 (150)	120 (45)	

(Compiled by Restrepo et al. 2006, from various sources. *Milliman 2001, doi:10.1006/rwos.2001.0074). Loads and yields in parentheses represent present-day values, the result of river damming and diversion)

2.3. Ocean circulation[10]

The Caribbean Sea is influenced by several ocean currents including the North and South Equatorial, North Brazil, Guiana, and Caribbean currents, as well as the Colombia–Panama Gyre (Figure 2.2). Water for the major surface circulation (Caribbean Current) originates from the equatorial Atlantic Ocean via the North Equatorial, North Brazil, and Guiana currents. The Caribbean current results from the flow of the South Equatorial current as it moves northwards along the coast of Brazil. It continues in a north-westward direction through the Caribbean along the coast of South America and into the Gulf of Mexico, where it forms the Gulf Stream.

The counter-clockwise circulation of the Columbia–Panama Gyre is evident offshore from southern Central America (Nicaragua, Costa Rica, and Panama) and northern Colombia. The Guiana Current, which enters the Caribbean along the northern coast of South America, is considerably influenced by freshwater discharges from the Amazon and Orinoco rivers (Morrison and Smith 1990). Similarly, discharges from the Mississippi and Magdalena Rivers also influence the ocean circulation in the region. In addition, hurricanes play a significant, but transient role, in shaping the region's ocean circulation.

Figure 2.2. Major ocean currents influencing the Wider Caribbean Sea
(https://en.wikipedia.org/wiki/Caribbean_Current).

River outflow is transported by ocean currents into the Caribbean Sea and northwards through the Gulf of Mexico. Since both the Caribbean Sea and the Gulf of Mexico are semi-enclosed seas, this means that contaminants may not be flushed as rapidly compared to open ocean areas. Furthermore, mesoscale eddies and meanders in the Caribbean Sea may retain contaminants for extended periods. For example, a ten-month journey from the Lesser Antilles to the Yucatan Channel is typical for most eddies (Murphy et al. 1999).

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[10] Description based on Gyory et al., (2013).

2.4. Permeable soils and karstic groundwater aquifers

Certain geologic features, such as a permeable limestone soil, which is characteristic of many of the Caribbean islands, Florida, and the Yucatan Peninsula, can enhance groundwater flow into coastal waters. Another feature is the predominantly karstic nature of some coastal groundwater aquifers, which discharge directly into coastal waters. Many of these aquifers have been found to be polluted.

2.5. Living marine resources

The complex interaction of riverine discharge and coastal and ocean processes promotes high marine ecological and biological diversity. Among the region's marine ecosystems are coral reefs, mangroves, seagrass beds, beaches, wide expanses of muddy continental shelf, and pelagic systems, as well as all of the biodiversity associated with these ecosystems. The region is characterized by a rich marine biodiversity with high endemism, and also boasts the longest barrier reef in the Western Hemisphere—the 220 km long Mesoamerican Reef (MAR) system, which extends from the Yucatan Peninsula to Honduras. Details on the WCR's marine habitats are presented in the State of Nearshore Marine Habitats in the Wider Caribbean report. As mentioned in Chapter 1, the goods and services provided by marine ecosystems underpin important economic sectors (e.g., fisheries and tourism) in the WCR.

3. APPROACH AND METHODOLOGY

APPROACH AND METHODOLOGY

3.1. Conceptual framework

The assessment is based on the Driver-Pressure-State-Impact-Response (DPSIR) framework (Figure 3.1), which is widely used to assess and manage environmental concerns. Developed by the European Environmental Agency, it describes the interactions between human society and the environment (EEA 2007).

Driver (or driving forces): The socioeconomic and sociocultural forces driving human activities, which increase or mitigate pressures on the environment (e.g., coastal human population, agriculture). The EEA defines them as "the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns" (EEA 2007).

Pressure: The anthropogenic factors inducing environmental change. They are defined as developments in release of substances (emissions), physical and biological agents, the use of resources, and the use of land by human activities (e.g., nutrient loads introduced to coastal areas from sewage and agricultural run-off).

State: The condition of the environment and/or a socioeconomic system. The combination of the current State and the existing Pressures leads to Impacts (e.g., concentration of nutrients in coastal waters).

Impact: Changes in environmental functions affecting social, economic, and environmental dimensions, which are caused by changes in the State of the system. Another concept of "Impact" is the "distance" between the current environmental and socioeconomic state and desired state that society aspires to.[11] These Impacts trigger Responses.

Response: Responses by society to address the environmental state and which attempt to prevent, eliminate, compensate, or reduce the consequences of that state.

Using the DPSIR framework, a set of questions was developed to guide the assessment (Box 3.1):

Box 3.1. Guiding questions

1. What is the current state and trends in the condition of the marine environment with respect to substances of concern under the LBS Protocol?
2. What are the human drivers and sources of pressures and how are they changing in space and time?
3. How is changing environmental state affecting ecological and human health and economies, and our ability to achieve societal goals?
4. What mechanisms are in place to address land-based marine pollution? What is constraining their effectiveness?
5. Where are we headed if we continue with 'business-as-usual'? What should we do differently?

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[11] CLME+ Project

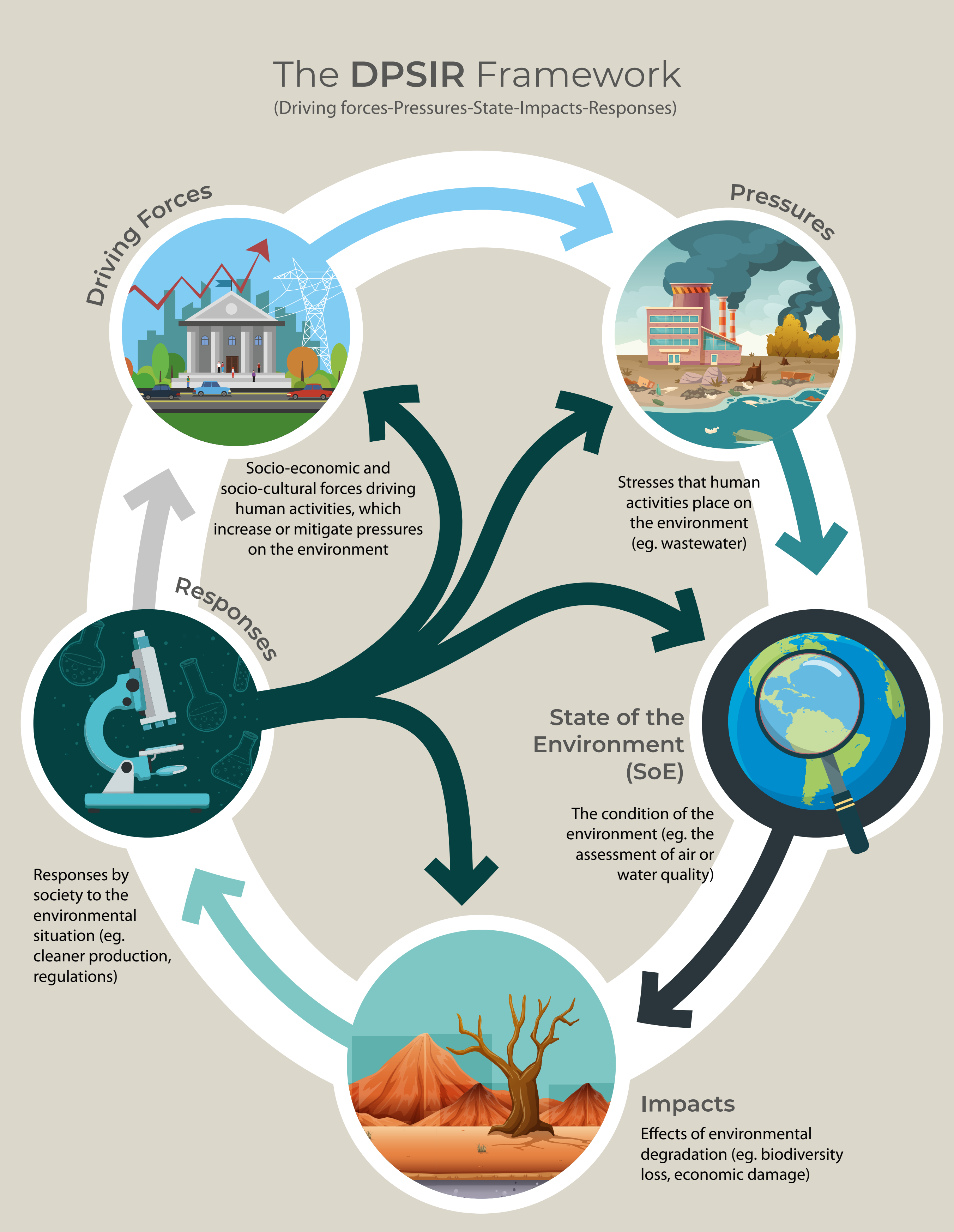

Figure 3.1. Driver-Pressure-State-Impact-Response Framework
(Source: Delphine Digout, UNEP/GRID-Arendal; https://www.grida.no/resources/5810)

3.2. Geographic scale

The broad geographic scale of the assessment is the Cartagena Convention area (Figure 1.1). This area encompasses the entire Gulf of Mexico and Caribbean Sea LMEs, and part of the North Brazil Shelf LME and the Southeast US Continental Shelf LME. The Caribbean Sea and North Brazil Shelf LMEs are covered by the CLME+ Project and are referred to as the CLME+ region. For the purposes of this assessment, the Convention Area was divided into the five sub-regions (Figure 3.2 and Table 3.1) designated in the UNEP-CEP Technical Report 52 (UNEP-CEP 2010a).

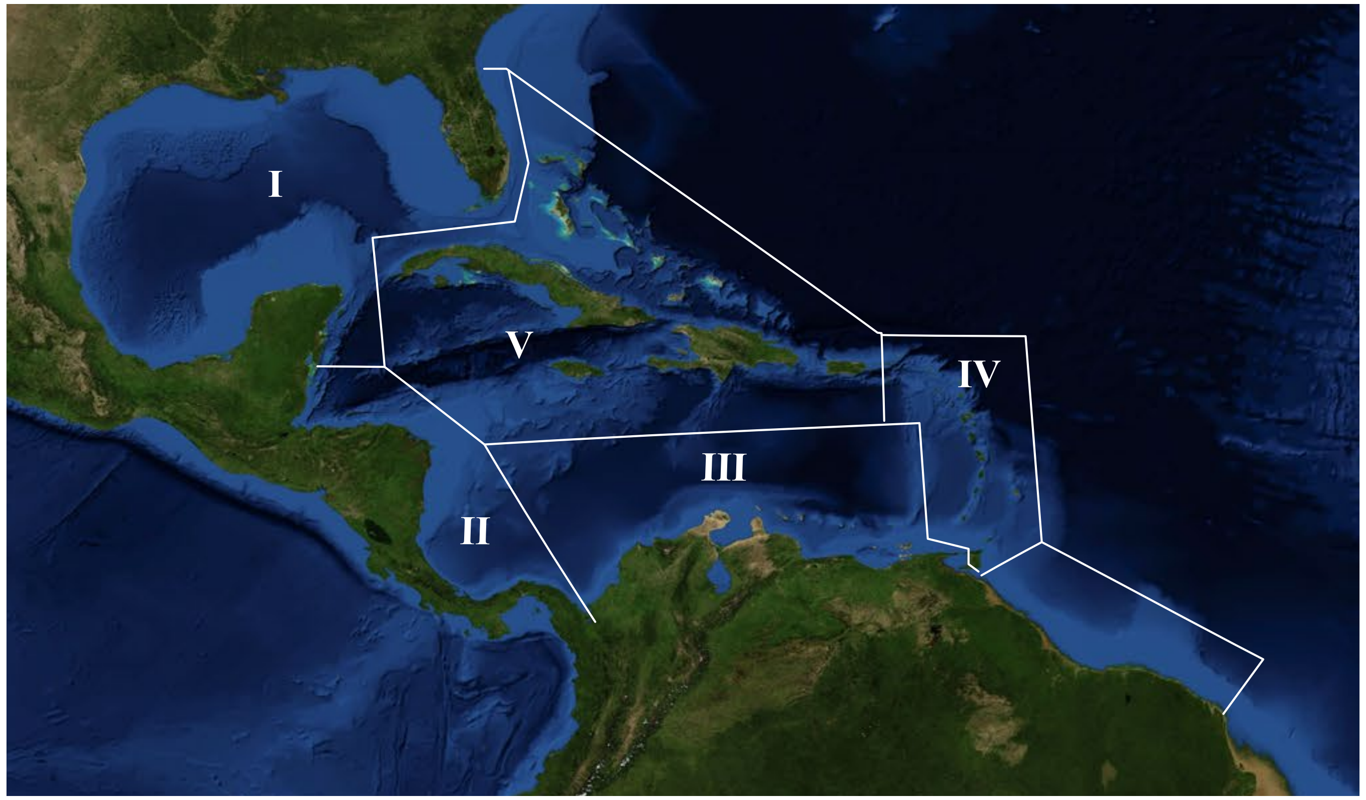

Figure 3.2. The Wider Caribbean Region and the five SOCAR sub-regions (see Table 3.1 for associated countries and territories).

Table 3.1. Table 3.1. Countries and territories in each of the five SOCAR sub-regions.

Sub-region	Name	Countries/ Territories
I	Gulf of Mexico	United States of America, Mexico
II	Western Caribbean	Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama
III	Southern Caribbean	Colombia, Venezuela, Guyana, French Guiana, Suriname, Aruba, Bonaire, Curacao
IV	Eastern Caribbean	Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Saba, St. Eustatius, St. Martin, Sint Maarten, Saint Lucia, St. Barthelemy, St. Kitts and Nevis, St. Vincent and the Grenadines, US Virgin Islands, Trinidad & Tobago
V	Northeastern and Central Caribbean	The Bahamas, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Turks and Caicos Islands

3.3. Thematic scope

3.3.1. Priority LBS sources and parameters

LBS source categories were arranged by the SOCAR inception workshop according to high, medium, and low priority (Table 3.2).

Table 3.2. LBS source categories and corresponding priority assigned by the workshop.

High	Medium	Low
● Domestic sewage ● Agricultural point and non-point sources ● Chemical industries	● Oil refineries ● Resource extraction industries ● Intensive animal rearing operations (in small islands) ● Sugar factories and distilleries	● Food processing ● Pulp and paper factories

The workshop also identified a list of priority ambient coastal water quality parameters considered important for this assessment (Table 3.3).

Table 3.3. The core SOCAR LBS parameters and other priority parameters.

Core SOCAR LBS Parameter	Other priority parameters
● Nutrients (Dissolved inorganic nitrogen and Dissolved inorganic phosphorus) ● Chlorophyll-a ● Dissolved oxygen ● Turbidity ● pH ● *Escherichia coli* ● *Enterococcus species*	● Fats, oil, and grease ● Biochemical oxygen demand ● Floating plastic density ● Total suspended solids ● Salinity ● Temperature

In selecting indicators, consideration was given to the source categories and associated parameters covered in the LBS Protocol Annexes: Annex I (nutrients), Annex III (sewage), and Annex IV (agricultural non-point sources). After the 2016 workshop and following extensive discussions, the LBS Data Sub-group agreed in February 2018 that the report would focus on the original eight LBS parameters. It is important to note that the original LBS parameters were for effluent discharges; however, for the SOCAR report these parameters are assessed in the receiving waters. Consideration was also given to indicators for SDG 14, Target 14.1 (nutrients, plastics) and the harmonized set of Regional Seas indicators. In addition, an overview of marine litter (including plastic) is also given since it is increasingly being recognized by the LBS COP as a priority. A brief discussion of mercury is also presented, owing to its high toxicity to humans and the recent discovery in several Caribbean SIDS of high levels in humans who were thought to be exposed to mercury through consumption of certain species of marine fish.

3.3.2. Socioeconomic parameters

A description of the region's key socioeconomic features is necessary to understand the linkages between the human system and the marine environment, and to assess the potential socioeconomic impacts of marine environment degradation and depletion of its living resources. A description is presented for demographic trends, urbanization, human development patterns, and major marine-based economic sectors, as well as land-based sectors that potentially impact the marine environment (e.g., agriculture and manufacturing). See Chapter 4 and associated annexes for input data sources and technical notes on the quantitative assessment of these parameters.

3.4. Data sources

3.4.1. National data

At the inception workshop, it was agreed that the assessment would be based on national water quality data, where available. It was also suggested that national data should be provided according to Class I[12] and Class II[13] waters (as defined in Annex III of the LBS Protocol), but this was not feasible since most of the assessment countries have not yet classified their waters. The baseline years for the current assessment are 2009–2014 (although data for 2015 and 2016 were included where available).

A template was developed by the Secretariat and distributed to the WCR countries with a request for national water quality data sets. Data for at least 70 different parameters was submitted by 16 countries/territories (nine countries of which are Parties to the LBS Protocol) in sub-regions I, III, IV, and V (Figure 3.3). The data from Guyana was for sugar factory effluent and was not included in the coastal water quality assessment. No data was received from countries in sub-region II. In addition, bacteriological data for four countries (Barbados,[14] Dominica, Saint Lucia, and St. Vincent and the Grenadines) were available in a Master's thesis[15] from the University of the West Indies and provided by the Caribbean Public Health Agency (CARPHA). Countries and territories that submitted data, as well as the main parameters covered by the data, are given in Annex 3.1. Locations of water quality sampling sites by country/territory are provided in Annex 3.2.

Because of sensitivity by the assessment countries around the release of national water quality data, it was agreed that raw data would not be included in the report or made public by any means. This was respected throughout the assessment. The Cartagena Convention Secretariat is the repository for all data and methodologies used in the assessment, as well as for the assessment results.

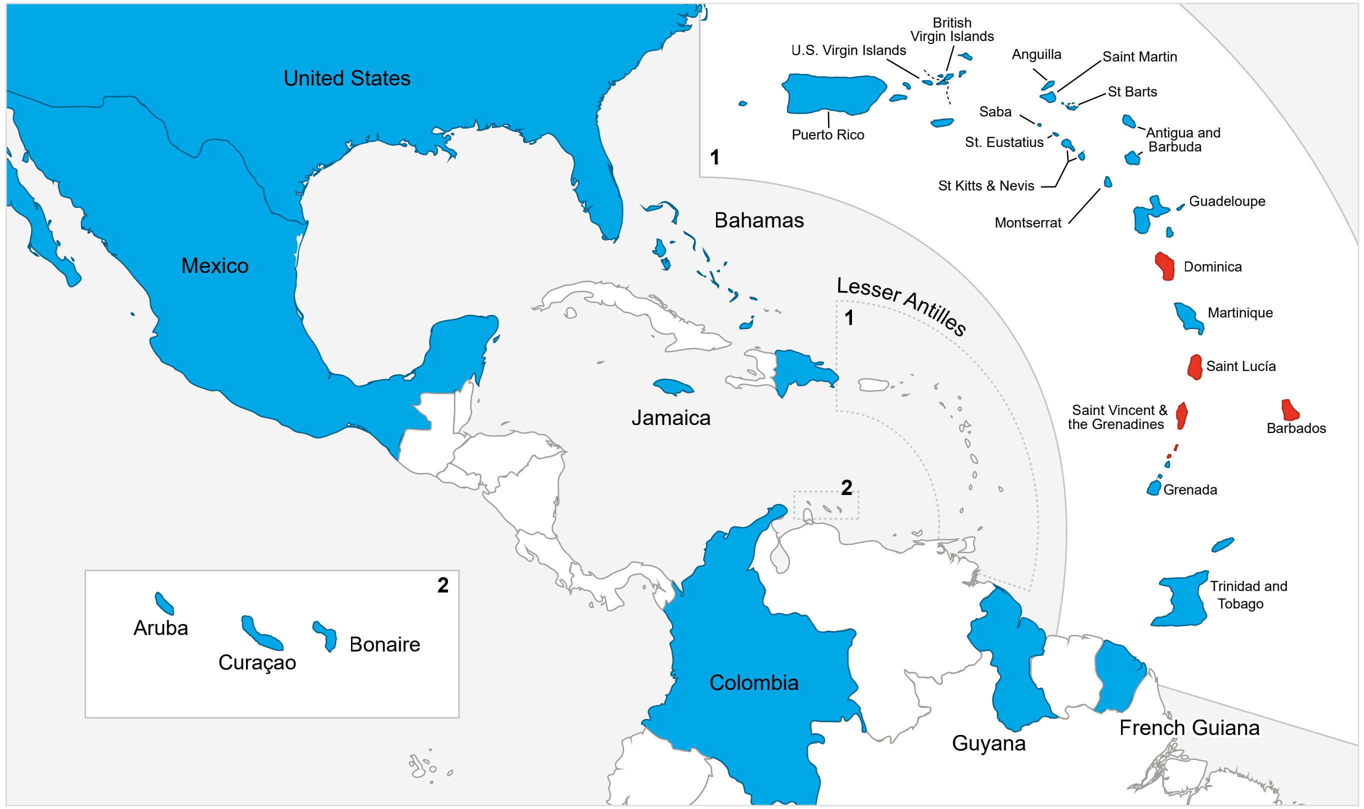

Figure 3.3. Submission of water quality data by countries

(blue: data submitted by countries; red: data from CARPHA).

3.4.2. Regional and global data sets

Modelled results for dissolved nutrient loads (DIN, DIP) moving from watersheds to coastal areas for the five sub-regions were provided by E. Mayorga (University of Washington). Inventories of fertilizer use and domestic wastewater generation and discharge were developed for this study using data from the World Bank and FAO Aquastat. In addition, total nitrogen (TN) and total phosphorus (TP) loads by anthropogenic and natural sources were estimated using input data from Beusen et al., (2016). See Chapter 4 and associated annexes for input data sources and technical notes.

3.5. Analysis of national water quality data

For each country and territory, where data availability allowed, separate analyses were conducted for the dry and wet seasons[16] for each of the core parameters. For each parameter, the seasonal average was produced for each sampling site (all years combined). Assessment ranges (or cut values) for good, fair, and poor (or acceptable) status (see Chapter 6 for the ranges) for each of the core parameters were recommended by the STAC (2014) and endorsed by the COP. [17]The assessment ranges are based on the United States National Coastal Condition Report III (2008),[18] except for *E. coli* and *Enterococcus*, for which cut values were taken from Annex III of the LBS Protocol for discharges to Class 1 waters.

For each of the core parameters, the appropriate cut value was applied to each site average, and the proportion of sites in each range was generated by season (colour-coded: green [good], yellow [fair], and red [poor]; or within [green] or outside [red] of the acceptable range). Maps were also prepared for each country/territory showing the status of each sampling site by season. Examples of such maps were presented at the SOCAR workshop held prior to the LBS STAC meeting in 2018. However, the LBS STAC requested that the status of each site not be shown (due to sensitivity by the countries) and to show instead the percentage of sites in each assessment range.

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[12] Class I waters: waters in the Convention area that, due to inherent or unique environmental characteristics or fragile biological or ecological characteristics or human use, are particularly sensitive to the impacts of domestic wastewater.

[13] Class II waters: waters in the Convention area, other than Class I waters, that due to oceanographic, hydrologic, climatic, or other factors are less sensitive to the impacts of domestic wastewater and where humans or living resources that are likely to be adversely affected by the discharges are not exposed to such discharges.

[14] Not used in this assessment

[15] De Leon, Shervon L. R. 2012. Adequacy of bacterial pollution indicators in tropical recreational waters. A Thesis Submitted in partial fulfillment of the requirements for the Degree of Masters of Philosophy in Microbiology, University of the West Indies, cave Hill, Barbados.

[16] Information on the duration of each season was obtained for each country/territory from one of two sources: The Caribbean Regional Climate Centre/Caribbean Institute for Meteorology and Hydrology (https://rcc.cimh.edu.bb/caribbean-climatology/1981-2010/) and the World Bank Climate Change Knowledge Portal (http://sdwebx.worldbank.org/climateportal/).

[17] Draft Cut Values to Evaluate Monitoring Data from Coastal Segments in: Report of the Working Group on Environmental Monitoring and Assessment, 2013- 2014. UNEP (DEPI)/CAR WG.35/INF.5, 21 April 2014.

[18] http://water.epa.gov/type/oceb/assessmonitor/nccr/index.cfm.

4. INTERACTION OF HUMANS WITH MARINE ECOSYSTEMS: DRIVERS OF ENVIRONMENTAL CHANGE

INTERACTION OF HUMANS WITH MARINE ECOSYSTEMS: DRIVERS OF ENVIRONMENTAL CHANGE

Key messages

Marine-based economic sectors make substantial contributions to the Gross Domestic Product in specific WCR countries and territories. These include tourism, fisheries, shipping, and the petroleum sectors, which provide livelihoods—and in the case of fisheries, food security—for millions of the region's inhabitants. Tourism and fisheries are critical pillars of the economies of many of the countries and territories, and are dependent on healthy marine ecosystems.

People and economies are major drivers of environmental change in the region. Changes in demographic trends including urbanization, and production and consumption patterns are shaping the condition of the marine environment and marine ecosystems. Concentration of human populations and economic activities in coastal areas, accompanied by poor urban planning, inadequate wastewater treatment facilities, and inadequate solid waste management give rise to diverse pressures on the marine environment. Human population, urbanization, and economic sectors such as tourism are projected to continue to grow over the coming decades, which will intensify pressures on the marine environment under a "business as usual" scenario.

4.1. Introduction

People and the economy are major drivers of environmental change. In the WCR, demographic trends, production and consumption patterns, and intensity of economic activities contribute significantly to shaping the condition of the marine environment, including water quality and ecosystem health. Understanding human–environment interactions in sustaining natural resource-based economies and food security is key to maintaining the well-being of ecosystems and that of dependent coastal communities. Understanding socioeconomic linkages and dependencies is also critical to supporting WCR countries as they explore blue economy approaches.

This chapter provides the socioeconomic context for the assessment of land-based pollution in the Cartagena Convention area. Socioeconomic data from existing global and regional data sets, and indicators estimated in this study, are organized by country and sub-regional scales to examine patterns of change and their potential contribution to the changing quality of coastal and marine waters in the region. Where spatial data is available, features of the coastal 100 km margin of continental countries are used, and likewise presented. All data sources and methods are provided in Annex 4.1.

4.2. Demographic trends

4.2.1. Population change, 1950–2050

Using historical country data and projections from the UN World Urbanization Prospects (2018), population shows a decelerating increase over a 100-year period from 1950 to 2050. This occurs at rates slower than those for the rest of the world, with the exception of sub-region II (Figure 4.1A). Over the 30-year historical period from 1960 to 1990, Western Caribbean countries (sub-region II) and Southern Caribbean countries (sub-region III) more than doubled their populations (Figure 4.1B). For the contemporaneous period from 1990–2020, population growth rates are estimated to decrease across all five sub-regions. Projections for the following 30-year period from 2020 to 2050 indicate no population increase for sub-region IV, Eastern Caribbean (Figure 4.1B).

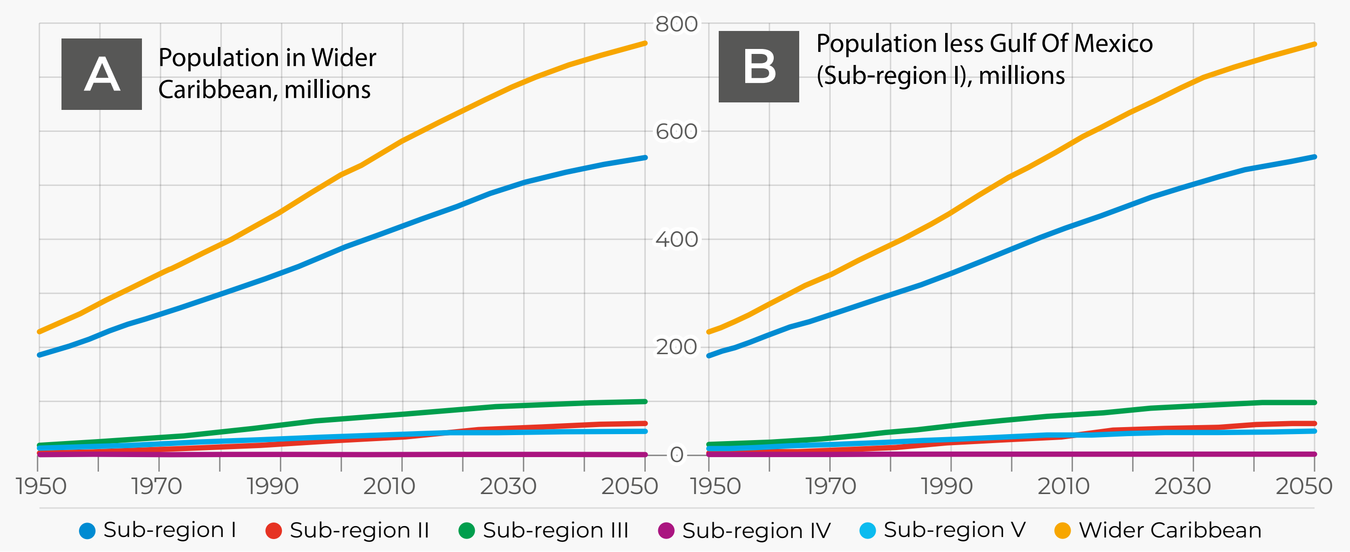


Figure 4.1. Demographic patterns in the Wider Caribbean using national population estimates for the period 1950–2050.
(Data source: UN World Urbanization Prospects 2018).

4.2.2. Contemporary spatial distribution of coastal population

Examining spatially explicit population data for 2010, 2015, and 2020, inhabitants along the 100 km Caribbean coastal areas of continental countries (sub-regions I, II, and III) account for 68–71% of the regional population (Table 4.1). Those residing in the island states and territories of sub-regions IV and V make up the remainder. The total regional population of 132 million in 2010 is projected to increase to 149 million by 2020. Population densities in continental coasts range from 7 persons per km^2 in French Guiana to 132 persons per km^2 in Costa Rica. The islands show a higher density range, from 35 per km^2 in Turks and Caicos to 1,049 per km^2 in Sint Maarten.

Relative to the aggregate national populations and land areas of mainland countries, those living on the coast make up 17% of the total mainland population, but are confined to only 9% of combined national areas. Because of their relatively small land masses, islands are considered to be entirely coastal. Indeed, the region's coastal margin is a favoured area for habitation and commerce. This trend, however, comes with potentially serious consequences for the health of the region's marine and coastal ecosystems through intense natural resource exploitation and pollution.

Table 4.1. Continental and island coastal populations in the Wider Caribbean Region.

Coastal population (within 100 km of the continental coast and island-scale)	**2010**	**2015**	**2020**	**Population densities (2015)**
Continental countries in sub-regions 1, 2, & 3; scale = population in 100 km coast	90,137,759 (68% of WCR total)	97,160,339 (69% of WCR total)	105,352,988 (71% of WCR total)	7/km^2 (French Guiana) to 132 / km^2 (Costa Rica)
Island States & Territories in sub-regions 3, 4, & 5; scale = total island population	42,140,864 (32%)	42,810,106 (31%)	43,952,122 (29%)	35/ km^2 in Turks & Caicos to 1,049/ km^2 in Sint Maarten
Total WCR coastal population	132,278,623	139,970,445	149,305,110	

Population distribution in each sub-region in 2010, 2015, and 2020 is shown in Figure 4.2 and country-scale demographic data are summarized in Annex 4.2.

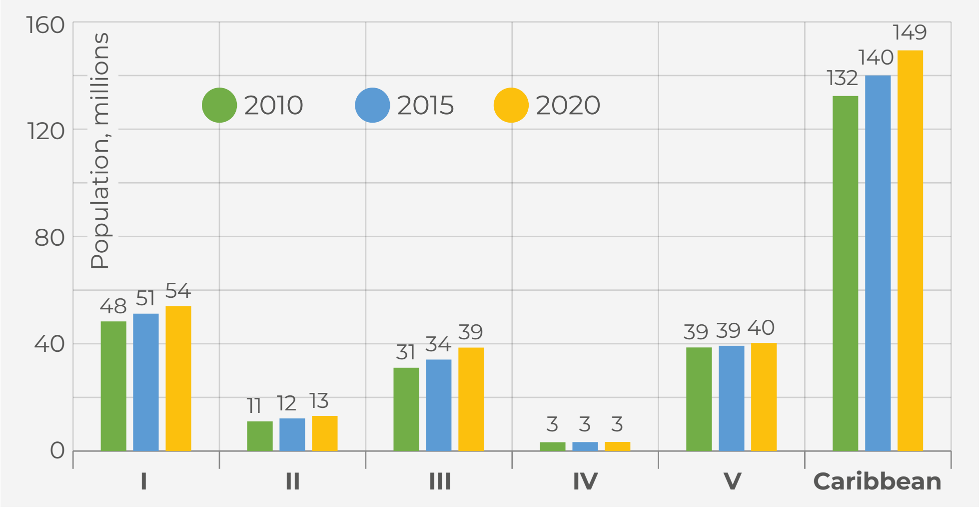


Figure 4.2. Population distribution in the Wider Caribbean Region for contemporary years 2010, 2015, and 2020 within 100 km of the coast and at the sub-regional and WCR scales.

Over the 10-year period, the resident population averaged 140 million inhabitants (input data source: Spatial population data from Columbia University CIESIN 2017, and processed by CATHALAC).

4.3. Urbanization, 1950–2050

At both local and regional scales, urbanization has profound impacts on land cover and use, water cycles, and biogeochemical cycling (Talaue-McManus 2010, Seto et al., 2010). Urban growth in the region has not been accompanied by adequate urban planning, especially in small- and medium-sized cities (UNEP 2016a). As a result of inadequate or non-existent wastewater treatment facilities and solid waste management, urban areas along the coast have become major sources of untreated wastewater and litter that are placing increasing pressure on urban freshwater ecosystems and coastal areas.

Despite a projected slow-down in population growth rate from 1950 to 2050, the WCR is urbanizing rapidly—sub-regions I, III, and V will reach over 84–90%, and sub-regions II and IV will reach 73% and 67%, respectively, by 2050 (Figure 4.3, Table 4.2). In fact, the WCR, along with the rest of Latin America, has the highest rates of urbanization on the planet (Guzman et al., 2006, Barragan and Andrés, 2015).

To identify centres of coastal population growth for the period 1950–2030, coastal cities and population agglomerations that had a population size of 300,000 people and higher in 2017 were classified into five groups following the Urbanization Prospects 2018 Revision (UN Population Division): (1) 300,000–500,000; (2) 500,000–1,000,000; (3) 1–5 million; (4) 5–10 million, and (5) 10 million and greater (Figures 4.4 and 4.5).

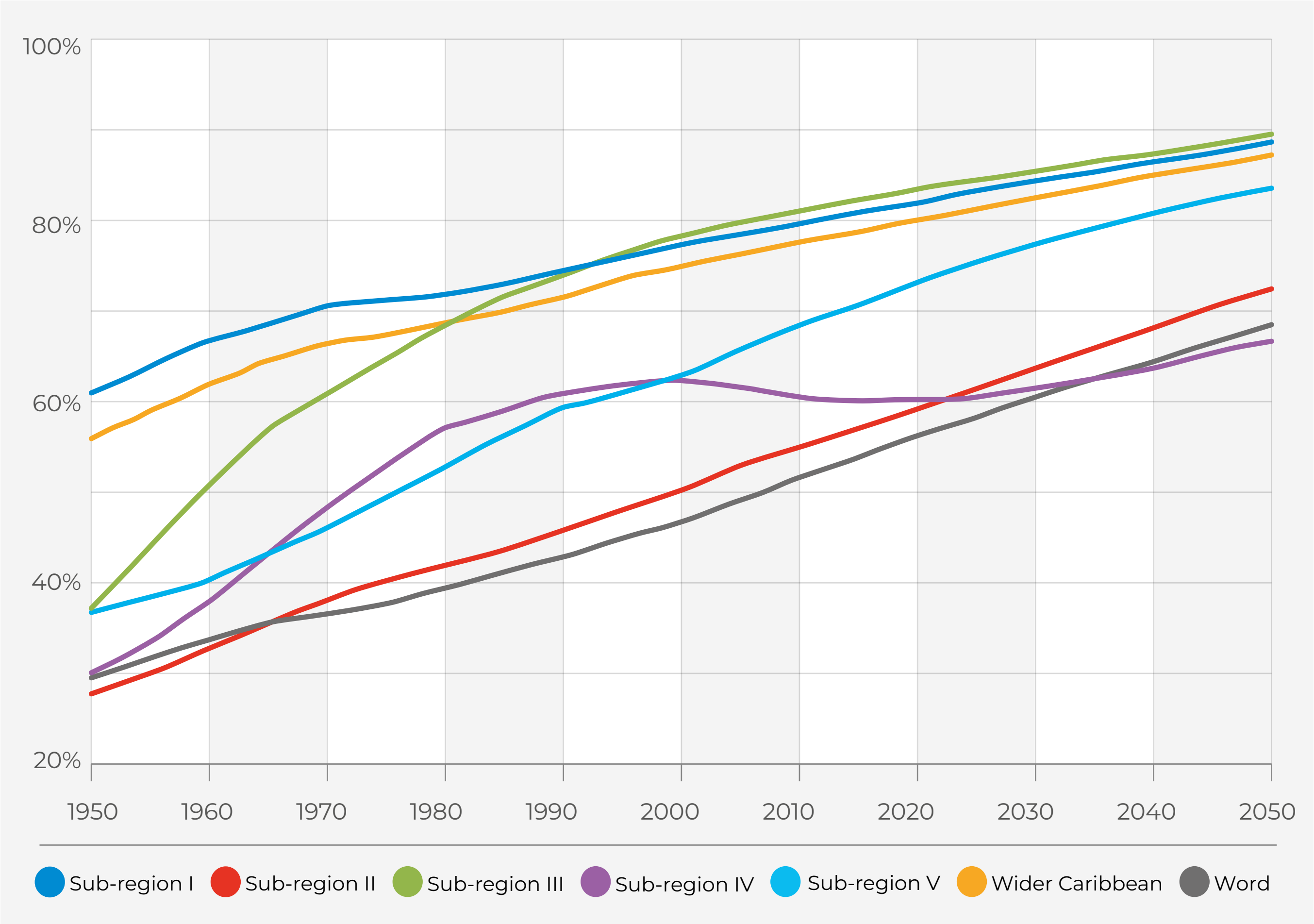


Figure 4.3. Urbanization rate in the WCR for the period 1950–2050

(Input data source: UN Population Division Urbanization Prospects 2018).

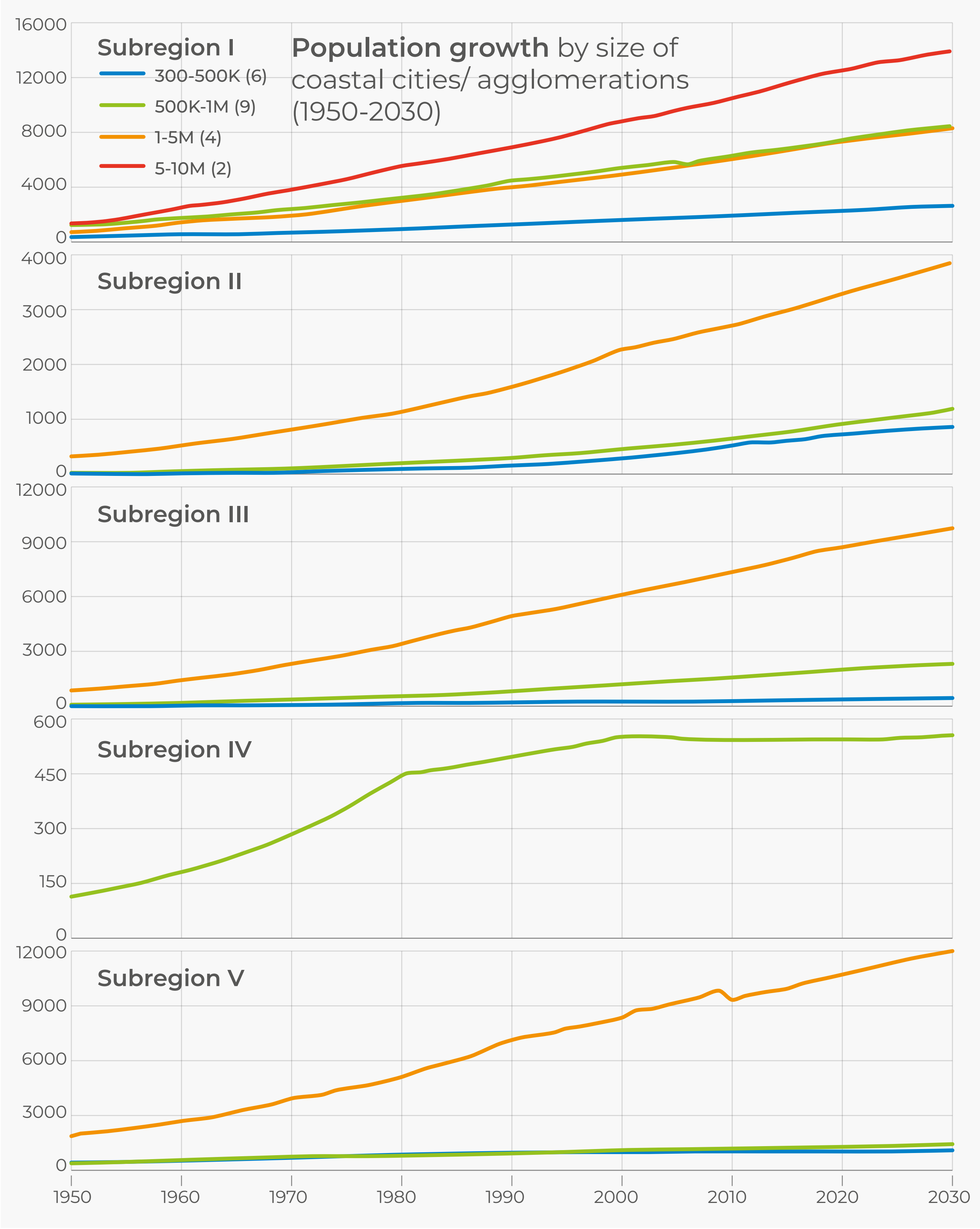


Figure 4.4. Sub-regional population growth (in thousands) by size of coastal cities and population agglomerations for the period 1950 to 2030.
(Input data source: UN Population Division Urbanization Prospects 2018).

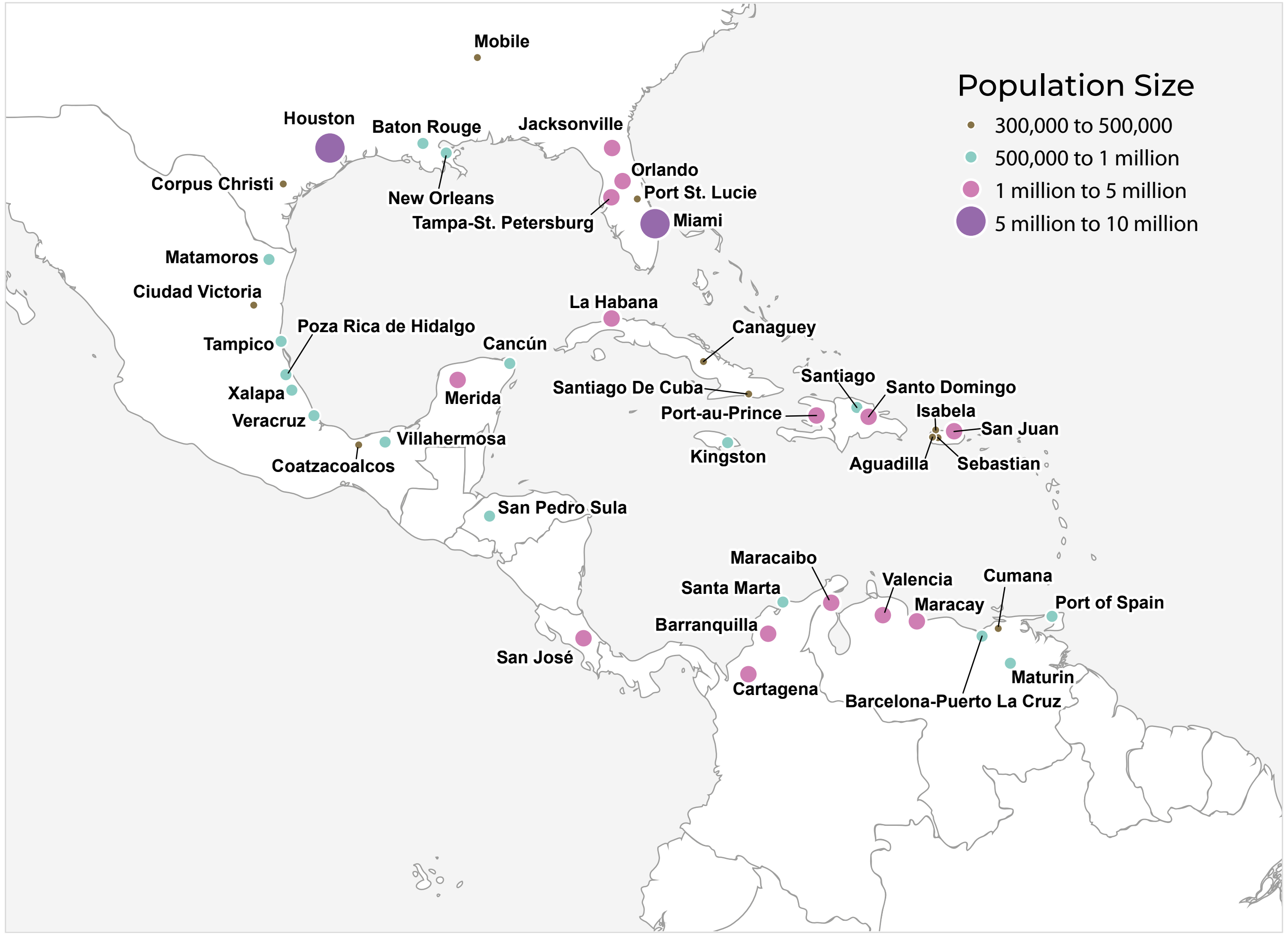
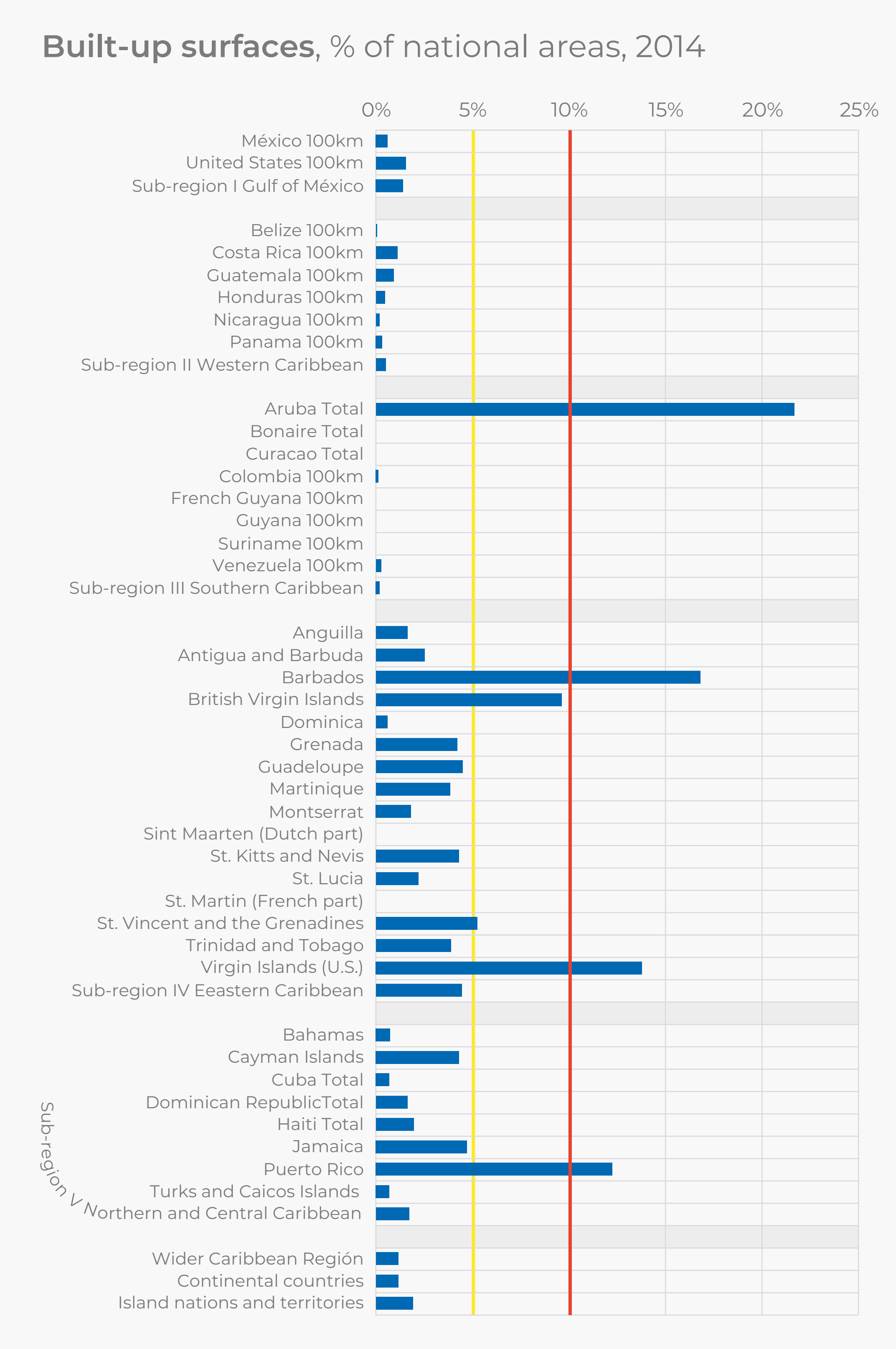


Figure 4.5. Main coastal urban centres in the WCR based on population sizes in 2017
(data from UN Population Division Urbanization Prospects 2018; map prepared by CATHALAC).

Pressures on coastal areas from urban centres are exacerbated by increased urban run-off due to replacement of vegetation (such as forests and agricultural lands) with paved surfaces and built-up areas that are impervious to water infiltration, including on hillsides and steep slopes. One of the most serious impacts of urbanization results from the rapidity with which sediments, nutrients, waste, and other contaminants from both the upland and low-lying coastal areas flow in episodic pulses to wetlands, rivers, estuaries, and marine ecosystems via run-off. Impermeable surfaces also prevent water infiltration that helps replenish groundwater.

Since the late 1970s, studies began to chronicle the visible degradation of aquatic ecosystems in situations where about 10% of land in the adjacent watershed becomes impervious (Klein 1979, Schueler and Holland 2000, Beach 2002). In the WCR, island states and territories are particularly vulnerable to losing their already limited natural landscapes as paved surfaces increase. Aruba, Barbados, the US Virgin Islands, and Puerto Rico exceeded the 10% threshold in 1990 (Figure 4.6). The British Virgin Islands, Grenada, Guadeloupe, St. Kitts and Nevis, St. Vincent and the Grenadines, and Jamaica, are among those currently around or past the halfway mark of 5%. Among the solutions to address increased run-off from paved surfaces are techniques such as "green" infrastructure"—for example, green rooftops and walls, roadside plantings, landscaped parks, urban farming, and other swatches of vegetation placed inside modern cities. These techniques can be costly at first, but in the longer term, going green can be a far more cost-effective solution than constructing large wastewater treatment plants (see WWAP/UN-Water 2018).

Figure 4.6. Built-up areas by country or territory as a percentage of national territory area in 2014 (data from OECD.Stat), including the 5% threshold yellow line and 10% threshold red line.



Demographic and development changes in the Wider Caribbean cross the threshold of irrevocable land use change caused by an increase in built-up surfaces decades before this happens in the world at large. These changes may be reaping both the positive and negative consequences of urban expansion. A long-term, forward-looking approach is needed to maintain ecological, social, and economic well-being in urbanizing continental coastal and island settings.

4.4. Human development patterns

The metrics and indices used as inputs to assess the Human Development Indices (HDI) for each of the 25 sovereign countries in the WCR for which data are available are given in Annex 4.3 (with technical notes in Annex 4.1). Based on the average five-year HDI for the period 2011–2015, 19 states have high HDI, 4 have medium HDI, 1 has very high HDI, and 1 has low HDI. Average life expectancy at birth (the lone health metric of HDI) ranges from 62.42 years for Haiti to 79.24 years for Costa Rica. Average expected years at school show a range from 9 years for Haiti to almost 17 years for the USA. Per capita Gross National Incomes exceed US$20,000 for several countries, including the USA, Antigua and Barbuda, Saint Kitts and Nevis, The Bahamas, and Trinidad and Tobago.

With the majority of the WCR's sovereign states having a high HDI ranking, the region in general enjoys a high level of affluence. This affluence whets appetites for lifestyles that require greater consumption of energy and higher extraction rates of ecosystem goods and services than in countries with lower HDI rankings. According to the World Bank, there is a connection between the income level and degree of urbanization of a country and the amount of waste generated. As populations increase, consume more, and lack the capacity to recover, re-use, or treat waste, a variety of consumer products and substances of industrial origin end up in coastal and marine waters.

4.5. Major economic sectors related to the marine environment

Tourism and capture fisheries, in addition to agriculture, shipping, manufacturing, and petroleum industries are among the major contributors to the Gross Domestic Product (GDP)[19] in specific WCR countries. On the other hand, these sectors also represent major sources of pressure on the environment and natural living resources, pressures that include land-based pollution. As such, sectors like fisheries and tourism, which are dependent on a clean environment and productive ecosystems, can be a threat to themselves. It is clear that key economic sectors must be part of the solution to the issue of land-based pollution. Their impacts on ecosystem health, human well-being, and food and income security must be measured and thoughtfully considered in integrated assessments if business and consumptive practices, as well as policy development, are to shift in fundamental ways towards sustainability.

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[19] It must be underscored that GDP does not account for environmental damages and other external costs, such as the depletion of renewable and non-renewable natural resources.

4.5.1. Tourism, fisheries, and aquaculture

Tourism

The Caribbean is more dependent on the travel and tourism sector than any other region worldwide. This sector accounts for 26% of GDP (this study) and 13.2% of jobs at the regional scale (Spalding et al., 2018). This high-value industry is a critical pillar of the economies of every Caribbean island state and island territory, with major contribution to their GDPs (Figure 4.7). As shown in Figure 4.7, on average, tourism contributes 33% of the GDP among Caribbean islands in general, and accounts for over 50% of GDP for specific countries and territories like the British Virgin Islands (86%), Aruba (83%), Antigua and Barbuda (60%), Anguilla (56%), and the former Netherlands Antilles (53%), as averaged for the period 2011–2015 using data from the World Travel and Tourism Council 2018. In contrast, the continental countries are less dependent, on average obtaining only 12% of their GDP from tourism. At the regional scale, using 2015 constant US$ currency, average annual contribution of tourism to national GDPs in the WCR for the period 2011–2015 amounted to US$1,685 billion per year.

Much of the tourism sector is marine-based, notably through beach-related activities, cruise tourism, and in-water activities such as sailing and diving. One of the biggest natural assets that support tourism in the region are coral reefs. A recent study estimated that the total value for all reef-associated tourism (on-reef and reef-adjacent[20]) in the Caribbean was over US$7.9 billion of expenditure involving more than 11 million visitors, with an average of 660 visitors and US$473,000 per km^2 of reef per year (Spalding et al. 2018). This study also found that the countries and territories that are most dependent on reef-adjacent tourism are many small island nations and territories, mostly in sub-region IV (Anguilla, Antigua and Barbuda, Bermuda, St Kitts and Nevis, and St Martin), where there may be relatively few livelihood alternatives to reef-based tourism.

The World Tourism and Travel Council (WTTC) has forecasted an increase in international arrivals in the WCR from 26.5 million in 2018 to 30 million in 2028 (WTTC, 2018). In addition, the Caribbean is one of the world's major cruising markets. Leading globally, in 2013 it was the main target destination for 34% of all cruises (UN 2016). The Caribbean cruise ship sector hosted 24.4 million passengers in 2015, an increase of 1.3 % from the previous year (CTO 2016). High water quality and healthy ecosystems make for premium destination. The provision of economic incentives continue to encourage the development of high-value tourism packages for the region.

But tourism, particularly mass tourism, can be a threat to itself, which may be more pronounced around coral reefs, since they are highly sensitive to physical and chemical impacts associated with dredging, pollution, anchor-damage, and other threats. The projected growth in tourism can lead to significant increases in waste loads from both land and marine-based tourism sources to coastal waters, unless wastewater treatment and management of solid waste are improved. Tourists generate substantial amounts of solid and liquid waste, and construction and operation of tourism infrastructure (which tend to be concentrated in coastal areas), such as hotels, marinas, and golf courses, are major sources of a range of contaminants that reach coastal waters (sewage, sediments, fertilizers, and pesticides).

Cruise ships, in particular, as well as other recreational vessels, produce vast quantities of waste. For example, on a one-week voyage, a moderately-sized cruise ship, which can accommodate around 3,500 passengers, generates about 795,000 litres of sewage, 3.8 million litres of grey water, 500 litres of hazardous waste, 95,000 litres of oily bilge water, and 8 tonnes of garbage (WWF 2015). An important component of the tourism services complex in the region is the yachting and marina subsector (Phillips 2014). Potential environmental impacts of marinas and recreational boating arise from discharges of sewage and oil/fuel, vessel maintenance and repair, and marine debris, among others (Ocean Conservancy, 2017). Inadequate waste infrastructure at ports, marinas, and anchorages for both solid and liquid waste can become a major deterrent to tourism growth in the region.

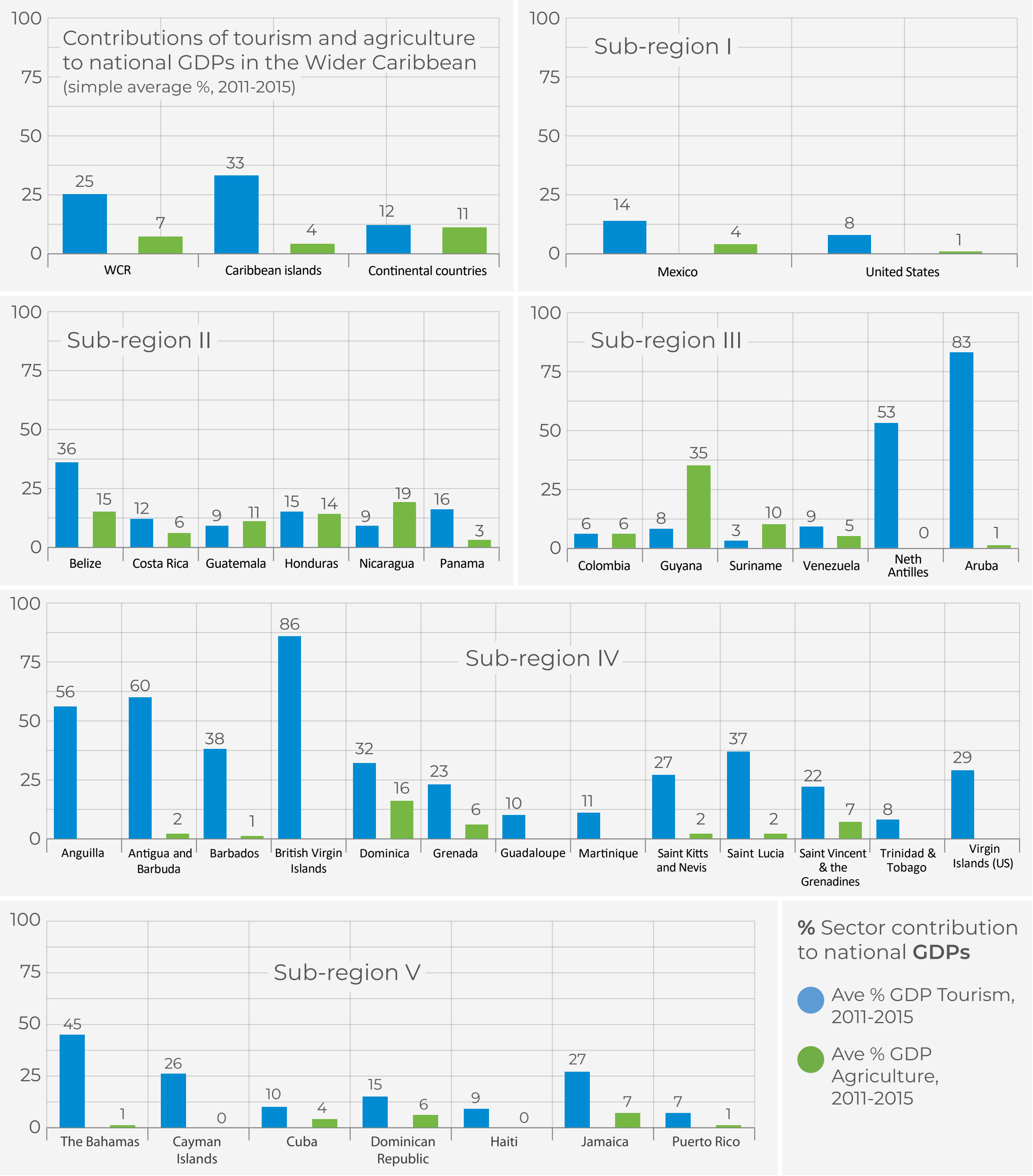

Figure 4.7. Contributions of agriculture and tourism sectors to national GDPs in the Wider Caribbean Region, averaged for the period 2011–2015

(Data sources: FAO, World Travel and Tourism Council. Only countries with data were included in computing simple averages—zeroes are rounded non-zero values; see Annex 4.1 for technical notes).

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[20] Reef-adjacent tourism is the component of tourism that depends on coral reefs without making direct use of them for activities such as diving and snorkeling. Instead, it includes values derived from views, calm waters, coastal protection, beach generation, and high-quality seafood.

Fisheries

Using the latest available 5-year dataset from 2010–2014, the average annual landed fisheries catch of 2.2 million tonnes in the WCR was priced at 2010 US$5.5 billion. The value chain generated an additional 90% of the landed value, on aggregate, an amount that provides supplemental household fishing income. The annual total economic value of marine capture fisheries in the region (including additional household income) over the 5-year period averaged about US$13 billion (input data sources: http://www.seaaroundus.org, Dyck and Sumaila, 2010; see Annex 4.1 for technical notes and Annex 4.4 for country-scale results). However, the contributions to national GDPs are low, ranging from 0.01% for Costa Rica and Guatemala, to 7.39% for Guyana, and 4.30% for Suriname (Figure 4.8).

With the exception of the US, Bahamas, Cayman Islands, and Sint Maarten (where industrial fishing dominates) and Aruba (where recreational fishing is the major fishing subsector), the majority of fishers in countries and territories of the WCR are artisanal, consisting of small-scale commercial fishers who fish mostly in domestic waters with passive (stationary) gear (Pauly and Zeller, 2016).

Some of the countries and territories, particularly the islands, show a high dependence on fish as a protein source, where fish protein consumption as a percentage of total animal protein reaches over 15% in a number of them, mostly in sub-region IV (Figure 4.8). Countries where this indicator exceeds 20% are Antigua and Barbuda, Barbados, Grenada, St. Kitts and Nevis, and Guyana. In addition to providing food security, the fisheries sector is an important source of livelihoods for millions of people, including women, in the region. Moreover, the sector (including fish farming) represents a vital social safety net, especially for rural communities.

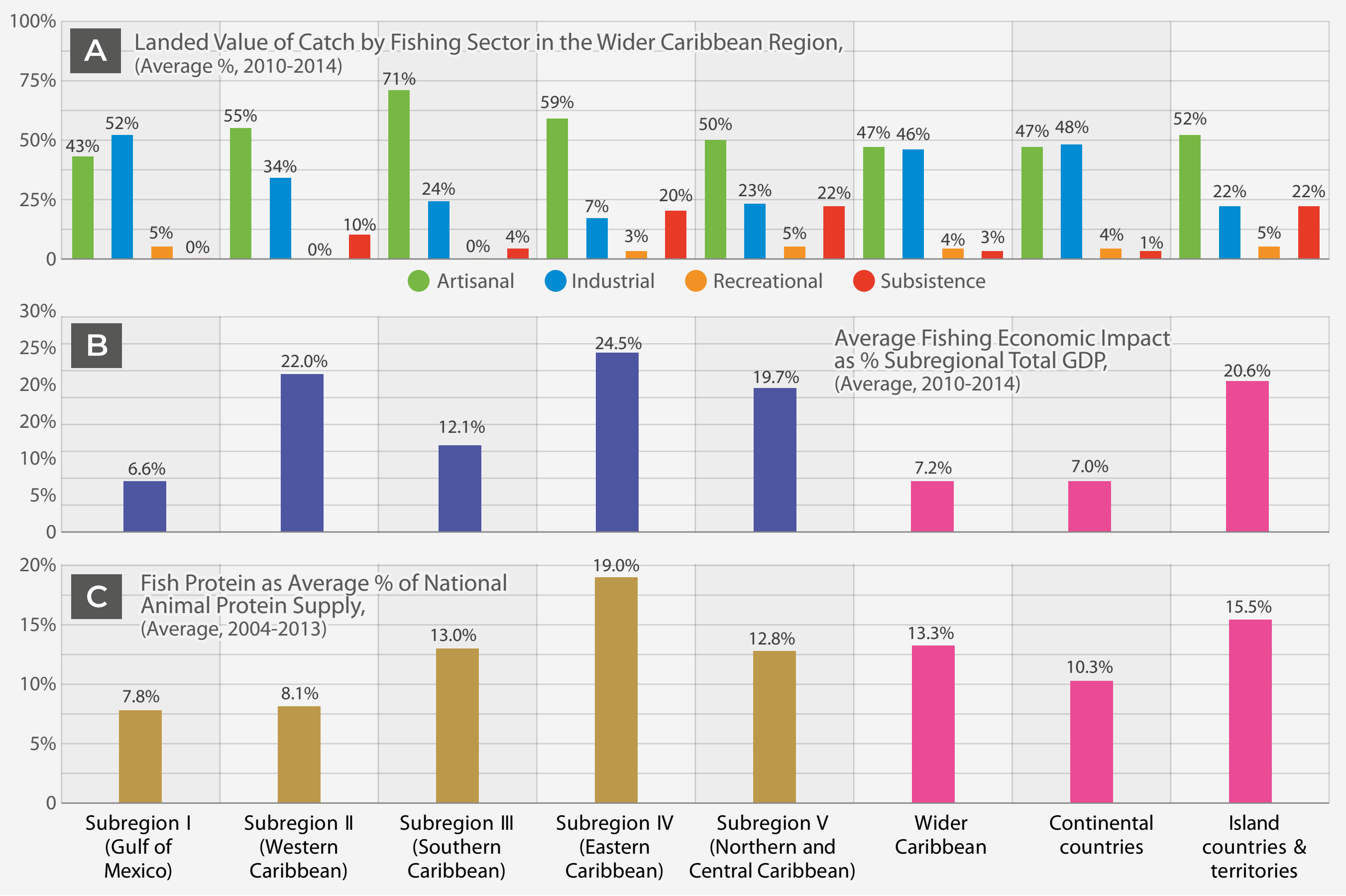

Figure 4.8. Characteristics of marine fisheries in the WCR and its total economic value for 2010–2014.

A. Landed value as average percentages from artisanal, industrial, recreational, and subsistence fishing sectors for 2010–2014; **B.** Fishing economic value as a percentage of sub-regional GDP or Group total GDP for 2010–2014; and **C.** Fish protein as an average percentage of national animal protein supply for 2004–2013.

(See Annex 4.1 for data sources and technical notes and Annex 4.4 for country-scale results.)

From 2000 to 2010, overexploited and collapsed fish stocks increased to 24% and 25%, respectively, in the four LMEs that make up the Wider Caribbean fishing grounds, representing almost half of the total number of fish stocks. As a result of decreasing catches (as is evident in the Gulf of Mexico and Caribbean Sea) and growing demand, the region is increasingly reliant on imports to meet 30% of its seafood consumption (FAO Caribbean Office, 2014).

While the consumption of fish is usually considered to be a healthy dietary choice, there is undisputed evidence that shellfish and predatory fish species such as tuna, swordfish, snappers, and groupers can be contaminated with harmful chemicals (e.g., mercury, biotoxins such as ciguatoxin that causes ciguatera fish poisoning in humans). They can also be contaminated with other harmful substances such as microplastics, which can be transmitted to humans through consumption of tainted seafood.

Poor water quality and degradation of marine ecosystems can contribute to a reduction in the abundance of fish populations. Land-based fisheries installations, such as fishing ports and fish processing plants, can be an important source of marine pollution from solid and organic wastes, oil, grease, cleaning products, and other substances. However, there have been limited studies on this aspect of the fishing industry, with focus being on the impacts of fishing effort and gear on marine ecosystems and fish stocks. Identification and quantification of the environmental impact of shore-based fisheries installations are needed and the information integrated into decision-making to ensure a more sustainable fishing sector.

Rebuilding collapsed and overexploited stocks, building resilience to climate change impacts, managing high-value species, and ensuring minimal seafood contamination from pollutants and pathogen- or toxin-bearing organisms amid increasing demand by residents and tourists for seafood, are some of the tough challenges currently faced by the fishing sector.

Aquaculture and mariculture

Aquaculture (including mariculture) continues to grow faster than other major food production sectors (FAO, 2018). Offshore mariculture (cage culture) is slowly gaining momentum in the region. A recent study (Thomas et al., 2019) found that the Caribbean has a significant potential for offshore mariculture, with the ability to produce about 40 million tons of fish in an area that covers less than 1.5% of their Exclusive Economic Zones (EEZs). Production in Latin America and the Caribbean (LAC) from 2012–2014 by countries that produced 100 tonnes or more per year is presented in Table 4.2. In 2015, Mexican farmed shrimp production amounted to 90,600 tonnes, according to preliminary figures from the National Committee of Aquaculture and Fisheries (Conapesca). In Colombia, Costa Rica, Cuba, and Honduras, aquaculture accounted for over 50% of total fish landings in 2012–2014; in Guatemala and Nicaragua, it contributed between 30–49%, while in the Dominican Republic and Venezuela its contribution varied between 10–29 % (FAO, 2017). In other countries/territories including Belize, El Salvador, Haiti, Jamaica, Mexico, and Panama, fish farming is of low importance (1–9 % of total fish landings).

Table 4.2. Aquaculture/mariculture production (rounded to the nearest whole number) in LAC by countries that produced 100 tonnes or more per year, 2012–2014

Region	Volume (tonnes)	Value (US$ million) 2015
Caribbean	32	46
Central America	328	1,240
South America	2,188	12,007
TOTAL	**2,548**	**13,293**

(FAO, 2017 based on data in FAO FishStat 2016).

Aquaculture requires good water quality, but the activity itself can have significant adverse environmental impacts on surrounding areas. Increased production has been combined with greater use of antibiotics, fungicides, and anti-fouling agents, which in turn pollute down-stream ecosystems. Many types of non-fed aquaculture (e.g., mussel farming) can filter and clean waters, but other types (e.g., intensive cage culture) may diminish water quality. Fed and intensive aquaculture can result in export of animal excreta, uneaten feed, and pharmaceutical drugs to water bodies (FAO, 2018). Adding the contribution of contaminants from other sectors can result in poor water quality, which jeopardizes the development and sustainability of aquaculture and mariculture in the region. This is particularly concerning when the increasing demand for seafood, overfishing and collapse of some fisheries, and the large imports of seafood by many of the countries are considered.

4.5.2. Agriculture

In the WCR, 22 countries generate considerable wealth through agriculture (crop and livestock farming), with 12 reporting that agriculture contributed at least 5% to GDP per year, on average, for the period 2011–2015 (Figure 4.7, this study). Among Caribbean islands, agriculture posts a modest average contribution of 4%, given real constraints in the amount of arable land, although Dominica leads with 16% of its GDP from agriculture. In continental countries, agriculture contributes an average of 11% of GDP, but this is higher for countries such as Guyana, whose agriculture sector contributed 35% of its GDP during the period 2011–2015. At regional-scale aggregation and using 2015 constant US$ currency, average annual contribution of agriculture to national GDPs in the WCR amounted to US$338 billion per year, on average, for the period 2011–2015. Scaled to the regional total of national GDPs (averaging at least US$18,146 billion per year), the sectoral contribution of agriculture is 7%. In general at the macro-scale, agriculture and fishing, which deal with food commodities, appear to generate low contributions to GDP compared to service sectors such as tourism.

Unsustainable agricultural practices such as conversion of primary forests, poor soil management, cultivation on steep slopes (characteristic of the islands), overgrazing, and excessive application of fertilizers and pesticides, generate a variety of pressures or stressors that can have severe consequences for coastal and marine ecosystems. Additionally, the livestock sector is one of the top three contributors to the most serious environmental problems, including water quality degradation, at every scale from local to global (FAO, 2006). Livestock production accounts for 70% of all agricultural land and 30% of the land surface of the planet (FAO and IWMI, 2017). Most of the water used for livestock drinking and servicing returns to the environment in the form of liquid manure, slurry, and wastewater. Livestock excreta contain considerable quantities of nutrients, oxygen-depleting substances, and pathogens, which can pollute surface and groundwater. In intensive systems, livestock excreta also contains heavy metals, drug residues, hormones, and antibiotics (FAO, 2018).

Crop farming is greatly challenged by globalized trade and environmental variability because of a warming climate. As demand for food continues to grow globally and regionally, the viability of the agriculture sector will depend on the choices farmers make in terms of target products and markets, and how these choices account for changing climate patterns. Adopting climate-smart agriculture, safeguarding soil nutrients and the microbial communities that keep soils fertile, adapting practices that promote organic farming and minimal use of synthetic fertilizers, and prudent use of water and biocides, are just a few practices among many that should reshape farming in the region. How such shifts alter fertilizer use and nutrient loading is difficult to gauge. But if agriculture makes a turn towards sustainable farming, where fertilizer use and emission of livestock waste to the environment are controlled, there is hope that nutrient reduction in the WCR can be achieved.

4.5.3. Maritime transport

Shipping and its associated infrastructure, such as ports and harbours, are vital to the region's economy. In fact, shipping dominates the ocean economy in the Caribbean, representing about 76% of this sector (Figure 4.9). In the container shipping industry, the share of the total global shipping revenues that flow through the Caribbean, including through the Panama Canal, amounts to US$311.3 billion (Rodrigue and Ashar, 2015). This includes the value of port services.

Some of the region's container ports (Colon and Balboa in Panama; Georgia and Houston in the USA) are among the world's largest ports.[21] The Caribbean Sea plays an important role in international maritime shipping owing to the Panama Canal, which was recently expanded to accommodate larger vessels. It was estimated that in 2012, about 8% of the global container shipping volume passed through the Panama Canal and generated an estimated US$53 billion (Rodrigue and Ashar, 2015). Regional transhipment activity is likely to increase, and a new regional hub could possibly emerge among the Organisation of Eastern Caribbean States (OECS) ports (CBD, 2016). With the opening of the expanded Panama Canal in 2016, maritime transport in the Caribbean basin is expected to experience significant transformation as ship sizes increase and shipping line patterns change due to the new economics of the maritime sector.

Shipping imposes substantial and widespread pressures on the marine environment. Those pressures are also diverse—some result from shipping disasters and others are chronic, such as oil discharges, loss of containers, garbage, sewage, air pollution, noise, anti-fouling treatments, and transport of invasive species (UN, 2016). Dredging of ports and harbours is another concern because of the mobilization and introduction of significant quantities of sediments and associated contaminants into surrounding waters.

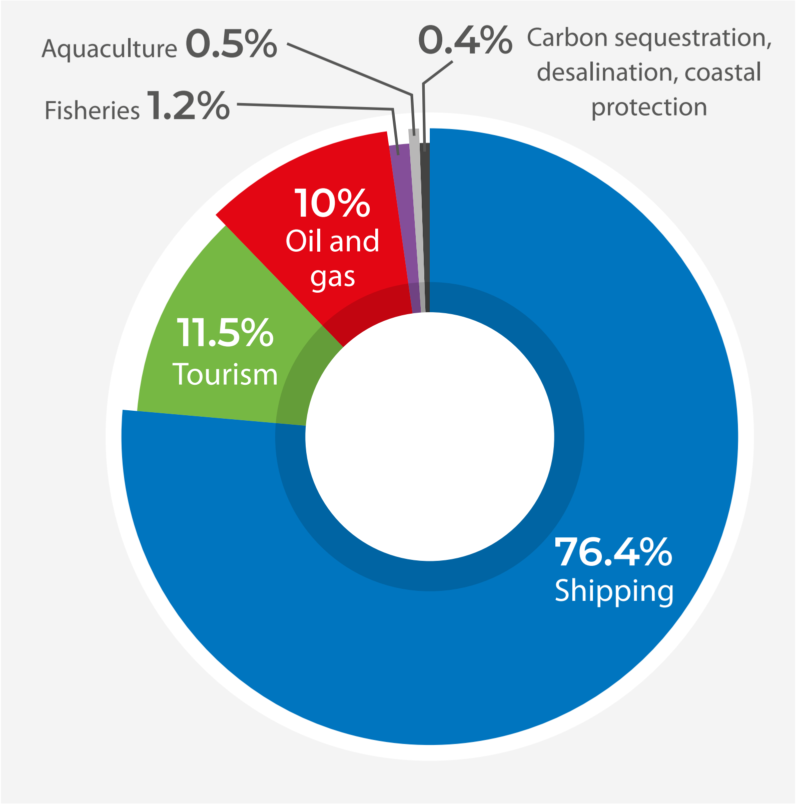

Figure 4.9. The measurable ocean economy in the Caribbean in 2012
(Data from Patil et al., 2016).

4.5.4. Industries

Major industrial centres within the WCR are concentrated in a few "hot spot" areas, such as the Texas-Louisiana Gulf coast in the USA; the industrial area of Lake Maracaibo, Venezuela; the "El Mamonal" industrial complex in Cartagena Bay, Colombia; the west coast of Trinidad; Kingston Harbour, Jamaica; and Havana Bay, Cuba. Industrial facilities and activities in WCR countries include sugar factories, refinery, and distillery; drinks and spirits; food processing plants; pulp and paper; chemicals; textiles; basic industry (iron, steel, machinery, non-ferrous metals); soaps and perfumes; mining; plastics; lathe operations; power stations; and galvanization (UNEP-CEP, 2010). The most heavily industrialized countries, in terms of the number of different types of industrial activities, are Colombia, Dominican Republic, Mexico, Trinidad and Tobago, and the USA. In the insular Caribbean, Trinidad and Tobago has the most active manufacturing sector, which contributes 19% of its GDP, based

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[21] World Shipping Council 2014. Top 50 world container ports.

on a well-developed petrochemical industry (including world-scale ammonia and methanol plants) and free-trade zone.

An important sector is the oil and gas industry (extraction, refining, and transport), with Colombia, Mexico, Trinidad and Tobago, USA, and Venezuela being the major producers. Guyana is poised to become a major oil producer following the recent discovery of immense reserves of oil and natural gas in its marine waters. There has also been increased exploration in Trinidad and Tobago, Suriname, Jamaica, and The Bahamas. Oil refineries and terminals are widespread across the region, with nearly 100 refineries in several countries/territories (Figure 4.10).

Bauxite mining is particularly important for the economies of Guyana, Jamaica, and Suriname—and to a lesser extent, the Dominican Republic and Haiti. Other mining operations in the region include bed extraction for nickel oxide production, which takes place mainly in Cuba and the Dominican Republic (UNEP CEP, 2010).

Increased industrial diversification is taking place in many WCR countries. However, while the industrial sector brings significant socio-economic benefits, there is evidence of widespread environmental degradation and threats to living marine resources and human health from industrial pollution. Industrial installations are commonly situated along the coast or near rivers, and in the absence of adequate industrial waste management and treatment facilities, marine and coastal waters continue to be contaminated by substances of industrial origin. Some of these substances (such as mercury) are hazardous to marine biota and human health, and bio-accumulate and bio-magnify in the marine food chain.

Figure 4.10. Oil terminals in the WCR
(source: http://cep.unep.org/racrempeitc/maritime-traffic).

PRESSURES FROM LAND-BASED SOURCES AND ACTIVITIES

5. PRESSURES FROM LAND-BASED SOURCES AND ACTIVITIES

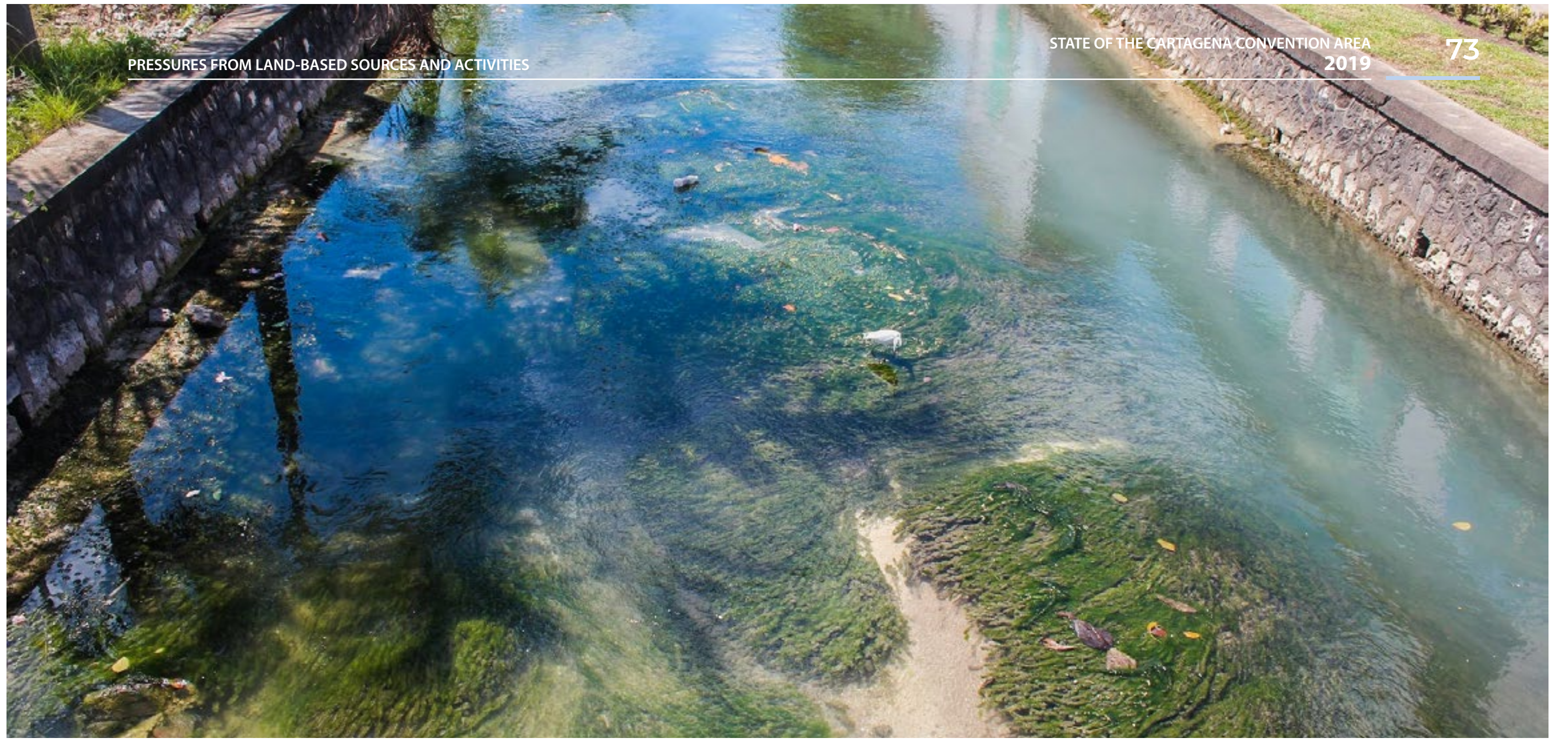
Key messages

Discharge of untreated domestic wastewater into coastal waters continues to be a significant threat to the region's marine environment. Most WCR countries are still plagued by inadequate domestic wastewater treatment infrastructure. Of the estimated 15 km^3 of domestic wastewater generated in 2015, 63% (instead of the commonly used 85%) was untreated and released directly to the environment.

Over the 20th century, nutrient loads delivered from river basins to coastal areas almost doubled. Nutrient enrichment of coastal waters is explicitly addressed in SDG 14.1, owing to its potential to radically impair the functioning and productivity of marine ecosystems. About 560,000 tonnes of total nitrogen and 190,000 tonnes of total phosphorus are estimated to have been released to the WCR's coastal waters from domestic sources in 2015.

Agriculture is the single most important anthropogenic source of nutrients in coastal waters in the region, greatly exceeding contributions from domestic wastewater and sewage. However, groundwater impacted by agricultural run-off, rather than agricultural surface water, introduces the highest loads of nitrogen to coastal waters. This underscores the need for increased attention to non-point sources of nutrient pollution and to protection of groundwater resources.

The highest loads of domestic wastewater and nutrients discharged occur in sub-regions along the continental margins, particularly the northern Gulf of Mexico and the southwestern Caribbean. These sub-regions are heavily influenced by rivers that drain extensive watersheds in which urban centres and agricultural and industrial activities are concentrated.



5.1. Introduction

Pressures (or stressors) are direct threats to the environment and ecosystems that can result in changes in the structure and functioning of the ecosystems and their ability to continue to produce goods and services. The coastal and marine environment in the WCR is subjected to a diverse range of anthropogenic pressures that originate from various land- and marine-based sources and activities. While economic activities generate wealth and livelihoods, they can also profoundly change the state of ecosystems. Economic valuation is insufficient to account for these "externalities." This assessment focuses on two major anthropogenic land-based pressures—untreated domestic wastewater/sewage and nutrients because of their potentially severe impacts on the marine environment and ecosystems, and on human health and economies. Annex 4.1 contains data sources and technical notes for assessing these indicators.

5.2. Pathways for introduction of contaminants to the marine environment

Contaminants from land-based activities enter coastal and marine waters through point sources (rivers and outfalls) and non-point sources (run-off and leaching), as well as atmospheric deposition. While polluted rivers are generally considered to be the main entry point for the introduction of land-based contaminants to coastal waters, there is growing evidence that submarine groundwater discharge from coastal aquifers is also an important pathway, with many of the region's groundwater aquifers showing signs of pollution (Box 5.1). Coastal waters are highly susceptible to pollution from groundwater. Water laden with contaminants percolates through the ground easily, eventually discharging into the coastal environment with little assimilation. Directly emitting domestic wastewater and sewage through submarine outfalls is another common practice in the region.

5.3. Domestic (municipal) wastewater loads

5.3.1. Overview

Untreated municipal wastewater is of particular concern in the WCR, because of the direct threat to public health arising from sewage and associated bacterial content. This concern is addressed by Annex III of the LBS Protocol on sewage. Numerous studies have singled out untreated wastewater entering the world's oceans as the most serious and pervasive problem contributing to marine pollution. Untreated wastewater is an important source of nutrients, organic matter, fecal bacteria, chemicals, suspended solids, and contaminants of emerging concern (such as endocrine disruptors[22] and hormones), among other contaminants. Nutrients and fecal bacteria (as indicators of fecal contamination) are of particular focus in this assessment.

Population growth, including the rapid expansion of urban populations without accompanying improvement in wastewater treatment infrastructure, has resulted in substantial volumes of untreated or poorly treated domestic wastewater being discharged into freshwater bodies or directly into the sea throughout the WCR (, 2010). Most WCR countries have historically faced limited access to basic sanitation and domiciliary connection to sewer systems, often employing low-cost household systems consisting of septic tanks, dry latrines, or simple pit latrines (UNEP-CEP, 2010). However, the situation is improving, with 93.8% of the population in LAC having access to improved sanitation services (WHO/UNICEF, 2017). An assessment for the WCR shows that sanitation coverage has increased and reaches 85% of the upstream coastal population, facilitated by the extended use of low-cost technologies (UNEP-CEP, 2010). Unfortunately, connection to sanitation services still does not translate into reduced pollution because of extremely low capacity in the countries to treat sewage (GEF CreW, 2016).

Even where treatment occurs, the generated effluent may not comply with established sewage effluent standards. In some cases, the introduction of improved wastewater treatment has led to increased pollution from other media, such as wastewater sludge. The apparent disconnect between sanitation coverage and environmental impacts, especially in coastal and marine areas, has to do in part with what constitutes improved sanitation and how well it is managed (Nurse et al., 2012). Although domestic sewage is biodegradable, the large quantities of sewage being discharged in many locations exceed the natural decomposition and dispersal capacity of the recipient water bodies, resulting in degraded water quality.

It is often cited that an estimated 85% of untreated wastewater is discharged into waterways, including coastal waters (GEF CreW, 2016), but data to support this estimate does not appear to have been documented. This report is the first attempt at quantifying the volume of municipal wastewater generated and the volume that is potentially discharged into coastal waters, given available data on treatment levels.

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[22] Chemicals that may interfere with the body's endocrine system and produce adverse developmental, reproductive, neurological, and immune effects in both humans and wildlife. They are found in various materials such as pesticides, metals, additives or contaminants in food, and personal care products.

5.3.2. Volume of municipal wastewater potentially discharged into coastal waters

This report provides the first ever attempt at analyzing untreated and discharged wastewater for the WCR. The approach uses municipal water withdrawal, municipal wastewater production (exclusive of sewage sludge), and extent of sewerage connections to estimate the volume of untreated wastewater produced in 2015. An estimated 20 x 10^9 m^3 of municipal water was withdrawn in the region, from which 15 x 10^9 m^3 of wastewater were generated, with only 37% reaching treatment plants. Untreated wastewater amounting to 10 x10^9 m^3 or 63% of produced wastewater is assumed to have been disposed directly into coastal waters (Table 5.1; see data sources, technical notes and input data in Annex 4.1 and additional results in Annex 5.1A). The highest volume of untreated domestic wastewater comes from sub-region III, followed by sub-regions I, V, II, and IV (descending order). This report's estimate of 63% of untreated wastewater discharged is lower than the claim of 85% presumably discharged without treatment that is commonly used in other reports and assessments.

At the current level of technology, only tertiary and more advanced treatment methods can rid wastewater of nutrients, pathogens, heavy metals, and toxins. Data on the level of sewage treatment (primary, secondary, tertiary), the population percentage connected to each treatment level, and the amount of wastewater discharged or re-used post-treatment, are needed to better estimate the quantity and quality of post-treatment wastewater that reaches adjacent aquatic systems, including coastal waters. The contribution of hotels and other tourist accommodations to wastewater emissions has not been quantified and should be included in subsequent analyses of domestic liquid waste, noting that tourism will remain a major long-term economic driver in the region.

Table 5.1. Municipal wastewater discharged in the WCR in 2015, expressed as annual volume and the water's nitrogen (N) and phosphorus (P) composition, by sub-region.
(see Annex 4.1 for input data and methods).

WCR Sub-region	**Untreated wastewater** volume in 2015, km^3	**Tg N in untreated wastewater, 2015** (N = 60 g m^{-3} of sewage)	**Tg P in untreated wastewater, 2015** (P = 10 g m^{-3} of sewage)
Sub-region I (Gulf of Mexico)	3.26	0.20	0.03
Sub-region II (Western Caribbean)	0.87	0.05	0.01
Sub-region III (Southern Caribbean)	3.99	0.24	0.04
Sub-region IV (Eastern Caribbean)	0.24	0.01	0.00
Sub-region V (Northern & Central Caribbean)	1.79	0.11	0.02
WCR	**10.15**	**0.61**	**0.10**
Continental countries	8.12	0.49	0.08
Island states and territories	2.03	0.12	0.02

5.4. Nutrients

5.4.1. Overview

The over-enrichment of water by nutrients such as nitrogen and phosphorus (eutrophication) is one of the leading causes of degraded coastal water quality. Eutrophication promotes increased growth and biomass of phytoplankton (detected as increased chlorophyll-a concentrations in the water column) or of opportunistic macro-vegetation near the sea floor. The two most acute impacts of eutrophication are the incidence of hypoxia (low oxygen concentration) in bottom waters (often referred to as "dead zones" because of the absence of macrofauna) and harmful algal blooms (HABs), which have become a global-scale challenge (Mayorga et al., 2010). This concern is also reflected by SDG Target 14.1: *By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and* ***nutrient pollution***, with the Index of Coastal Eutrophication (ICEP) as the SDG indicator of nutrient pollution. ICEP represents the potential for new production of harmful algal biomass in coastal waters, associated with high nutrient inputs (see Section on ICEP in Chapter 8).

As a result of the intensification of human activities in coastal areas and watersheds that increase nutrient loading of rivers, combined with inadequate waste management, nutrients are being introduced into coastal waters from diffuse (non-point) sources and point sources in increasing quantities. Among the major anthropogenic sources of nutrient loading to coastal areas are untreated sewage, run-off from agricultural fertilizer use and livestock production, and atmospheric nitrogen deposition (Seitzinger and Mayorga, 2016; Beusen et al., 2015, 2016). Nutrients are also delivered to water bodies from aquaculture facilities, and are primarily a function of feed composition and fecal wastes (FAO, 2017). Fertilizer use in tourism, especially for golf courses in coastal areas, may be another substantial source of nutrients via run-off or groundwater infiltration, especially in SIDS. Submarine groundwater discharge can also introduce nutrients to coastal waters; it has been found that nitrate from agriculture is the most common chemical contaminant in the world's groundwater aquifers (WWAP, 2013). As populations and economies grow, the global discharge of nitrogen and phosphorus into coastal waters is expected to continue increasing in the coming decades.

5.4.2. Assessing nutrient inputs into coastal waters

Nutrient composition of domestic wastewater

In this report, data on nutrient composition of domestic wastewater (UNEP-CEP, 2015) were used to estimate the discharge of total nitrogen and total phosphorus contained in wastewater in 2015 (see Table 5.1, and Annex 4.1 for input data sources and technical notes). The 15 x 10^9 m^3 of domestic wastewater generated in 2015 contained about 610,000 tonnes (0.61 Tg) of nitrogen and 100,000 tonnes (0.1 Tg) of phosphorus.[23] These values are slightly higher than the model year 2000 values of 0.51 Tg for nitrogen and 0.07 Tg for phosphorus calculated from the Beusen et al., 2016 global data set, noting a 15-year difference in model years.

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[23] One teragram (Tg) is equal to 10^{12} grams and to 10^6 tonnes.

Fertilizer input inventory

Agriculture is currently the single most important anthropogenic nutrient source that dominates nutrient biogeochemistry in watersheds and in coastal waters (Campbell et al., 2017), including in the WCR. A coarse inventory of agricultural fertilizer use in WCR countries was developed for this study using FAOSTAT data on fertilizer usage expressed in total nutrient (nitrogen and phosphorus) weights for the year 2002. The values that were obtained, which were at national scale, were scaled to the total drainage basin area draining to WCR coastal waters relative to the sizes of national areas (Figure 5.1.A). Fertilizer use in the WCR region in 2002 amounted to 6.44 Tg total nitrogen (Figure 5.1B), and to 2.34 Tg total phosphorus (Figure 5.1C). In comparison with these inventory results, the modelled estimate of agricultural sources of total nitrogen for model year 2000 was 3.3 Tg and 0.34 Tg for total phosphorus (based on Beusen et al., 2016). Future analysis should incorporate areas of arable land within the total watersheds, and the fertilizer application rates per hectare of arable land in total nutrient weights to further constrain estimates. (See Annex 4.1 for data sources and methods).

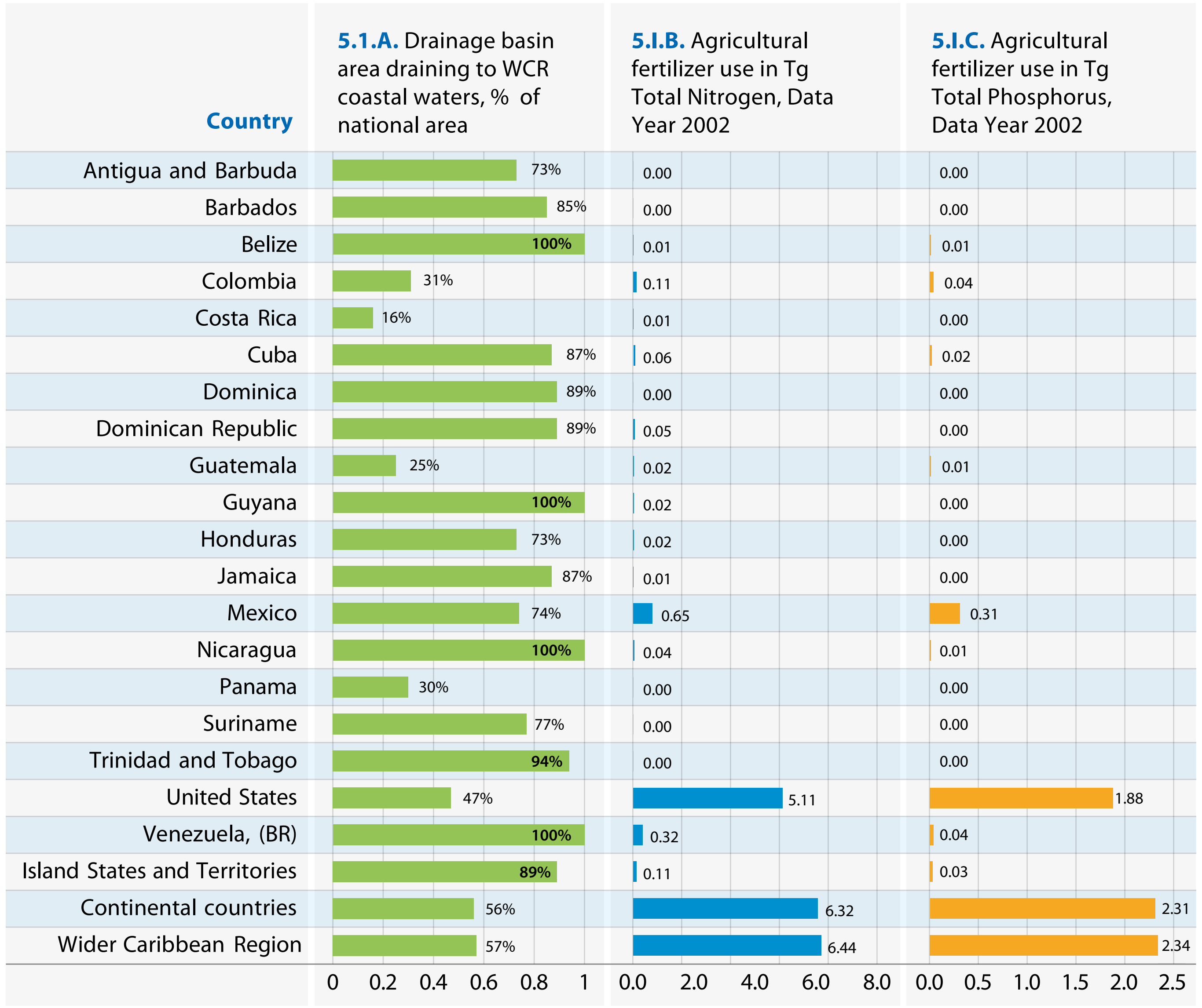

Figure 5.1. A. Fertilizer use in Tg Total Nitrogen and Tg Total Phosphorus, in drainage basins of the WCR for data year 2002.
See Annex 4.1 for data sources and methods.

Model-based assessment of nutrient sources and loads

A fundamental limitation of nutrient source inventories is the absence of monitoring programs that regularly track both diffuse and point nutrient sources, at watershed scale. Integrated models offer a mechanistic approach to help understand how socio-economics, biogeochemistry, hydrology, and climate—among other factors—interact to move nutrients from their sources to coastal and marine waters. Models provide scientific bases for validating processes with empirical data, so that governance and policy priorities may be identified and implemented to effectively address the issue of concern. An assessment of nutrient input by source will inform the development of a regional nutrient reduction strategy and action plan being undertaken by the UNEP-CEP with support from the CLME+ Project.

Relevant values of nutrient sources, retention, and deliveries for the WCR were extracted and analyzed in this assessment using results of an integrated global nutrient model for year 2000 by Beusen et al., 2015, 2016.[24] Modelled values of nitrogen by source, extracted from the global modelled dataset, are presented for the WCR in Table 5.2 and Figures 5.2 and 5.3 (detailed results by sub-region are given in Annex 5.2). Agriculture surface run-off and groundwater from agricultural land account for 3.3 Tg or about 60% of nitrogen sources at the regional scale (Figure 5.2). Groundwater impacted by agricultural lands is not regularly monitored, although there is growing evidence that this is a significant source of nutrients and other contaminants. The integrated modelling results indicate that this can and should be empirically validated.

Sewage contributed 0.51 Tg N or 9% in model year 2000 (Figure 5.2), which compares well with the domestic wastewater inventory of 0.61 Tg N for year 2015 presented above, noting the 15-year difference. The greater contribution of nutrients from both agricultural sources (surface run-off and groundwater), compared to sewage, as well as the dominance of groundwater (non-point sources) at the regional scale have come as surprises, considering that the conventional focus has been on sewage under Annex III of the LBS Protocol. Clearly, greater attention must be paid to addressing agricultural non-point sources, which is covered under Annex IV. There is also a need to estimate nutrient inputs from industrial sources in the region.

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[24] https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:64145/tab/2.

Table 5.2. Modelled values of nitrogen by source for the WCR for year 2000 (input data: Beusen et al., 2016). See Annex 4.1 for technical notes and Annex 5.2 for data by sub-region.

	Atmospheric deposition	Vegetation in floodplains	Surface run-off (agric)	Surface run-off (natural)	Groundwater (agricultural)	Groundwater (natural)	Sewage	Aquaculture	All N inputs
WCR (103 tonnes)	58.49	749.31	1,083.15	63.60	2,195.23	798.97	509.42	9.59	5,467.76
WCR (Tg N)	0.058	0.749	1.083	0.064	2.195	0.799	0.509	0.010	5.468
WCR (%)	1.1	13.7	19.8	1.2	40.1	14.6	9.3	0.2	100.0

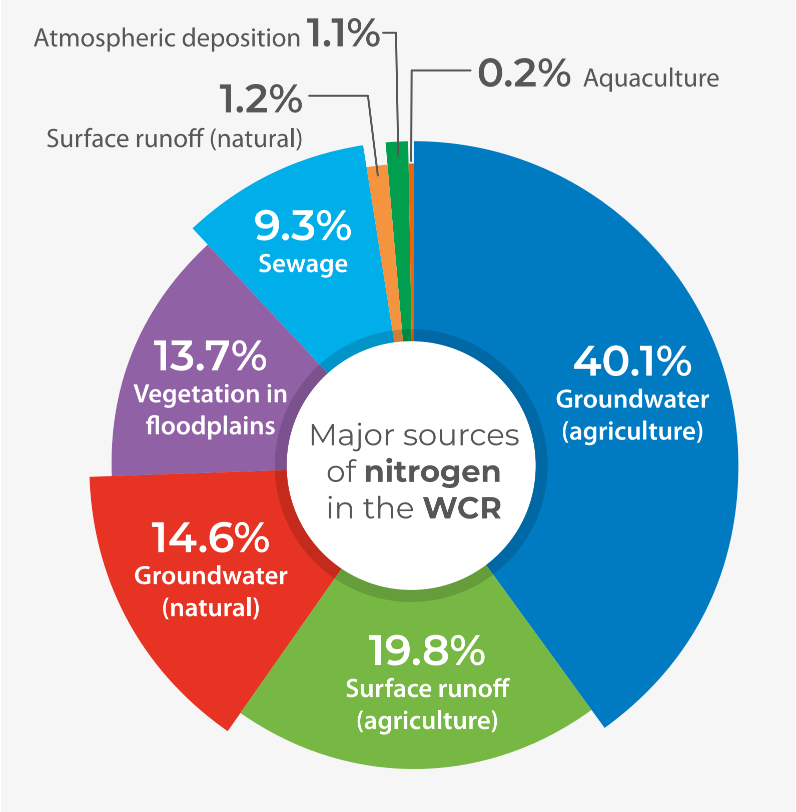

Figure 5.2. Proportion of nitrogen by source for the WCR for year 2000
(see Annex 4.1; based on data from Beusen et al., 2016)

Looking more closely at nitrogen inputs from the major anthropogenic sources for each sub-region as a proportion of the regional total (Figure 5.3), the dominant sources by sub-region are as follows:

- Sub-region I: agricultural groundwater followed by surface run-off
- Sub-region II: agricultural surface run-off followed by agricultural groundwater
- Sub-region III: agricultural groundwater followed by surface run-off
- Sub-regions IV and V: agricultural groundwater followed by sewage

Groundwater from agricultural land dominates in all the sub-regions except sub-region II, where agricultural surface run-off dominates. An important result to note is that sewage nitrogen rises in significance in sub-regions IV and V compared to the regional-scale estimates.

Modelled values of phosphorus by source and by WCR sub-region were computed from Beusen et al., 2016 (see Annex 4.1 for technical notes) for year 2000 (see Table 5.3, Annex 5.3 for additional results). Percentages estimated from sub-regional and regional totals allow comparisons across these two scales. At the regional scale, phosphorus discharges consist of about 56% agricultural run-off and 11% sewage (Figure 5.4). The inventory for domestic wastewater phosphorus at 0.10 Tg in 2015 in this assessment is higher than modelled sewage phosphorus at 0.07 Tg for model year 2000, noting the 15-year difference between model and inventory data years (Annex 5.2). High amounts of sewage phosphorus are observed in sub-regions IV and V at 19% and 20%, respectively. High amounts of sewage nitrogen are also observed in these two sub-regions. These results highlight the need to adopt effective, low-cost wastewater treatment technologies and improved fertilizer use efficiency in the short and immediate term.

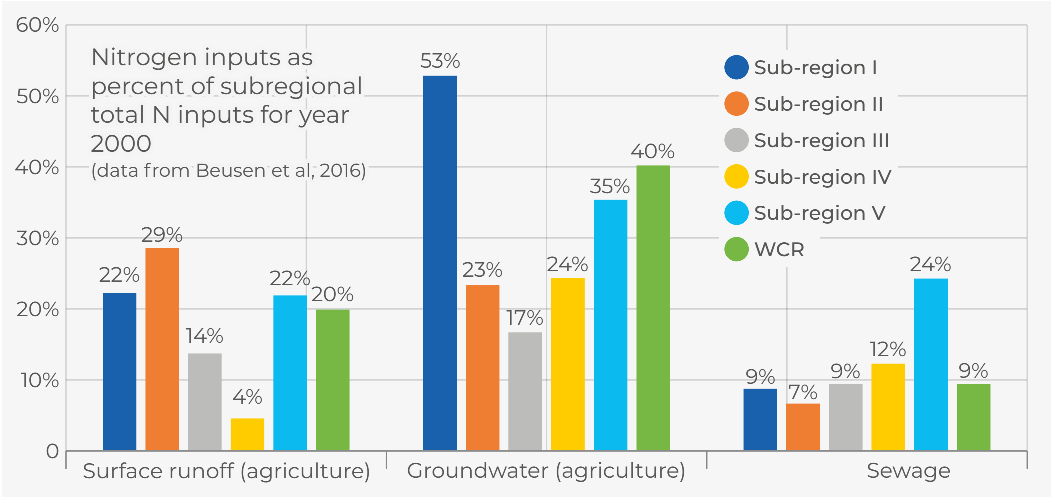

Figure 5.3. Nitrogen contribution by major anthropogenic source as proportions of sub-regional totals for each source.
(see Annex 4.1; data from Beusen et al., 2016)

Table 5.3. Table 5.3. Modelled values of phosphorus by source for the WCR for year 2000

(Input data: Beusen et al., 2016). See Annex 5.3 for data by sub-region and Annex 4.1 for technical notes.

	Weathering	Vegetation in Floodplains	Surface Run-off (Agriculture)	Surface Run-off (Natural)	Sewage	Aquaculture	All P inputs
WCR(10^3 tonnes P)	119.66	62.44	338.55	19.74	66.39	1.07	607.86
WCR (Tg P)	0.120	0.062	0.339	0.020	0.066	0.001	0.608
WCR (%)	19.7	10.3	55.7	3.2	10.9	0.2	100

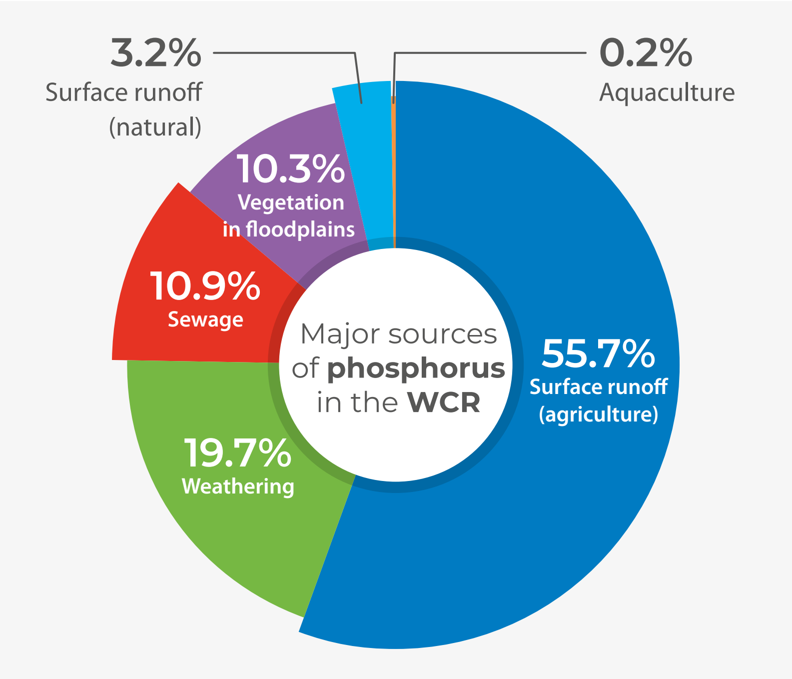

Figure 5.4. Proportion of phosphorus by source for the WCR for year 2000.

(based on data from Beusen et al., 2016).

Phosphorus input from major anthropogenic sources is compared across sub-regions as a proportion of the regional total for surface run-off (agriculture) and sewage (Figure 5.5). Surface run-off from agriculture dominates in all sub-regions except sub-region IV, where sewage as a source of phosphorus dominates. Weathering makes an important phosphorous contribution, especially in sub-regions II, III, and IV, which must be taken into account when monitoring and assessing nutrient inputs.

Table 5.4 compares two sets of modelled data (Mayorga, this study, based on Seitzinger and Mayorga 2016; Talaue-McManus, this study, using data from Beusen et al., 2016) generated by integrated models resolved at 0.5° X 0.5° scale. Results for both total N and total P loads show similar orders of magnitude with differences in basin count resolved at scale and discharge volumes. The nuanced approaches in model construction, choices of input data, and differences in algorithms that dictate how model components simulate processes and interactions underpin dissimilar results. Empirical calibration and refinement of model input data should be undertaken to refine estimates of nutrient load over time.

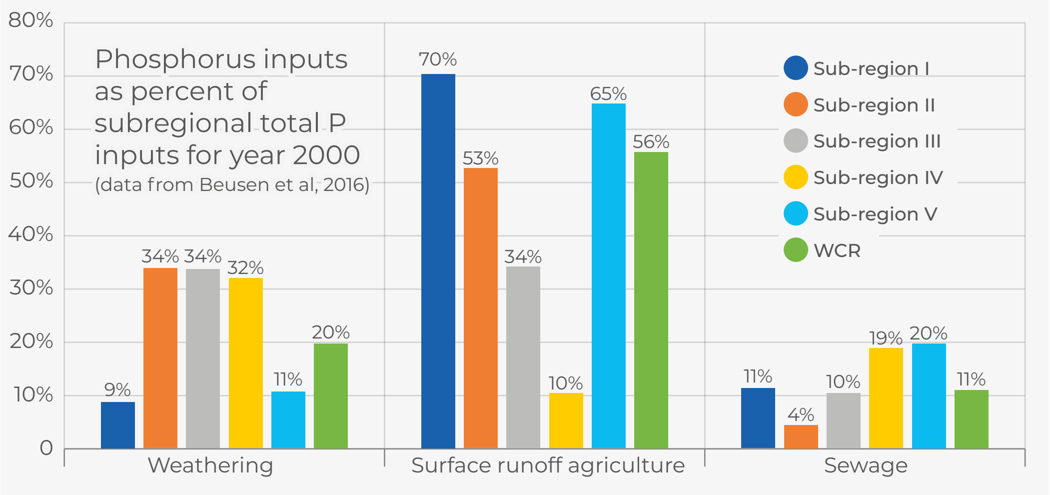

Figure 5.5. Phosphorus contribution by major anthropogenic source (and weathering) for each sub-region, as a proportion of sub-regional totals for each source.

See Annex 5.3 for detailed phosphorus sources by sub-region (based on Beusen et al., 2016).

Table 5.4. Comparison of modelled total nutrient loads for year 2000 in the WCR.

Estimated by Mayorga for this study based on Seitzinger and Mayorga, 2016 and by Talaue-McManus using data from Beusen et al., 2016.

Nutrient Loads (Year 2000)	Basin Count		Basin Discharge, km^3/yr		Total Nitrogen Load, Tg N/yr		Total Phosphorus Load, Tg P/yr	
WCR Sub-region	Talaue-McManus (this study)	Mayorga (this study)	Talaue-McManus (this study)	Mayorga (this study)	Talaue-McManus (this study)	Mayorga (this study)	Talaue-McManus (this study)	Mayorga (this study)
I	117	96	756.71	1,116.08	1.2699	1.8000	0.0766	0.2348
II	48	39	311.62	480.11	0.1195	0.5433	0.0251	0.1359
III	88	66	2,282.20	1,989.50	0.9522	1.7162	0.1169	0.2889
IV	25	2	10.73	3.44	0.0222	0.0017	0.0023	0.0003
V	151	62	72.42	85.14	0.1213	0.1418	0.0214	0.0384
WCR	**429**	**265**	**3,433.67**	**3,674.27**	**2.4851**	**4.2030**	**0.2423**	**0.6982**

Annual trends in modelled coastal nutrient loading, 1900–2000

Over the 20th century, modelled nutrient loads in the region (this study, using input data from Beusen et al., 2016) show a jump in nitrogen loading beginning in the 1960s, when total loading exceeded 2 Tg (two million tonnes) for the first time (Figure 5.6A). This was coincident with the doubling of the agricultural market share in Latin America and the Caribbean from 9.5% in 1980 to 18.1% in 2010 (Flachsbarth et al., 2015). Peak loadings occurred in the period 1985 to 1995, reaching up to 2.8 Tg of nitrogen discharged to coastal waters. In the case of phosphorus loads, the 100-year model indicates a more gradual increase than that for nitrogen, with sub-regions I (Gulf of Mexico) and III (Southern Caribbean) tracking each other (Figure 5.6B).

The magnitudes and ratios at which nutrients[25] are conveyed to coastal waters is of particular importance, since these influence the growth and biodiversity of phytoplankton, which form the base of marine food webs and has immediate implications on the viability of biomass production, including fish (Turner, 2002). The Beusen model results show that ratios of nutrient loading increased from 8.56 in 1900 to 10.26, 100 years later. These ratios depart from 16N:1P ratio that satisfies the growth requirements of diatoms, which make up the base of diatom-zooplankton-fish food webs. An immediate consequence of excessive nutrient loading is that algae favoured by the existing elemental ratios proliferate to bloom proportions. It is critical to understand the role of anthropogenic activities and demographic trends in altering such ratios if strategic ecosystem management is to be implemented (Rabalais et al., 2009). Tracking the changes in N and P and the ratios at which they are loaded is necessary, but at the moment highly insufficient, and must be evaluated alongside other ecosystem indicators such as the availability of silica and other essential elements, and the accompanying changes in biota, biogeochemistry, livelihoods, and economies.

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[25] Including nitrogen, phosphorus, silica and other macronutrients (e.g., potassium, calcium, magnesium) and micronutrients (e.g., iron, zinc, molybdenum).

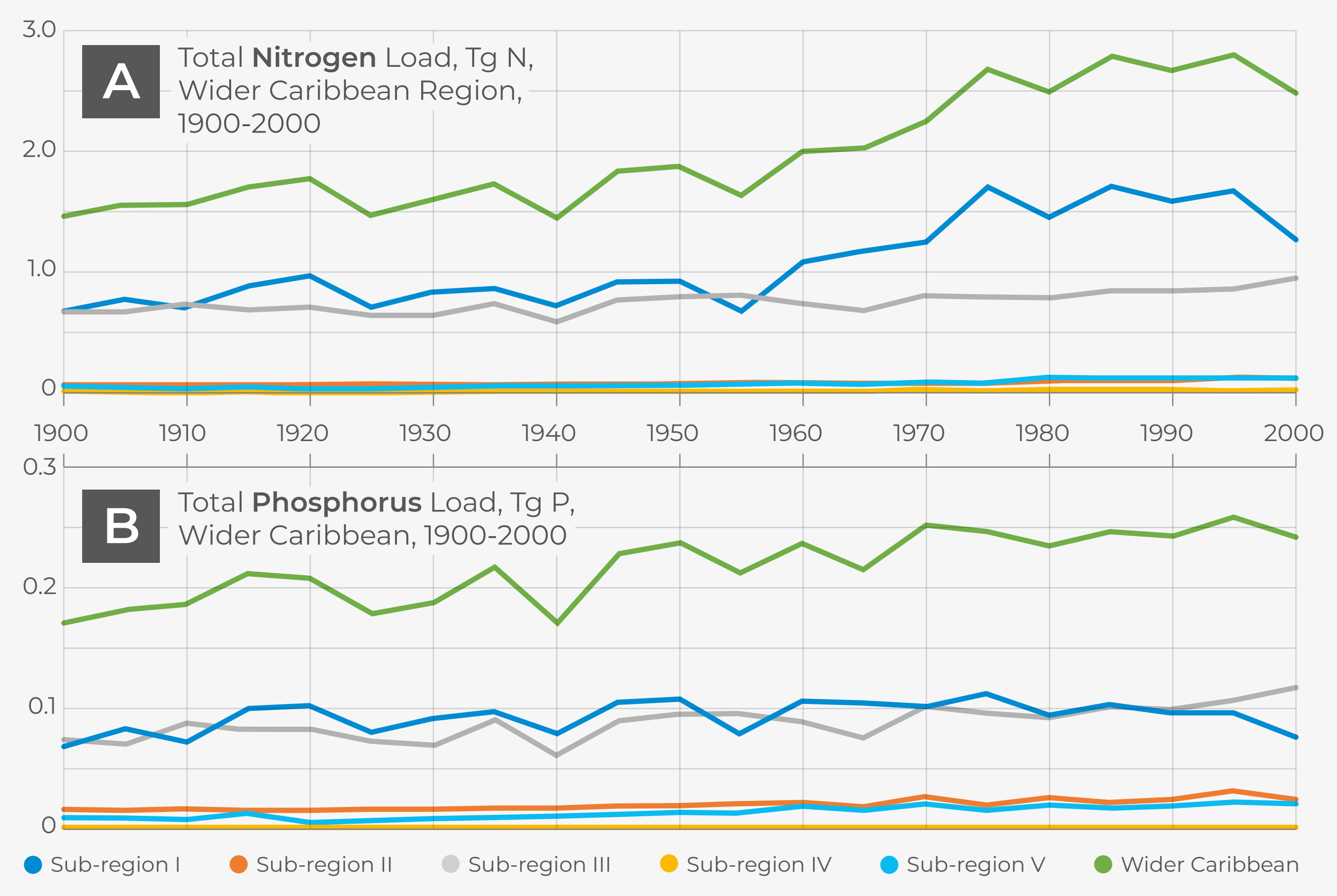


Figure 5.6. Modelled nitrogen (A) and phosphorus (B) loads in each sub-region and across the WCR for the 20th century (input data from Beusen et al., 2016).

Model-based assessment of DIN and DIP loads from watersheds to coastal areas

Nitrogen is of paramount importance both in causing and controlling eutrophication in coastal and marine ecosystems (Howarth et al., 2000). Nitrogen in the form of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) can be directly utilized by marine plants. DIN is also the form of nitrogen that increases the most in rivers (and is subsequently delivered to coastal areas) as a result of human activity (Seitzinger et al., 2010). The nutrient indicators that were assessed for this study are DIN and DIP inputs from watersheds (modelled data) and DIN and DIP concentrations in the water column.

Estimates of DIN and DIP loads (year 2000) from watersheds to coastal areas in the five sub-regions were provided for this assessment by Emilio Mayorga (University of Washington), based on the Global Nutrient Export from Watersheds (NEWS) model (Beusen et al., 2009; Mayorga et al., 2010; Seitzinger et al., 2010).

Input of DIN from watersheds for each of the five sub-regions is shown in Table 5.5 and Figure 5.7 (the results for sub-region IV should be interpreted with caution, for the reasons given in Box 5.2). DIN inputs from watersheds to coastal areas estimated by the NEWS model range from 1.08 Tg yr^{-1} for the Gulf of Mexico (sub-region I) to 0.06 Tg yr^{-1} for the Greater Antilles (sub-region V). Sub-regions I and III receive the highest proportions of DIN (54% and 34%, respectively) and DIP (40% and 42%, respectively). These results are consistent with the global distribution of nutrient input intensity (addition of nutrients per unit area) in watersheds, and are associated with intense agricultural production supported by high fertilizer use, large urban populations, and/or large numbers of livestock.

The highest input of DIN to the Gulf of Mexico is mainly associated with intense agricultural production in the Mississippi/Atchafalaya Watershed. Sub-region III is also influenced by major rivers (notably the Magdalena River of Colombia, Orinoco River of Venezuela, and Essequibo River of Guyana) that drain watersheds with extensive agricultural activities and urban centres. The next two highest inputs may also be attributed to significant continental run-off in sub-region II, associated with river basins such as the Motaqua and Chamelecon. An assessment of nutrient pollution in transboundary river basins conducted under the Transboundary Waters Assessment Programme (TWAP) River Basin component (UNEP-DHI and UNEP, 2016) revealed that several rivers in the region had a high risk (Catatumbo, Massacre, Artibonite, and Motaqua) and moderate risk (Chamelecon and Rio Grande) of nutrient pollution. As expected, in general, larger watersheds have greater nutrient loads.

It is clear, however, that there is a critical need to validate the results of these models using empirical data. It should be noted that the Amazon River was not directly included in the NEWS model for the SOCAR. The dispersion of Amazon River discharge in the Wider Caribbean Sea is well-documented (see Chapter 2 of this report), and it is important to estimate its nutrient contribution through future monitoring and research efforts.

Table 5.5. Global NEWS model results for DIN and DIP (tonnes yr^{-1}) for the five sub-regions.

Sub-region	DIN	% DIN	DIP	% DIP
Sub-region I	1,084,500	54	55,080	40
Sub-region II	178,800	9	16,120	12
Sub-region III	694,400	34	57,610	42
Sub-region IV	NA	NA	NA	NA
Sub-region V	60,400	3	9,340	7
TOTAL	**2,018,100**		**138,150**	

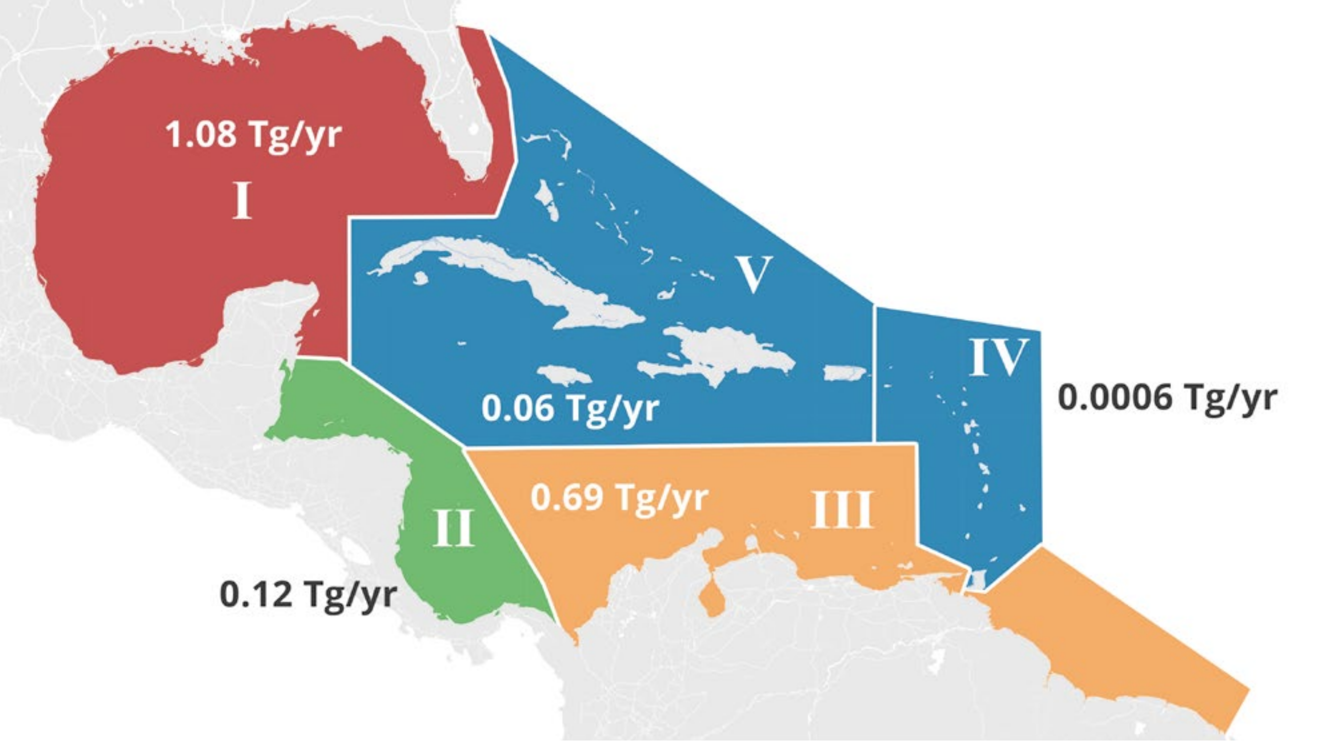


Figure 5.7. DIN inputs from watersheds to coastal areas in the five sub-regions, in Tg per year. Colours represent the range of values (red = highest; orange = high; green = medium; blue = lowest).

5.5. Sediment mobilization

Human activities and natural processes (including naturally occurring coastal erosion and local hydrodynamic and weather conditions) alter sediment fluxes and contribute to increases in the discharge of sediments to coastal areas. Among the latter are changes in land use practices in coastal areas and river basins (e.g., deforestation, agricultural activities, poor soil management, and urban and industrial development); as well as coastal construction, land reclamation, beach nourishment, and port construction, which are increasingly required to meet the growing economic and societal demands in coastal zones worldwide (Erftemeijer et al., 2012). An important source of sediments to coastal and marine waters is dredging, which is involved in many coastal development activities.

Estimates of sediment discharge for the major rivers influencing the WCR are presented in Table 2.1. In this region, the Magdalena River is the largest source of sediments to the Caribbean Sea (Cartagena Bay). An increase in sediment delivery from the Magdalena River has been attributed to deforestation and urbanization in the basin (Restrepo and Syvitski, 2006). The Magdalena River, which is the largest source of water and sediment discharges into the Caribbean Sea (LOICZ, 2002), is in the world's top ten in terms of sediment load, with about 560 t km^{-2} yr^{-1}. The extent of erosion within the Magdalena catchment has increased over the last 10 to 20 years (Restrepo et al., 2016a) and the percentage of forest cover is estimated to have declined from 46% in 1970 to 27% in 1990. The Urabá region is Colombia's main producer of bananas, with production driven by a growing international market. In this region, the coastal landscape has been severely transformed by deforestation and conversion of native forest into pastures, crops, and shrub lands for more than half a century. Modelling predictions show sediment fluxes to Cartagena Bay are intensifying and sediment loads are projected to increase by as much as 317% by year 2020 (Restrepo et al., 2016a). Estimates of total suspended solids (TSS) loads are presented for each sub-region in UNEP-CEP (2010a). The highest loads are from watersheds in sub-region I followed by sub-regions V and II (in decreasing order). Domestic loads are predicted to increase by about 1.5 times by year 2020. Sediments also adsorb various contaminants (including mercury, see below) and act as a sink for these substances that can later be re-suspended and affect water quality and living marine organisms.

Improvement in land use management is urgently needed to address the problem of erosion and transport of excessive sediment loads to the Wider Caribbean Sea.

5.6. pH

Land-based pollution may be a major driving force of changes in coastal pH; hence, this assessment focuses on coastal acidification, which can be affected by a variety of localized factors. Among these are discharges of polluted wastewater, mine drainage, chemical spills, discharge of detergents, decomposition of organic matter that releases carbon dioxide directly into the water, disturbance of tropical coastal (acidic) soils, and the reclamation of coastal wetlands. In addition, emissions from coal-fired power stations, certain industrial operations, vehicle exhaust, and thermal power stations give rise to atmospherically derived acids and potential acid deposition or acid rain, which can potentially lower the pH of seawater.

5.7. Industrial pollution and hazardous waste

Estimates of industrial pollution loads of biological oxygen demand (BOD$_5$), chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen, and total phosphorus discharged into the WCR are presented in UNEP-CEP, 2010. Discharges of chemical pollutants from industrial sources are likely to be significant considering the high level of industrial development in certain countries. However, the availability of data on industrial loads at the regional scale is very limited, which is a major gap that needs to be addressed in order to inform decision-making.

5.7.1. Estimates of hazardous waste

There is no recent, comprehensive compilation and analysis of inputs of hazardous substances to the Wider Caribbean Region marine environment, although there are specific areas where such problems are known to occur (Cartagena Bay, Colombia; Puerto Limon, Costa Rica; Havana Bay, Cuba; Kingston Harbour, Jamaica; and some locations in Puerto Rico). These largely result from the discharge of untreated wastewater from local industries. Estimates of hazardous waste produced in selected WCR countries are presented in Figure 5.8, based on data in Hoornweg and Bhada-Tata, 2012. Venezuela, Trinidad and Tobago, Colombia, and Cuba produce the highest volume of hazardous waste (ascending order). An overview of mercury in the marine environment and impacts is presented in Chapter 9 of this report.

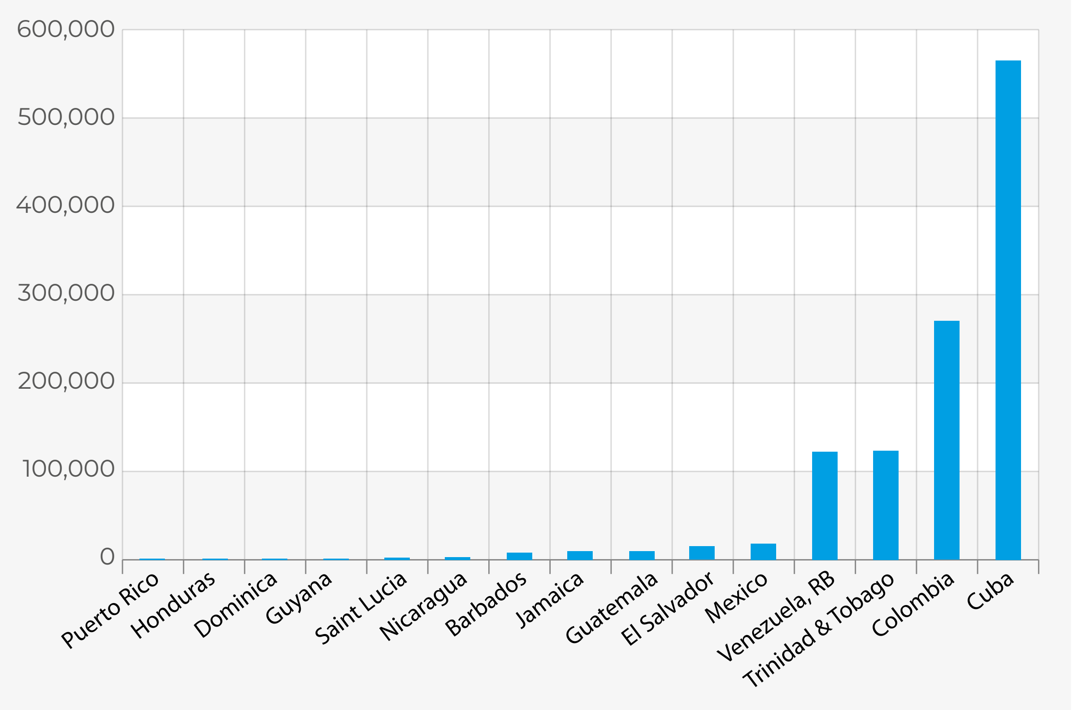


Figure 5.8. Hazardous waste (tonnes yr^{-1}) produced by selected countries in the WCR.
Source: https://datacatalog.worldbank.org/dataset/what-waste-global-database (Hoornweg and Bhada-Tata, 2012).

5.8. Emerging issues

For the purpose of this report, emerging environmental issues are considered to be “issues with either a positive or negative global environmental impact that are recognized by the scientific community as very important to human well-being, but not yet receiving adequate attention from the policy community” (UNEP, 2012). The following is a preliminary list of emerging issues relevant to pollution of the marine environment:

Emerging pollutants (Eps): Defined as synthetic or naturally occurring chemicals that are not commonly monitored in the environment, but which have the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects (Geissen, 2015). These substances include chemicals found in a range of products (pharmaceuticals, personal care products, pesticides, industrial and household products, flame retardants, plasticizers, microplastics, metals, surfactants, industrial additives, and solvents). Monitoring of Eps is challenging, since no established standardized analytical method may be available. Uncertainties in the detection, identification, and quantification of Eps stem from low detection limits required and little or no knowledge on their transformation products when exposed to the environment.

Electronic waste: Electronic waste (e-waste) refers to discarded electrical and electronic equipment (e.g., cell phones, batteries, computers, etc.). The global increase in use of electronic goods by an already expanding population, as well as rapid changes in new technology and obsolescence of old devices, has led to an increase in the build-up of e-wastes. E-wastes contain hazardous and toxic substances, such as heavy metals and persistent organic pollutants. Improper disposal of e-wastes can lead to environmental degradation and harm to human health, as these toxic substances may ultimately end up in water and food supplies.

Sargassum: Lingering uncertainties about the cause of the Sargassum outbreak requires urgent research to help understand the reasons behind the outbreaks in the region and to guide mitigation strategies. Early detection, use of forecast information, monitoring, reporting, assessing impacts, development of best practices, and communicating information on Sargassum influx can assist in mitigating impacts that require collaboration with national, regional, and international counterparts and institutions. (See Chapter 7 of this report.)

Linkage among environmental conventions: Enhancing effectiveness of the LBS Protocol through collaborative, integrated, and innovative approaches at national, regional, and international levels. This includes building synergies with other relevant environmental conventions (e.g., MARPOL, Minamata, Basel, Rotterdam, and Stockholm Conventions).

Sahara dust: Although the issue of Sahara dust and its impacts has long been recognized in the WCR, much uncertainty still exists. There is urgent need in the WCR for integrated environmental assessments incorporating air, land, and sea interactions as well as the long-range transport of airborne particles.

Microplastics in the marine environment: See Chapter 8 of this report.

6. STATE OF THE MARINE ENVIRONMENT WITH RESPECT TO LAND-BASED POLLUTION

STATE OF THE MARINE ENVIRONMENT WITH RESPECT TO LAND-BASED POLLUTION

Key messages

The marine environment continues to be acutely polluted from land-based sources and activities, as evidenced by low coastal water quality in many locations. For each of the eight core water quality indicators assessed based on data submitted by WCR countries, all except dissolved oxygen and pH showed sampling sites with ”poor” or ”unacceptable” status. In some countries and territories, the majority of the sampling sites were in these categories for specific indicator(s).

Fecal contamination of coastal waters is evident in all locations in every country and territory for which data was available. In many cases, the status of all or most of the sampling sites was outside the acceptable range for *Enterococcus* and *E. coli*, indicating widespread fecal contamination.

The proportion of sampling sites with poor status increased in the wet season. Elevated proportion of sites with poor status was generally observed in areas influenced by river discharge, which intensifies during the wet season. However, some exceptions were noted and may be linked to local conditions such as the high influx of tourists, inadequate wastewater treatment infrastructure, or discharge of contaminated groundwater.

Land-based pollution hotspots are apparent in several locations. Several areas showed relatively high proportions of sites with poor and unacceptable status for one or more of the indicators assessed. These areas may reflect potential pollution hotspots and are generally associated with areas influenced by riverine discharge. Improved monitoring and remedial actions are urgently needed in these areas.

6.1. Indicators of changing state

Pressures resulting from human population and land-based activities are expressed in the coastal and marine environment as changes in water quality and ecosystem degradation. As discussed in the preceding chapter, these pressures encompass a multitude of substances that are either directly harmful to ecosystems and living marine resources owing to their toxicity (e.g., hazardous chemicals) or promote processes that can eventually lead to ecological degradation and risk to public health (e.g., eutrophication and HABs).

The following eight core LBS water quality indicators were considered for this SOCAR assessment:

1. Dissolved inorganic nitrogen (DIN)
2. Dissolved inorganic phosphorus (DIP)
3. Chlorophyll-a (Chl-a)
4. Dissolved oxygen (DO)
5. Turbidity
6. pH
7. *Escherichia coli*
8. *Enterococcus species*

In addition, floating plastic and mercury were assessed because of the severity and pervasiveness of the threats to humans and marine ecosystems and biodiversity that they represent.

As mentioned in Chapter 2 of this report, the assessment of the core water quality indicators is based on data submitted to the Secretariat by national government representatives for the purposes of this report. It must be underscored that because of the spatial gaps in data due to the small proportion of countries that submited data for any one parameter, the results should not be considered as representative of the entire sub-region or region.

6.1.1. Nutrients

Data on the concentrations of nutrients in the water column are covered in the data sets of 11 countries and territories that submitted data. However, there is diversity among the nutrient parameters that the countries monitor, which include different forms of nitrogen (ammonia, nitrite, nitrate, Kjeldahl nitrogen, total nitrogen), phosphorus (phosphate, orthophosphate, total phosphorus, DIP), and silicate. DIN measurements were reported only in the continental USA (Gulf of Mexico) data set. In other cases, DIN was estimated as the sum of ammonium (NH_4), nitrite (NO_2), and nitrate (NO_3) for those countries and territories (Colombia, Dominican Republic, Guadeloupe, Puerto Rico, and Trinidad and Tobago) where data for these parameters were available for the same sampling sites on the same sampling dates. Monitoring and modelling of DIN and DIP should be strengthened among WCR countries to enable robust monitoring and evaluation of the impacts of management measures and to develop actions that will mitigate these issues.

DIN and DIP assessment ranges (cut values, or the range of values corresponding to good, fair and poor status) for continental and island environments are shown in Table 6.1. Note that assessment ranges for other forms of nitrogen and phosphorus have not been determined by the LBS Working Group.

Table 6.1. Assessment ranges and corresponding status for DIN and DIP for continental and island environments.

Indicator	Status	Continental mg.l^{-1}	Island mg.l^{-1}
DIN	Good	< 0.1	<0.05
	Fair	0.1 to 0.5	0.05 to 0.1
	Poor	>0.5	>0.1
DIP	Good	<0.01	<0.005
	Fair	0.01-0.05	0.005-0.01
	Poor	>0.05	>0.01

The assessment ranges were applied, as appropriate, to continental countries/territories and island states, except for the island of Trinidad (Trinidad and Tobago), where continental assessment ranges were used. Trinidad lies on the South American continental shelf and is heavily influenced by run-off from local rivers as well as from the Orinoco River, which is of particular note in the Gulf of Paria where the samples sites were located. On the other hand, island assessment ranges were applied to the island of Tobago (Trinidad and Tobago), which is more oceanic due to relatively low riverine influence on the island.

Dissolved inorganic nitrogen (DIN)

Data sets for the assessment of DIN concentration in coastal waters were available for six countries/territories in sub-regions I, III, IV, and V. The proportion of sampling sites with good, fair, and poor status in the dry and wet seasons is given in Figures 6.1. In general, nearly all the sites show good or fair status. However, in the Dominican Republic, Puerto Rico, and specific regions of Colombia (Antioquia and San Andres), all or most of the sites show poor status. In the Colombian Caribbean region, high loads of DIN and phosphate (up to ten times higher than those of the Pacific) are attributed to the influence of the Magdalena (Atlantico Department), Atrato (Antioquia Department), and Canal del Dique (Bolivar Department) rivers (INVEMER, 2017). The Magdalena River alone contributes 54% of DIN inputs (33,883 $t\ yr^{-1}$) and 93% of phosphate inputs (32,300 $t\ yr^{-1}$) to the marine environment. In Colombia, factors accounting for high nutrient loads include sewage input from cities and towns mainly in the Magdalena Basin, and fertilization of banana plantations in the lower courses of the Atrato River (Restrepo et al., 2006).

In neighbouring Venezuela, polluted small- and medium-sized rivers have DIN concentrations (278–6499 $\mu g\ L^{-1}$) that are between 2–60 times higher than that found in the Orinoco River (Bustamante et al., 2015). The Tuy River, which belongs to a watershed highly impacted by urban/industrial land use in Venezuela, has the highest DIN concentration, with ammonium being the dominant form (60% of total DIN) (Rasse et al., 2015). In Venezuela, about 96% of the urban population lives in the central northern region of the country (Muñoz et al., 2000, www.ine.gob.ve). Therefore, agricultural non-point sources and untreated urban sewage are the major anthropogenic sources of labile organic matter and nitrogen to watersheds and coastal areas of the Caribbean Sea (Rasse et al., 2015).

In the US Gulf of Mexico, all of the sites showing poor condition are in the Louisiana part of the shelf. This is consistent with well-documented records of the introduction of immense quantities of nutrients from the Mississippi-Atchafalaya River Basin (MARB) into the Louisiana-Texas shelf (e.g., Rabalais et al.,2002, Rabalais et al., 2014, Karnauskas et al., 2017). The watershed feeding into the MARB is the third largest in the world and its waters pass through the heart of the country's agricultural lands. As reported in the US National Coastal Condition Report IV (US EPA, 2012), DIN concentrations were rated poor in 1% of the Gulf Coast coastal area, representing several sites in Louisiana and Texas. The associated eutrophication and extensive hypoxic (low oxygen) zone in the northern Gulf of Mexico are discussed in Chapter 7.

Colombia, Dominican Republic, and Trinidad and Tobago show a higher percentage of sites with poor status in the wet season. This trend is reversed for Bolivar (Colombia), which showed a decrease in the wet season. This difference could be due to differences in sampling and local conditions.

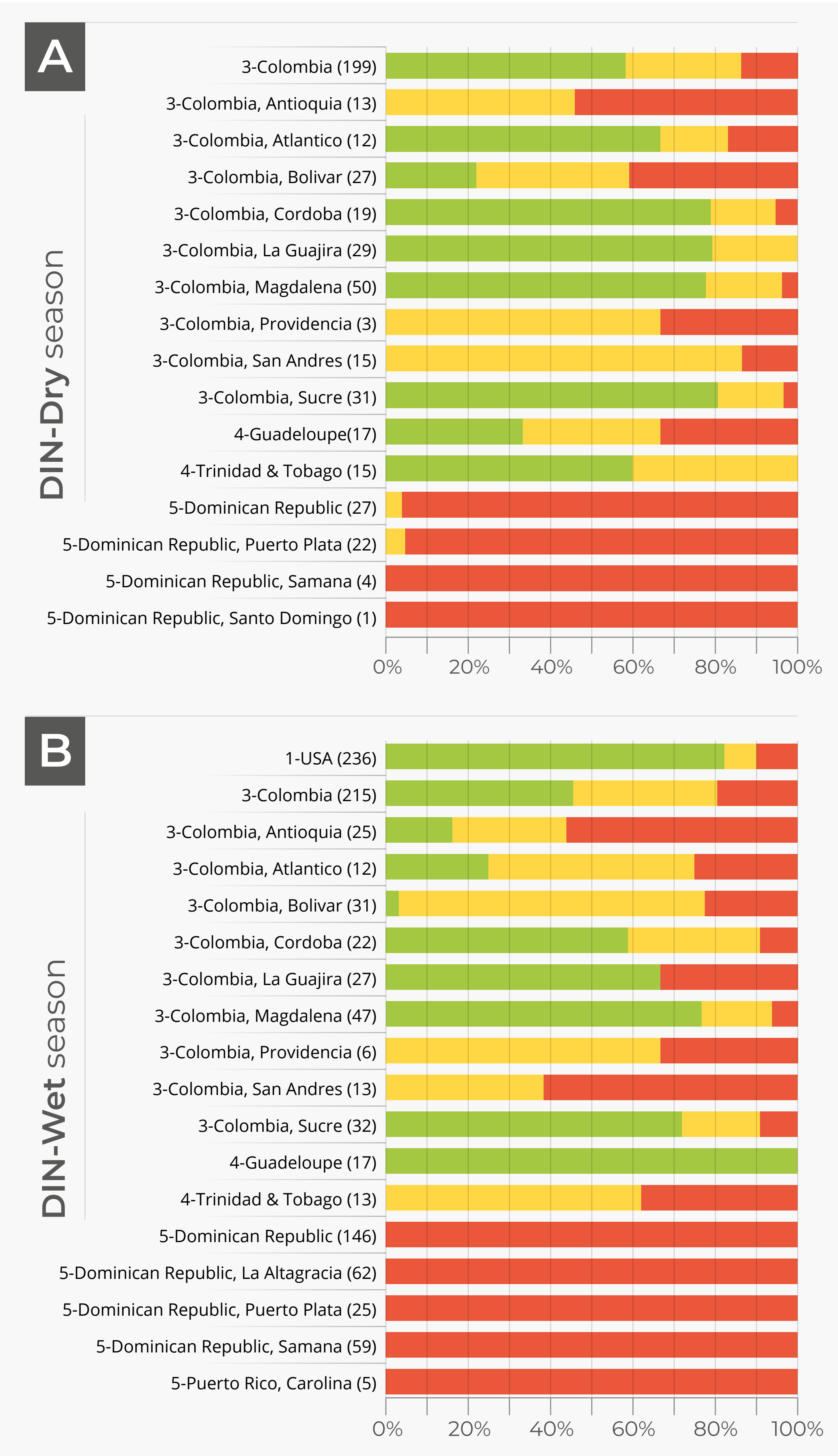
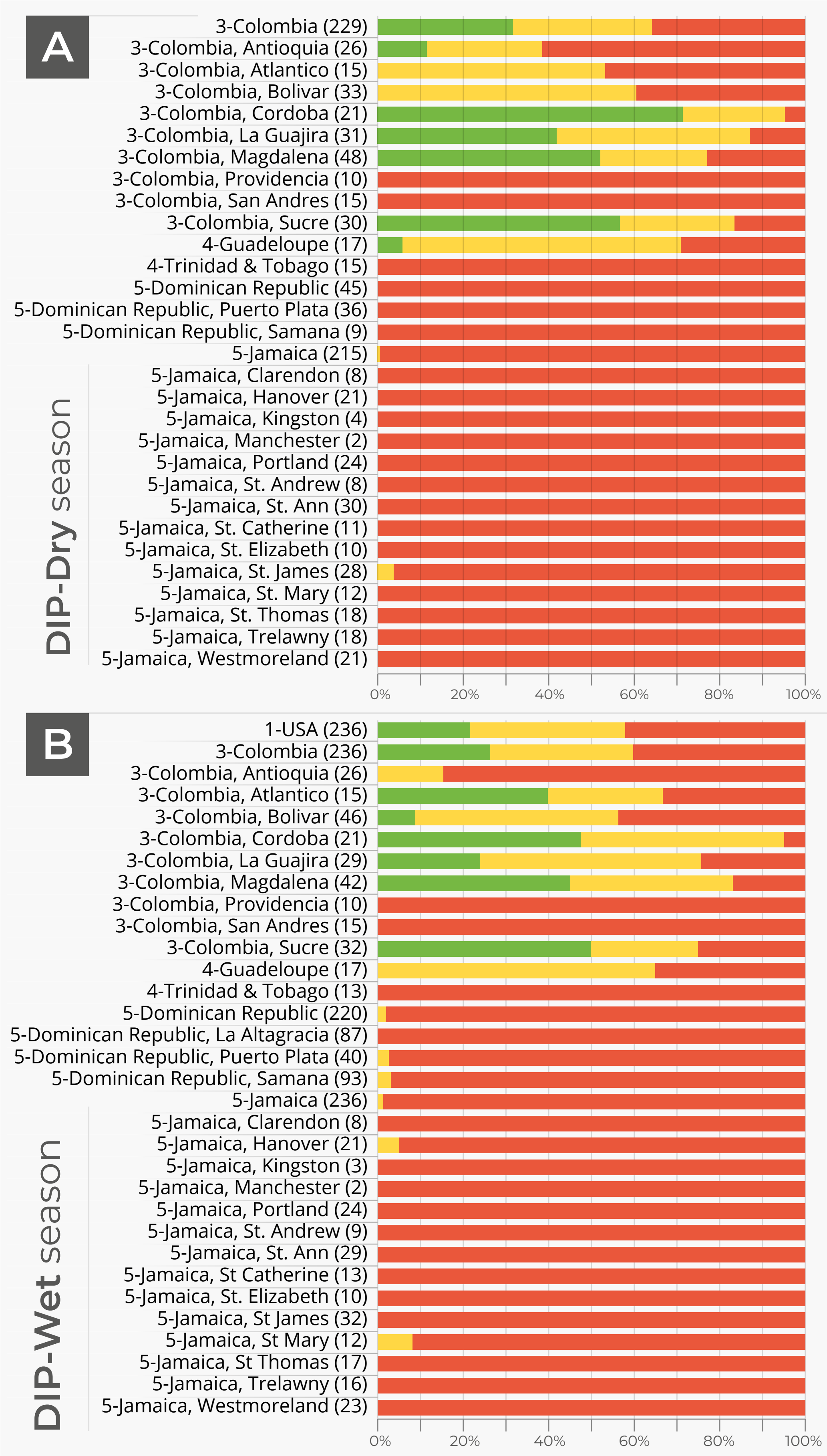


Figure 6.1. Proportion of sampling sites showing good, fair, and poor status in the dry (A) and wet (B) seasons for dissolved inorganic nitrogen (DIN).

The number preceding the country and 1st level administrative unit is the SOCAR sub-region; the number in brackets is the number of sampling sites. (Status: Green: good; yellow: fair; red: poor)

Figure 6.2. Percentage of sampling sites showing good, fair, and poor status in dry (A) and wet (B) seasons for dissolved inorganic phosphorus (DIP).

The number preceding the country and 1st level administrative unit is the SOCAR Sub-region; the number in brackets is the number of sampling sites. (Status: Green: good; yellow: fair; red: poor)



Dissolved inorganic phosphorus (DIP)

Data for the assessment of DIP were provided by six countries/territories in sub-regions I, III, IV, and V. The proportion of sampling sites with good, fair, and poor status in the dry and wet seasons is presented in Figure 6.2. In the majority of the sampling locations, all or most of the sites show poor status with respect to DIP concentration in the water column, particularly the Dominican Republic, Jamaica, Trinidad and Tobago, and the in Antioquia, Providencia, and San Andres departments of Colombia. The results for Jamaica are particularly notable. Overall, the percentage of sites with good and fair status increased in the wet season (from 14% to 18% and 17% to 27%, respectively) while the percentage of sites with poor status decreased (from 69% to 55%). This reflects generally improved conditions in the wet season, which is unexpected since there is higher discharge and presumably higher input of nutrients in the rainy season.

The high proportion of sites showing poor status with respect to DIP may be due in part to sewage, detergent, and industrial waste inputs to coastal areas. However, natural biogeochemical processes may be another factor influencing the concentration of phosphates in coastal waters. As reported in the US National Coastal Condition Report IV (US EPA, 2012), DIP concentrations are rated poor in 14% of the Gulf Coast coastal area. This includes sites in Tampa Bay and Charlotte Harbor (Florida) where high DIP concentrations occur both naturally (due to geological formations of phosphate rock in the watersheds) and artificially (due to substantial anthropogenic sources of DIP). These natural tendencies, which can be modified locally by anthropogenic loads or special circumstances, must be taken into account when developing measures to mitigate the effects of nutrient enrichment in coastal marine environments.

Excessive inputs of nutrients to coastal ecosystems give rise to eutrophication, which is manifested by increased growth of phytoplankton and benthic macro-vegetation. An Index of Coastal Eutrophication Potential (ICEP)[26] has been developed based on the ratio of dissolved silica (Si) to N or P in the nutrient loads delivered to coastal areas. A positive ICEP indicates a risk that potentially harmful (non-siliceous) algae (i.e., dinoflagellates[27]) bloom will develop. A zero or negative ICEP favours siliceous algae (such as diatoms[28]) that are generally not harmful unless they are in high abundance (due to high nutrient load rates). The ICEP has been adopted as an indicator for SDG Target 14.1. See Chapter 7 for further discussion of the ICEP.

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[26] Expressed in kilograms of carbon km^{-2} of river basin area.day^{-1}.

[27] Single-celled marine plankton (algae).

[28] Single-celled algae with a siliceous skeleton (composed of silica).

6.1.2. Chlorophyll-A

Chlorophyll-a (Chl-a) concentration is used as an indicator of phytoplankton biomass and is a commonly used indicator of the growing problem of coastal eutrophication (increased primary productivity due to nutrient enrichment). In general, the surface marine waters in the WCR are naturally oligotrophic or of low primary productivity, but high productivity is promoted in some areas by natural oceanographic processes and inputs of nutrients of anthropogenic origin (NOAA). Data on Chl-a concentration were submitted by six countries/territories in sub-regions I, III, and IV. Separate assessment ranges for continental and island environments were applied for Chl-a (Table 6.2).

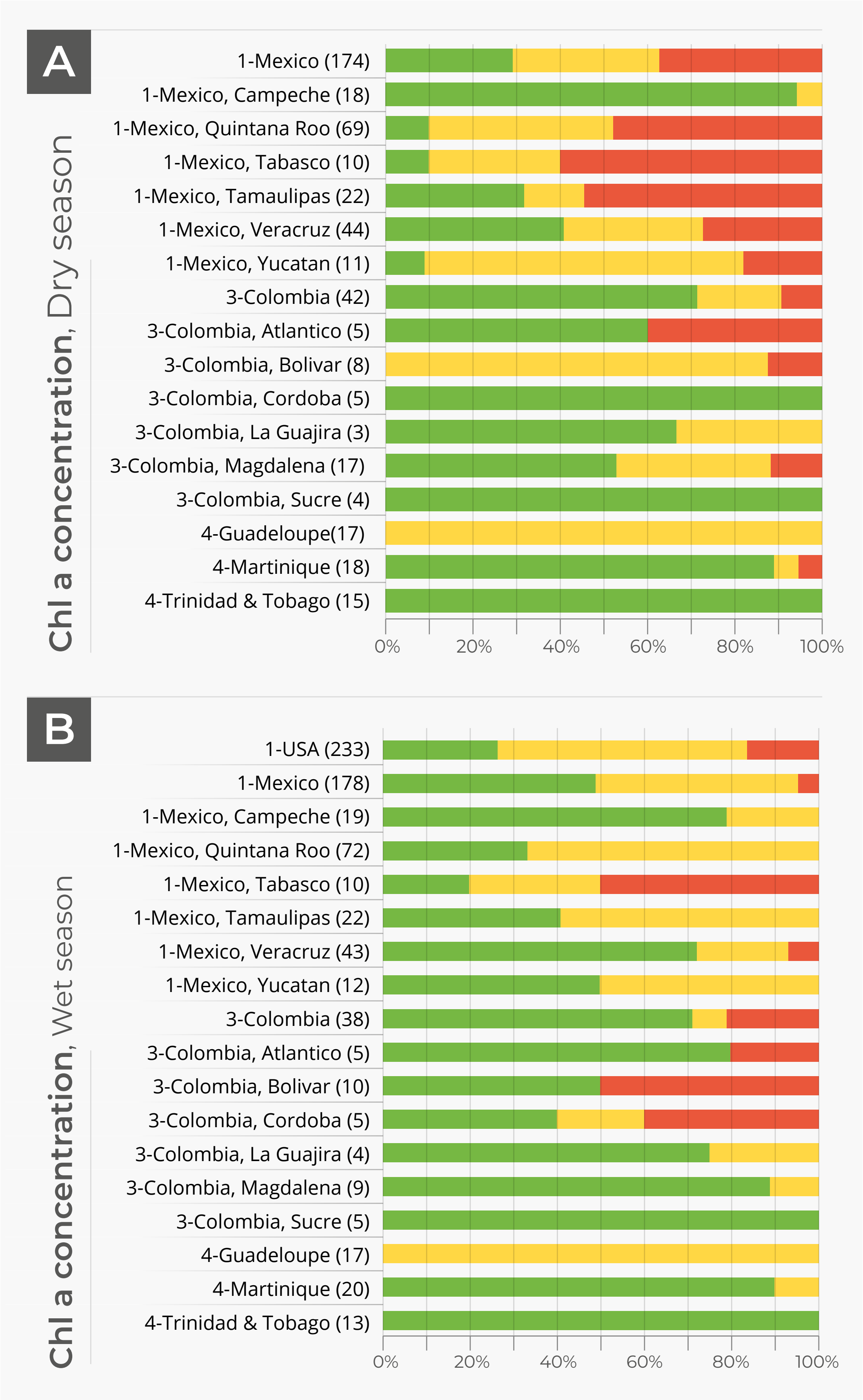
Table 6.2. Assessment ranges and corresponding ratings (status) for chlorophyll-a for continental and island environments.

Status	Continental μg l^{-1}	Island μg l^{-1}
Good	<5.0	<0.5
Fair	5.0 to 20.0	0.5 to 1.0
Poor	>20.0	>1.0

The percentages of sampling sites showing good, fair, and poor status in the dry and wet seasons are given in Figure 6.3.

Figure 6.3. Percentage of sampling sites showing good, fair, and poor status in dry (A) and wet (B) seasons for chlorophyll-a (Chl-a).

The number preceding the country and 1st level administrative unit is the SOCAR Sub-region; the number in brackets is the number of sampling sites. (Status: Green: good; yellow: fair; red: poor)



The majority of the sites show good status, except for sites in Tabasco, Tamaulipas, and Quintana Roo (descending order) in Mexico and Atlantico, Bolivar, and Cordoba in Colombia, where the highest percentages of sites with poor status occurred. This is likely associated with the influence of major rivers, such as the Grijalva–Usumacinta rivers (Tabasco) and the Rio Grande (Tamaulipas), underground rivers in Quintana Roo, karstic groundwater aquifers in the Yucatan Peninsula, the Magdalena River (Atlantico), and Canal del Dique (Bolivar Department). In Colombia, relatively high levels of DIN and DIP were noted for Atlantico and Bolivar in this assessment (as discussed above). Levels of Chl-a, along with nitrate, phosphate, and total phosphorus, are in excess of recommended threshold values for marine conservation and recreational use in Cartagena Bay, Colombia (Tosic et al., 2017).

While no data for DIN is available for Mexico, data for total nitrate submitted for the current assessment shows higher concentrations in Tabasco, Tamaulipas, and Quintana Roo, as well as Yucatan. In the continental USA (wet season), sites with poor status are in the Louisiana-Texas shelf, which is consistent with the DIN and DIP results obtained in the current assessment. High concentrations of Chl-a occur in the coastal areas of all five US Gulf Coast states (US EPA, 2012).

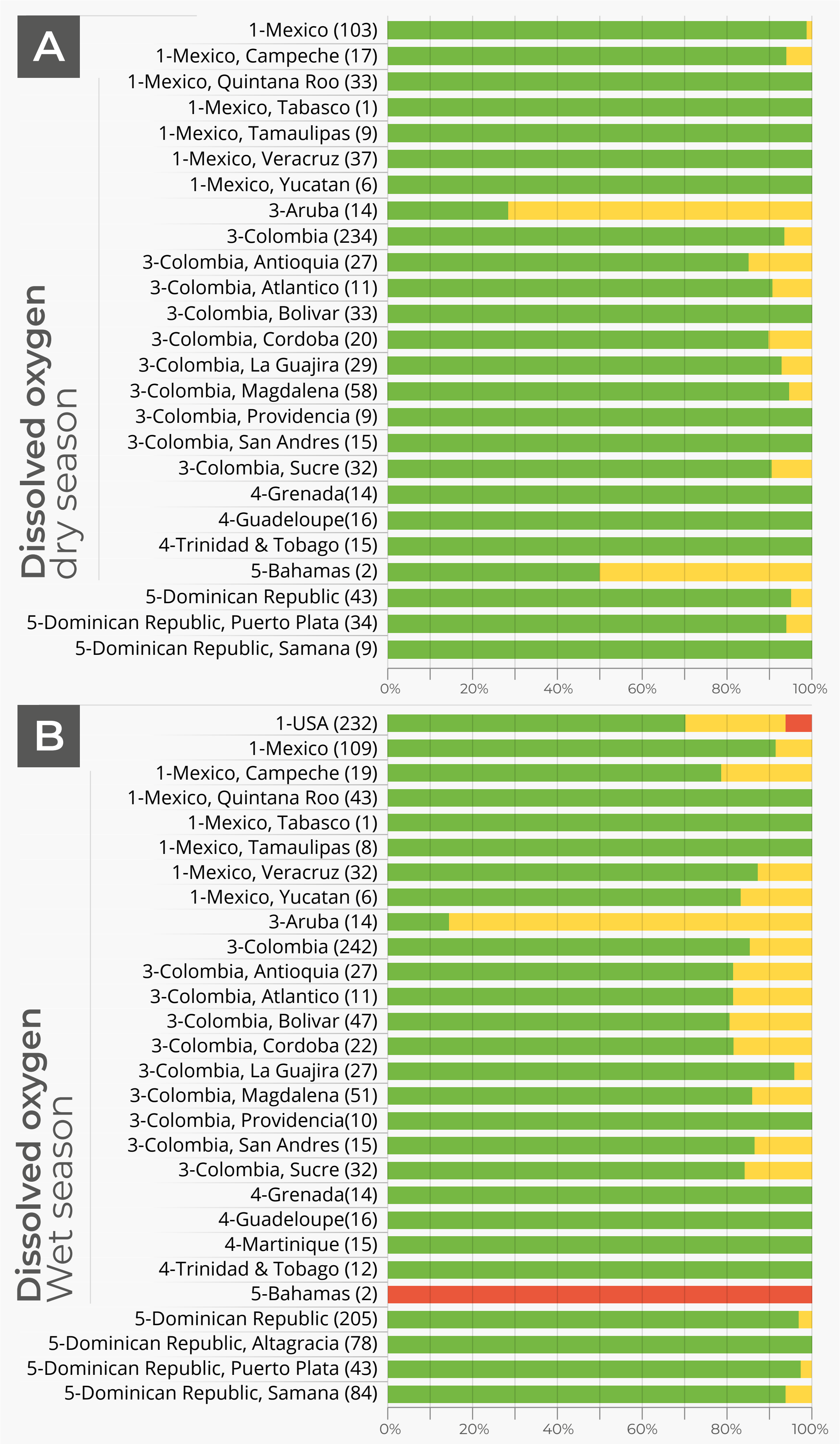
6.1.3. Dissolved oxygen

Dissolved oxygen (DO) concentration data were submitted by nine countries/territories. Bottom DO is the most appropriate indicator, since it is in bottom waters that oxygen depletion tends to occur as a result of sinking and decomposition of organic matter. However, information on the depths at which measurements were taken was provided only by Colombia, Guadeloupe, Martinique, Mexico, and the USA. DO measurements were taken in the bottom water by all of these countries except Colombia, which recorded DO at the surface. Results for those countries where the depth of DO measurements is unknown are inconclusive and not considered in further analysis in this report. The percentages of sampling sites with good, fair, and poor status in the dry and wet seasons are given in Figure 6.4.

All the sites in Guadeloupe and Martinique showed good status, while certain departments in Mexico showed less than 20% of sites with fair status (but none with poor status). Fourteen sites in the US Gulf of Mexico showed poor status. These are located along Louisiana, Texas, and Mississippi. These results are consistent with nutrient enrichment from the Mississippi River Basin and the associated hypoxic zone in the Gulf of Mexico, which extends from the Mississippi River westward to the upper Texas coast (Karnauskas et al., 2017). Low oxygen levels have been previously reported in other localities in the WCR (see Chapter 7). Local conditions at the time of sampling need to be considered in the interpretation of the observed DO values. There is a lag time between high nutrient load in the water and the resulting phytoplankton blooms and their decomposition, which is when bottom DO shows hypoxic levels. Sampling throughout the stages of a phytoplankton bloom may help resolve how changing bottom DO levels track changes in nutrient concentrations and phytoplankton biomass.

Figure 6.4. Percentage of sampling sites with good, fair, and poor status in dry (A) and wet (B) seasons for dissolved oxygen (DO).

The number preceding the country and 1st level administrative unit is the SOCAR Sub-region; the number in brackets is the number of sampling sites. Status: Green: good (> 5 mg.l-1); yellow: fair (5- 2 mg.l-1); red: poor (< 2 mg.l-1), island and continental environments.



6.1.4. Turbidity

Sediments, which affect turbidity (water clarity) of the water column, are listed in Annex I of the LBS Protocol as among the Primary Pollutants of Concern. Turbidity data were submitted by 10 countries/territories. Other related parameters monitored by several countries/territories are total suspended solids (TSS), total dissolved solids (TSD), conductivity, and mean Secchi disk depth. Only two assessment ranges are used to denote status with respect to turbidity: acceptable and non-acceptable, as agreed by the LBS Working Group. The acceptable range for turbidity is 0 – 1.5 NTU[29] or FNU[30]. Furthermore, the Working Group agreed that sites in areas with naturally turbid waters would not be assessed using the established ranges. These were Trinidad and Tobago (Gulf of Paria), French Guiana (entire coast), Colombia, and all the coastal states of Mexico except Campeche, Quintana Roo, and Yucatan.

Most of the sampling sites are outside of the acceptable range with respect to turbidity, except for Grenada, Guadeloupe, and Martinique (Figure 6.5). As expected, the overall proportion of sites outside the acceptable range increased in the wet season. The occurrence of high turbidity appears to be common in the region. Decreases in water visibility are found in all but one of the stations (Bonaire) assessed by the Caribbean Coastal Marine Productivity (CARICOMP) network, which were related to changes in human population density (Chollett et al., 2017).

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[29] Nephelometric Turbidity Unit.

[30] Formazin Nephelometric Unit.

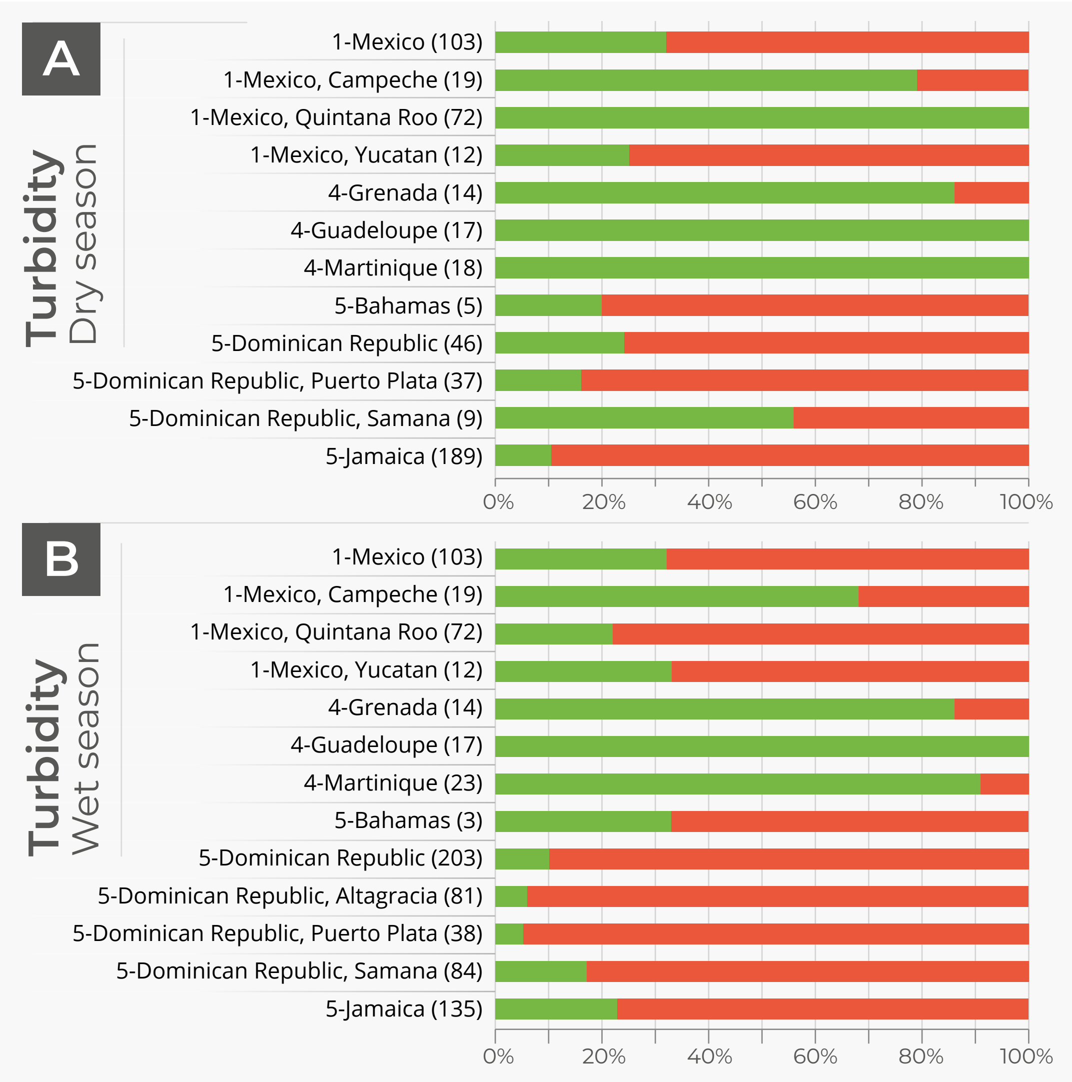

Figure 6.5. Percentage of sampling sites within and outside the acceptable range in dry (A) and wet (B) seasons for turbidity.

The number preceding the country and 1st level administrative unit is the SOCAR Sub-region; the number in brackets is the number of sampling sites. (Status: Green: acceptable (0-1.5 NTU); red: outside acceptable range)

6.1.5. pH

Acidity or alkalinity is measured using the pH scale, with a pH below 7 considered acidic, and a pH greater than 7 considered alkaline (or basic). The average pH of marine water near the surface is currently around 8.1. Current concern over changing pH in the global ocean focuses on decreasing pH (ocean acidification) linked to the release of CO_2 by human activities and its absorption or sequestration by the ocean, and the consequences of ocean acidification for marine life such as corals with carbonate exoskeletons. However, localized changes in pH due to human activities are also cause for concern, particularly since these changes may be more pronounced than changes in average pH in the global ocean.

Measurements of pH in coastal waters were submitted by 11 countries/territories. In this assessment, the acceptable range for pH is considered to be between 6.5 to 8.5. The proportion of sampling sites within and outside this range for the dry and wet seasons is shown in Figure 6.6. Nearly all the sites showed an acceptable status, with a low proportion of sites in certain areas outside the acceptable range (the majority greater than 8.5, which indicates more alkaline conditions). The highest proportion of sites outside the acceptable range in the dry season was observed in Tabasco (Mexico), Magdalena (Colombia), and Jamaica (Trelawny and St. Thomas). In the wet season, the highest proportion of sites outside the acceptable range was observed in Atlantico (Colombia), Altagracia (Dominican Republic), and Jamaica (Westmoreland and Portland).

Sites with low pH were found in Louisiana, USA (one site), and St. Mary and Portland, Jamaica (two sites). These results may be related to localized changes in pH due to pollution from various sources, including the mining industry. For example, the residue from bauxite mining (bauxite tailings) and industrial production of alumina, which is conducted in several WCR countries (e.g., Guyana, Jamaica, Mexico, Suriname, and Venezuela), is highly alkaline and detrimental to humans and marine organisms. The average pH of sugar factory effluent in Guyana was 5.99, which could potentially reduce the pH of coastal waters if released into this environment in adequate volumes. Other localized conditions (e.g., acid rain and decomposition of algal blooms) may reduce the pH of coastal waters. Further investigation is needed, including the use of other parameters along with pH to make determinations regarding the role of land-based pollution in changing coastal pH.

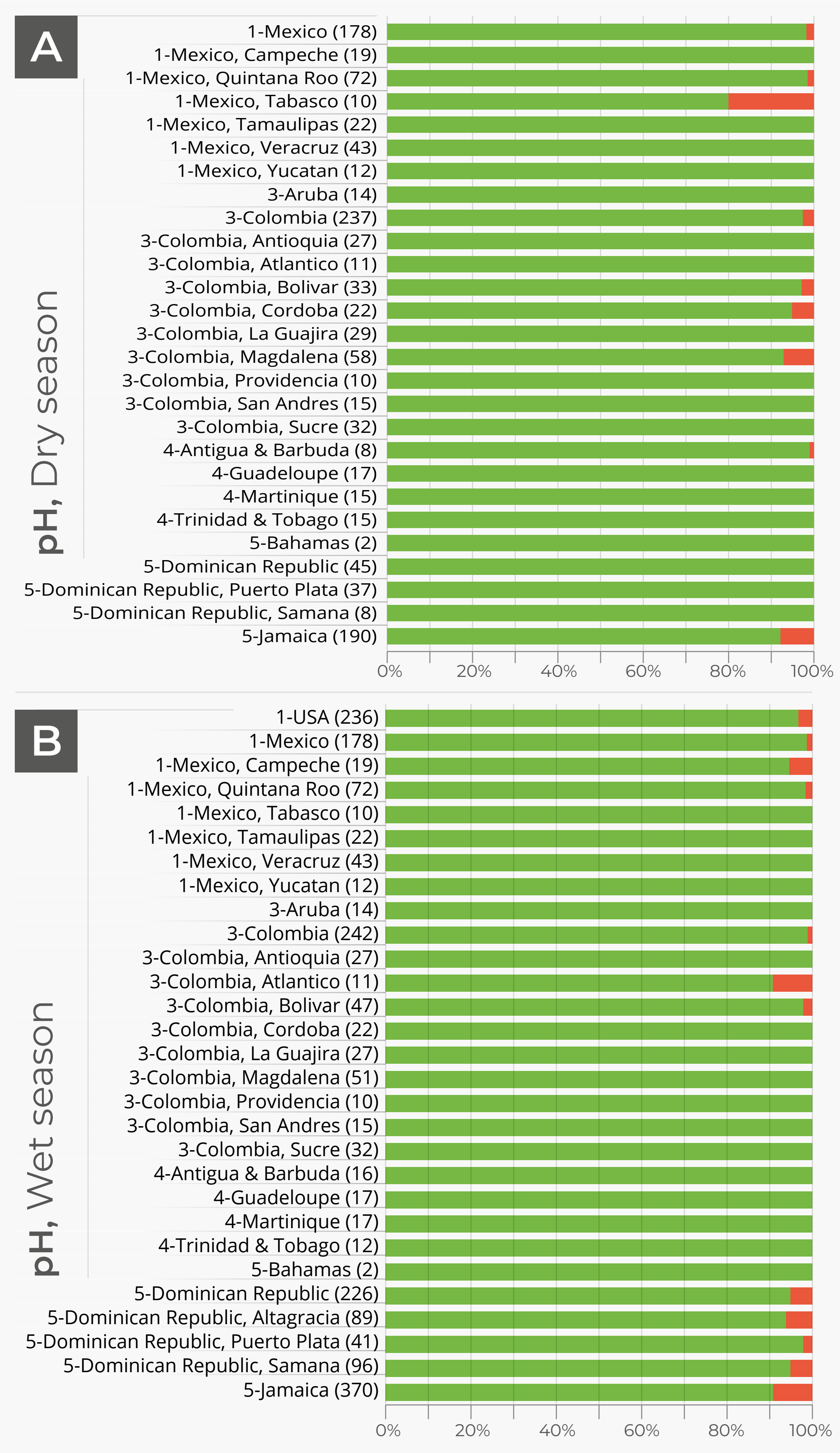

Figure 6.6. Percentage of sampling sites with acceptable and non-acceptable status in dry (A) and wet (B) seasons for pH.

The number preceding the country and 1st level administrative unit is the SOCAR sub-region; the number in brackets is the number of sampling sites. (Status: Green: acceptable (6.5-8.5); red: outside acceptable range)

6.1.6. Fecal contamination indicators

Domestic wastewater is the main contributor of pollution in the WCR marine environment (UNEP-CEP, 2010). Land-based wastewater discharge is the major contributor of bacterial loads and nutrients to nearshore waters (Nurse et al., 2012). Governments in the WCR have acknowledged that untreated sewage is a major threat to public health and the environment in the region.

The two commonly used indicators of human fecal pollution in water are *Enterococcus* sp. and *Escherichia coli*. *Enterococcus* is used as a proxy for polluted recreational waters and is the only fecal indicator recommended by the US Environmental Protection Agency (EPA) for brackish and marine waters. The most commonly monitored parameters among WCR countries are *Enterococcus* (15 countries), *E. coli* (12 countries), and fecal coliform (12 countries). This is likely related to a focus on complying with national drinking water and public health guidelines and standards.

Data for three countries (Dominica, Saint Lucia, and St. Vincent and the Grenadines) were obtained from a Master of Philosophy in Microbiology thesis at the University of the West Indies, Cave Hill, Barbados (De Leon, 2012). The (understandable) sensitivity of countries with respect to sharing bacteriological data has likely prevented some countries from contributing such data. Most of the data were collected in the wet season, with fewer countries/territories submitting data for the dry season.

The LBS Working Group agreed that only two assessment ranges (within and outside of the acceptable range) would be assigned to these two parameters (Table 6.3). These ranges are for both continental and island segments. It must be noted that several WCR countries have their own indicators and national standards for bacteriological contamination of coastal waters. However, for a regional assessment such as SOCAR, standardized assessment ranges are required to facilitate comparison across different spatial scales. Recommendations and decisions by the STAC and COP are needed regarding the incorporation of the various national standards in subsequent iterations of SOCAR.

Table 6.3. Bacteriological water quality criteria (assessment ranges) for *Enterococcus* and *E. coli*.

Organism	Acceptable range	Outside of acceptable range	References
Enterococcus	<35 CFU/100 ml	>35 CFU/100 ml	LBS Protocol Annex III – Discharges into Class I Waters
E. coli	0-126 MPN/100ml	>126 MPN/100ml	UNEP-CAR (2014). Report of the Working Group on Environmental Monitoring and Assessment 2013- 2014. UNEP (DEPI)/CAR WG.35/INF.5 WHO (2003). Guidelines for safe recreational water environments. Volume 1: Coastal and fresh waters. 219 pp.

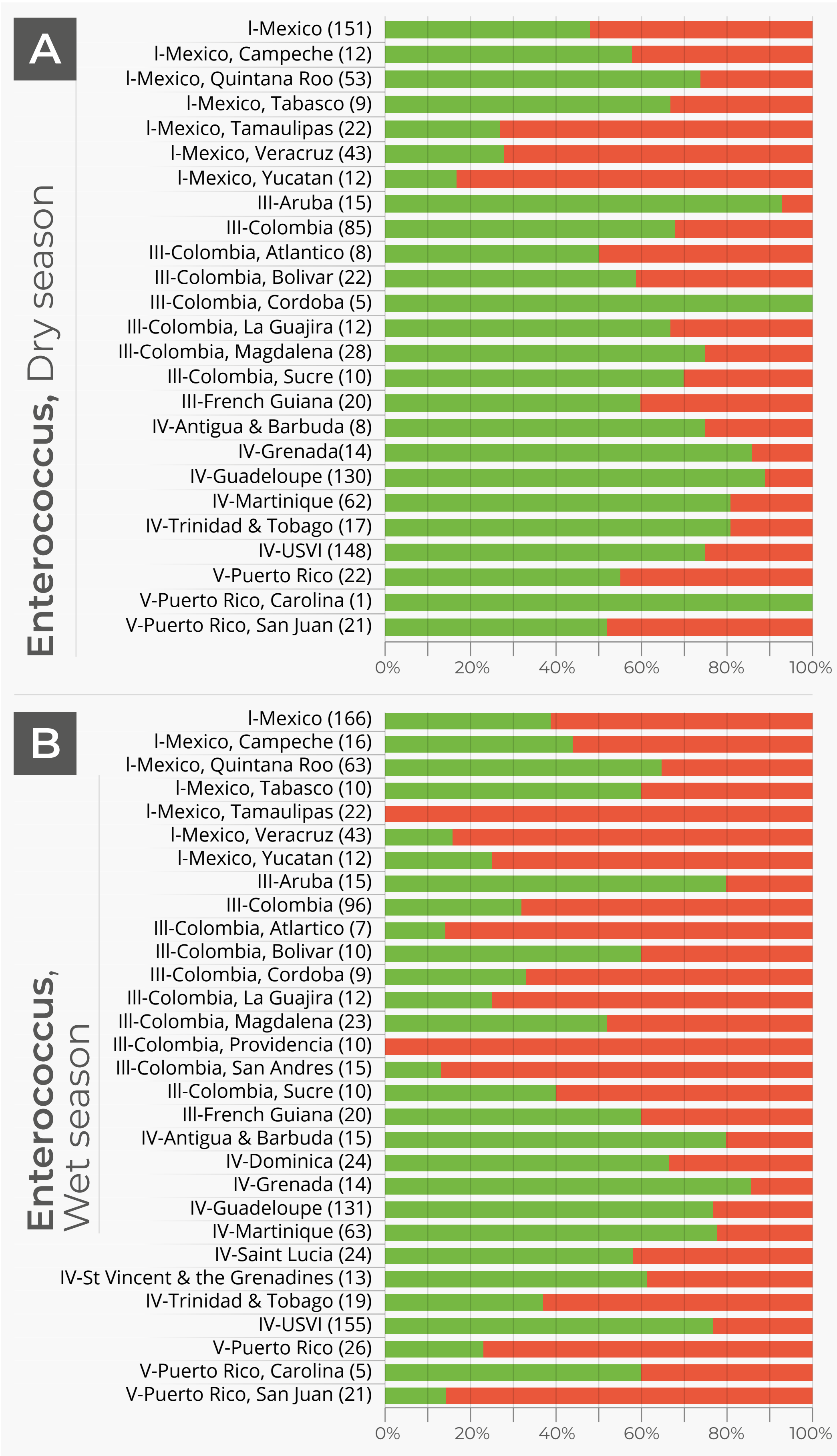

Figure 6.7. *Enterococcus*. Percentage of sampling sites within (green) and outside (red) the acceptable range in the dry (A) and wet (B) seasons.

The number preceding the country/territory and 1st level administrative unit is the SOCAR sub-region; the number in brackets is the number of sampling sites.

Enterococcus species

Data on *Enterococcus* was available for 14 countries/territories in sub-regions I, III, IV, and V. The percentage of sampling sites with good or poor status in the dry and wet seasons is shown in Figure 6.7. Overall, the majority of the sites show good status in the dry season. However, certain locations, particularly in continental areas, show that at least 40% of sites have poor status in both the dry and wet seasons. These include Campeche, Tamaulipas, Veracruz, and Yucatan (Mexico), Atlantico (Colombia) in the dry season and all Colombian locations in the wet season, French Guiana, Trinidad and Tobago, and San Juan (Puerto Rico). In the wet season, the percentage of sites with poor status increased for all of the locations in all continental areas and certain island locations. Exceptions are Antigua and Barbuda, and the US Virgin Islands (USVI), which show a reduction in the number of poor sites in the wet season. Overflow of sewage systems and leaching from septic tanks, particularly during heavy rains, can result in direct discharge of sewage into the environment.

Sampling sites with poor status are generally located in the vicinity of major rivers: Rio Grande (Tamaulipas), Papaloapan and Coatzacoalcos (Veracruz), and Grijalva–Usumacinta Rivers (Campeche and Tabasco) in Mexico and Magdalena River (Atlantico) and Canal del Dique (Bolivar) in Colombia. The highest domestic wastewater volume emitted in Colombia is in the Atlantico department, where the Magdalena River enters the Caribbean Sea in Baranquilla (INVEMAR, 2016). It is well established that the Magdalena River, which drains into the Caribbean Sea (Cartagena Bay) via the Dique Canal, introduces untreated domestic wastewater into coastal areas (Tosic et al., 2017, INVEMAR, 2016). The La Guajira department has no major rivers and the high proportion of poor sites may be linked to river outflow from outside of Colombia (i.e., Catatumbo River/Lake Maracaibo, Venezuela). The high proportion of sites showing poor status in the oceanic islands (Providencia, San Andres, and Puerto Rico) and areas not directly influenced by major river run-off (Yucatan) may be attributed to high coastal populations/urban areas compounded by significant annual influx of tourists (as discussed in Chapter 4), coupled with a low level of wastewater treatment.

Escherichia coli

The World Health Organization has designated *E. coli* as the principal indicator of fecal contamination for water and wastewater. Data on *E. coli* was available for 11 countries/territories in sub-regions III, IV, and V. The proportion of sampling sites showing good and poor status with respect to *E. coli* in the dry and wet seasons is shown in Figure 6.8. A high proportion of sites (40% and above) with poor status are found in Trinidad and Tobago and French Guiana in both dry and wet seasons, and Saint Lucia in the wet season. Aruba, Guadeloupe, and Trinidad and Tobago showed a slight increase in the proportion of poor sites in the wet season.

For both *Enterococcus* and *E. coli*, the majority of the sites monitored can be classified as acceptable. For *Enterococcus*, in countries/territories with samples in both dry and wet seasons, the overall proportion of sites outside of the acceptable range is higher in the wet season. Exceptions are for Antigua and Barbuda and USVI, where the proportion of sites with poor status is higher in the dry season. In general, the higher concentrations of *Enterococcus* and *E. coli* are found in areas influenced by river run-off and near to urban centres. These areas are indicative of (potential) hotspots, and should be more closely monitored and remedial actions implemented.

Figure 6.8. *Escherichia coli*. Percentage of sampling locations within (green) and outside (red) the acceptable range in the dry season (A) and wet season (B), by country/territory.

The number preceding the country/territory is the SOCAR sub-region; the number in brackets is the number of sampling sites.

IMPACT: CHANGING
MARINE ECOSYSTEM
CONDITION AND
HUMAN COSTS

7. IMPACT: CHANGING MARINE ECOSYSTEM CONDITION AND HUMAN COSTS

Key messages

Land-based pollution of the marine environment provokes a cascade of ecological changes, some of which have been documented in several localities the region. Harmful algal blooms, low oxygen levels in bottom waters, and mass mortality of marine fauna are among the more acute symptoms. The impact of local stressors, such as sewage and nutrients, as opposed to ocean warming, disease, and hurricanes, may have a greater impact on the health of marine ecosystems in the Caribbean. This requires that land- and marine-based stressors are simultaneously mitigated, especially in areas heavily influenced by continental fluxes.

Marine pollution poses a considerable threat to human health and economies. Globally, each year, there are millions of cases of gastrointestinal, respiratory, and other diseases that are linked to polluted coastal waters. Humans are also exposed to highly toxic pollutants such as mercury that bio-magnify and bio-accumulate in the marine food chain. Economic losses can amount to billions of dollars each year and affect important sectors such as tourism, fisheries, and mariculture.

Land-based pollution is a factor that can potentially contribute to precipitating the occurrence of ecological tipping points in marine ecosystems such as coral reefs. Ecological tipping points occur where small shifts in human pressures or environmental conditions bring about large, sometimes abrupt and irreversible changes in a system. Pollution, in particular by nutrients and sewage, coupled with coral diseases and the impacts of climate change may represent an "existential threat" to coral reefs in some areas.

The impacts of land-based pollution on human health and economies will seriously compromise our ability to achieve the SDGs and to develop a blue economy. Achieving the SDGs and targets related to pollution, and other relevant societal goals and targets requires urgent strengthening of efforts at all levels to diminish land-based pollution and mitigate its impacts, especially since land-based pollution is likely to increase.

7.1. Multiple impacts on marine ecosystems

Land-based pollution poses a significant threat to the condition of marine ecosystems and living marine resources, as well as to human health and economies. Multiple pressures or stressors affect ecosystem condition cumulatively and with a combined impact that is greater than that of the individual stressors (Halpern and Frazier, 2016). Moreover, little is known about which stressors are having the greatest impact on ecosystem condition, how they interact in the marine environment and the resulting cumulative effects, or how the composition of pressures is changing over time (Halpern et al., 2015; Wear and Vega Thurber, 2015). Within the WCR, information on the impact of pollution on marine ecosystems and human health and the associated economic costs is fragmented. These important knowledge gaps should be addressed in future pollution research and monitoring programs in which monitoring of water quality, habitats, and biota is done within an integrated environmental monitoring and assessment framework, which is the ideal approach. The knowledge gaps identified in this report should be included in the pollution research strategy that is being developed by the Gulf and Caribbean Fisheries Institute and others with support from the CLME+ Project. This report draws on published and unpublished sources that document the ecological and socioeconomic impacts of land-based pollution.

A recent and alarming example from this region that encapsulates how multiple human and natural pressures (including disease) combine to degrade marine ecosystems is provided in a report from the Nature Foundation Sint Maarten (25 February 2019) about the demise of coral reefs in this territory. It ends with a call-to-action to decision-makers and the wider community to address what is referred to as "an existential threat to our coral reefs" (Box 7.1). Undoubtedly, the message this report conveys will resonate with stakeholders throughout the entire WCR and indeed across the world where marine ecosystems are under threat.

The impact of pollution is manifested as different phenomena in the marine environment. Examples of several known key impacts are described below.

7.2. Eutrophication

Excessive input of nutrients to coastal waters (eutrophication) promotes an increase in primary production, which can result in a cascade of ecological changes. These include increases in the abundance of macroalgae (multicellular benthic vegetation), monospecific blooms of phytoplankton (some of which can be toxic—see harmful algal blooms, or HABs, below), and oxygen depletion at the sea floor as dead algal masses sink and decay.

In fact, HABs, hypoxia (low oxygen concentration in the water) and "dead zones" (areas devoid of macrofauna) are acute symptoms of the impacts of eutrophication. Other impacts include disruption in composition of aquatic communities, loss of habitat and biodiversity, reduced biological productivity, and water quality degradation. Some of these phenomena can also jeopardize public health.

7.2.1. Index of Coastal Eutrophication Potential

As mentioned in Chapter 6, the Index of Coastal Eutrophication Potential (ICEP) is an indicator for SDG Target 14.1. This index represents the potential for new production of harmful algal biomass in coastal waters (Seitzinger and Mayorga, 2016). A positive ICEP indicates a risk that potentially harmful algal blooms will develop, while a zero or negative ICEP favours algae that are generally not harmful. The ICEP was produced for each of the five sub-regions by E. Mayorga using the Global NEWS model (see Box 5.2). Results are presented in Table 7.1.

Table 7.1. Index of Coastal Eutrophication Potential (ICEP) for each of the five sub-regions (E. Mayorga, Univ. Washington).*

Sub-region	ICEP	Risk of harmful algal blooms
I	0.84	↑ Increasing risk
V	-3.01	
III	-3.17	
IV*	-12.90	
II	-33.21	

*Needs further study (See Box 5.2).

The spatial pattern of the ICEP generally corresponds with the pattern of nutrient inputs from watersheds. This index is positive for sub-region I (indicating a higher risk that potentially harmful algae will develop), which is consistent with high nutrient inputs from the Mississippi-Atchafalaya River Basin into the northern Gulf of Mexico and the associated eutrophication risk. Sub-regions III and V show moderate risk of eutrophication, which may also be associated with the discharge of nutrients into coastal areas from point and non-point sources. Sub-region III is heavily influenced by major rivers such as the Amazon, Orinoco, and Magdalena Rivers, as well as by many smaller rivers that drain large urban and agricultural areas. Sub-region V is influenced by the transboundary Artibonito River shared by Haiti and the Dominican Republic, as well as by urban and agricultural run-off from the land masses in this sub-region. The low risk for sub-region II may not be realistic, since this sub-region is also influenced by run-off from rivers and coastal urban areas. These results apply to relatively large spatial scales (such as the entire LME—see Figure 7.1) and there may be marked differences at smaller, localized scales. Further investigations on ICEP, including studies at smaller spatial scales and using empirical data, are required.

Seitzinger and Mayorga (2016) combined the ICEP and nitrogen loads to produce a "Merged nutrient risk indicator" to further explore the risk of eutrophication. They assessed this risk indicator for most of the world's 66 LMEs in years 2000, 2030, and 2050. Based on data for year 2000, the Gulf of Mexico and North Brazil Shelf LMEs are at very high risk and the Caribbean LME is at medium risk. To examine the risk of eutrophication of the WCR in a global context, the results for year 2050 are presented in Figure 7.1. If current trends continue, the Caribbean LME risk level for eutrophication will increase from medium to high in years 2030 and 2050, due to an increase in nitrogen loads and excess nitrogen or phosphorus relative to silica (demonstrated by eight LMEs worldwide). The risk levels of the other two LMEs will remain the same, at very high risk in 2050, demonstrated by six LMEs worldwide. The Northeast US Continental Shelf LME is at low risk of eutrophication.

Many eutrophic areas across the WCR have been previously documented (see Figure 7.4 below). Reduced nutrient inputs to specific watersheds are required to lower the estimated risks for eutrophication (Seitzinger and Mayorga, 2016). This can include, for example, increased nutrient-use efficiency in crop production, reductions in livestock and better management of manure, and increased treatment levels to remove nutrients from human sewage before it is discharged into the environment.

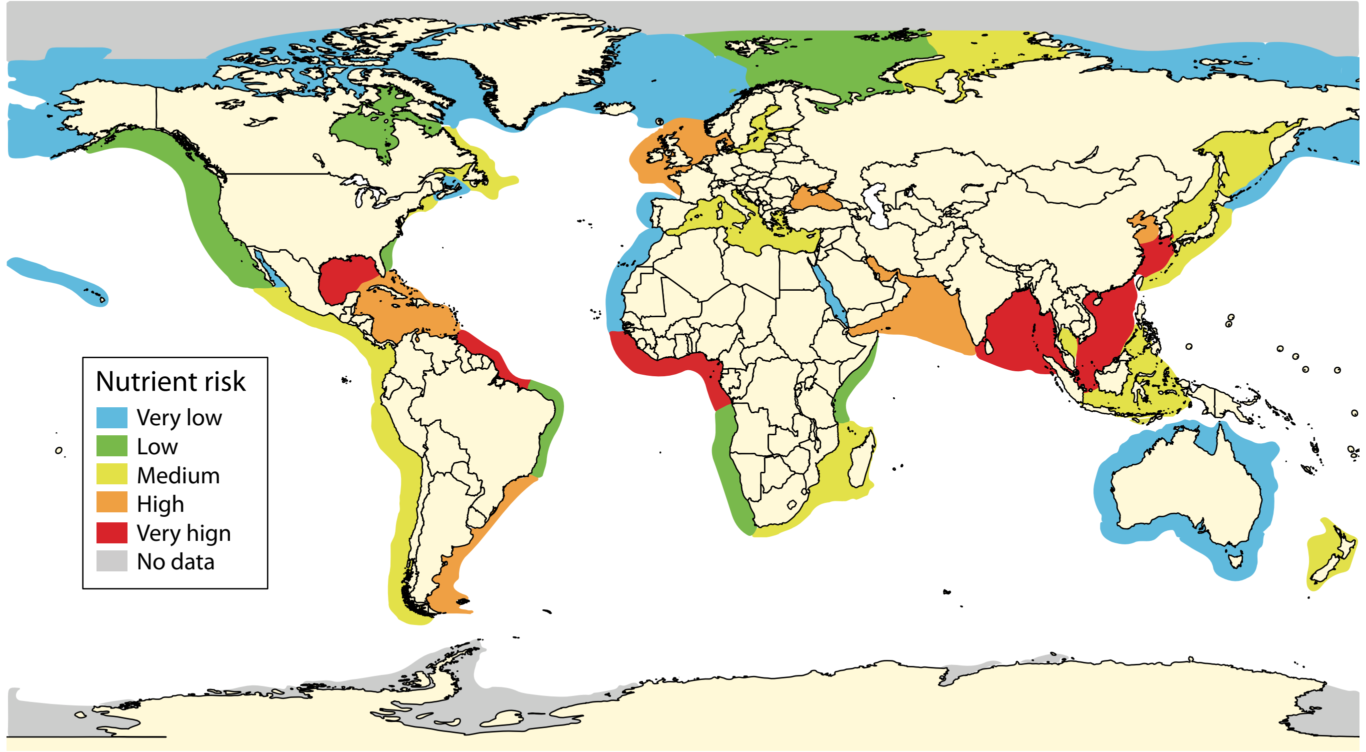

Figure 7.1. Merged Nutrient Risk Indicator projected to 2050 for LMEs
(Transboundary Waters Assessment Programme TWAP- Seitzinger and Mayorga, 2016. http://onesharedocean.org).

7.3. Harmful algal blooms

Excessive nutrient inputs, along with rising ocean temperatures, contribute to the sudden proliferation of microalgae or phytoplankton (algal blooms) in surface waters. Some species of microalgae are associated with the production of marine toxins that are harmful to fish, other marine fauna, and humans, hence the term "harmful algal blooms" (HABs). The most conspicuous effects include mass mortality of marine fauna and reductions in the quality of both recreational areas and shellfish harvesting areas, which results in substantial economic losses. In addition, human exposure to HABs, including by way of tainted seafood consumption (particularly shellfish), poses a substantial threat to human health. Human poisonings associated with HABs include paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera fish poisoning (CFP).

In recent years, the occurrence of HABs in Latin America and the Caribbean region has shown a clearly increasing trend (Méndez et al., 2018). However, comprehensive information on the incidence and associated costs of the impacts of HABs is generally limited for the WCR, and it is critical that this gap is addressed. Since 2009, several LAC countries, including Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Mexico, Nicaragua, Panama, Uruguay, and Venezuela, have been involved in a regional network[31] for early warning of HABs and biotoxins in seafood. Technical capacities have been developed at the regional level to identify toxic species, evaluate biota toxicity, and perform retrospective analysis of HAB occurrence (Cuellar-Martinez et al., 2018).

In the Harmful Algae Event Database (http://haedat.iode.org, 2018), HAB records from LAC countries in the early warning network indicated that between 1970 and 2007, about 7,800 documented reports of harmful algal

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[31] Supported by the International Atomic Energy Agency.

bloom toxin-related diseases, including 119 human fatalities, were mainly associated with PSP in the Pacific and Atlantic coasts, and with CFP in the Caribbean (Cuellar-Martinez et al., 2018). Recent records from the WCR include the occurrence of four HABs in the Magdalena Department of Colombia between 2010 and 2018 and several occurrences of fish mass mortalities caused by anoxic conditions that were produced by cyanobacteria blooms in Ciénaga Grande de Santa Marta. Mass mortality of sea turtles in El Salvador in 2013 was associated with PSP (Amaya et al., 2014). In recent years, there have been ongoing red tide outbreaks in Florida,[32] which in 2018 led the authorities to declare a state of emergency in some counties. One Florida county had to collect and remove more than 17 tons of dead fish since the red tide spread from South Florida into Tampa Bay (cbcmiami.com). It was also reported that tourists were keeping away from the affected areas.

HABs can result in significant economic losses within four main sectors: recreation and tourism, commercial fisheries, public health, and monitoring and management costs. In the USA, a preliminary and highly conservative nationwide estimate of the average annual costs of HABs is approximately US$50 million.[33] Public health is the largest component, representing nearly US$20 million annually or about 42% of the nationwide average cost. The effect on commercial fisheries averages US$18 million annually, followed by US$7 million for recreation and tourism effects, and US$2 million for monitoring and management. The actual dollar amount of these estimates is highly uncertain, due to a lack of information about the overall effect of many HAB events and difficulty in assigning a dollar cost to these events. Information on the economic costs of HABs in Florida is presented in Box 7.2.

Box 7.1. Economic cost (US$) of harmful algal blooms (red tides) in Florida

- Red tides are estimated to cause more than $20 million in tourism-related losses in Florida each year.
- The 2015–2016 red tide events resulted in a sales loss of $1.33 million to the hard clam aquaculture industry.
- Health costs attributed to medical expenses and lost work days associated with HABs cost the United States $22 million dollars annually. According to the Florida Department of Health, treatment of respiratory illness in Sarasota County during the 2015–2016 red tide event averaged $0.5 to $4 million dollars.
- In 1998, clean-up costs associated with the disposal of millions of tons of dead fish and marine life were estimated to be nearly $163,000 annually. However, in more severe events total clean-up costs for all affected areas can reach millions of dollars annually.

(Source: Krimpsky et al., 2019. Understanding Florida's Red Tide. https://www.flseagrant.org/news/2018/12/understanding-floridas-red-tide/)

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[32] For more information see: https://oceanservice.noaa.gov/news/redtide-florida/ and https://www.flseagrant.org/news/2018/12/understanding-floridas-red-tide/.

[33] http://www.whoi.edu/redtide/page.do?pid=15316.

7.4. Ciguatera fish poisoning in humans

In the WCR, a well-known illness associated with consuming certain groups of fish is ciguatera fish poisoning. The primary toxin involved is ciguatoxin, which is produced by the dinoflagellate *Gambierdiscus toxicus* throughout tropical regions, and particularly in coral reef environments. The conditions required for a bloom are not well understood, but are thought to include extended periods of elevated sea surface temperatures and high nutrient levels. *Gambierdiscus* growth is not harmful to humans unless a high concentration of toxin-producing cells develops and the toxin bio-accumulates in the food chain. Globally, ciguatera is the most common marine toxin disease (Camacho et al. 2007) and the most common form of non-bacterial seafood poisoning (Parsons and Richlen 2016).

Ciguatera is prevalent in the Caribbean (Figure 7.2) and is associated with consuming affected reef fish such as barracuda, grouper, and snapper. Although anecdotal information about ciguatera fish poisoning and its effects are widespread in the region, there is limited data on the incidence of this illness because of under-diagnosis and under-reporting. For example, in The Bahamas, only about 10% of cases are actually reported (Parsons and Richlen, 2016).

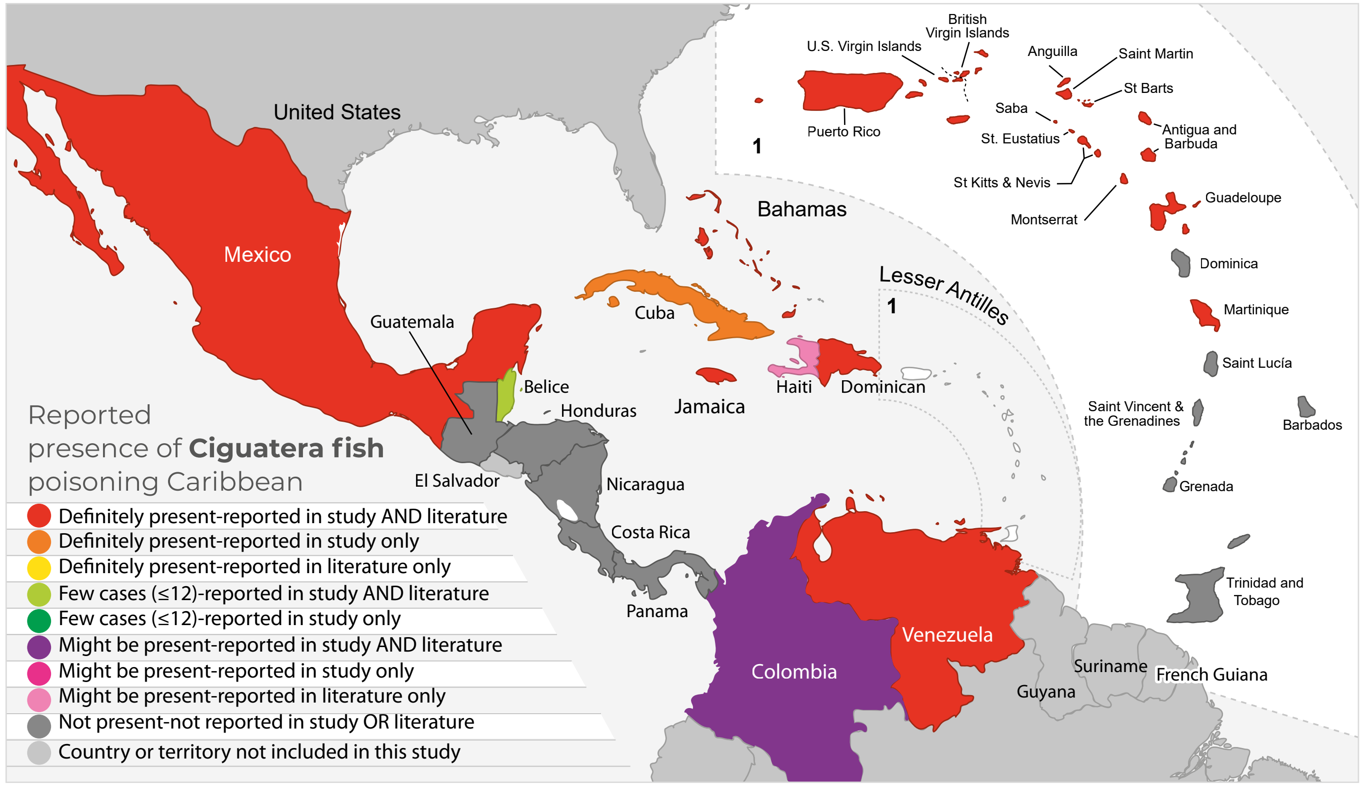
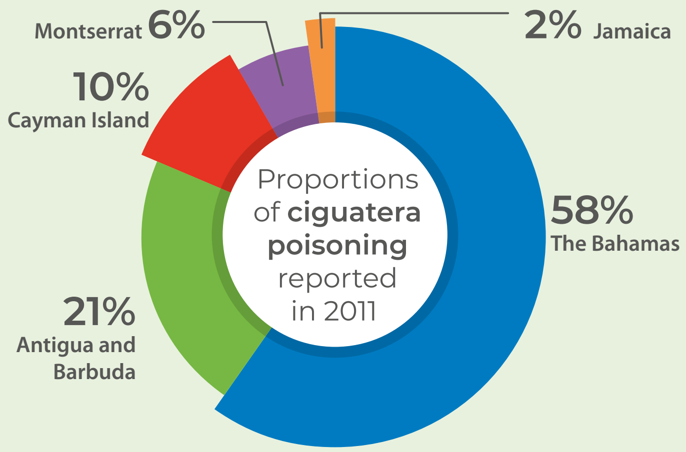


Figure 7.2. Ciguatera fish poisoning occurrence in the Caribbean reported by country from 1996–2006 (Source: Tester et al., 2014).

Examples of the incidence of ciguatera in some Caribbean islands are shown in Box 7.3. The Caribbean Epidemiology Centre/Pan American Health Organization reported that in 2011, ciguatera poisoning was the second most commonly reported foodborne disease (following salmonellosis) in member countries, a trend that has been observed since 2007. Efforts should be made by WCR countries to improve documentation of the incidence of ciguatera and to estimate the associated economic costs ciguatera poisoning.

Box 7.2. Ciguatera in the WCR

- During 2011, a total of 248 cases of clinically diagnosed ciguatera poisoning were reported from six countries, a slight increase of four cases over that reported in 2010. The chart below shows the largest proportions of ciguatera poisoning reported in 2011 (Caribbean Epidemiology Centre/Pan American Health Organization Annual Report 2011).



- US Virgin Islands and the French West Indies: Ciguatera affects an estimated 3% of the population each year*.
- St. Thomas: a household survey estimated that 4.4% of all households suffered from ciguatera annually (at least 2,640 persons per year or an annual incidence of 600 cases per year)*.
- Puerto Rico: 7% of the residents have experienced at least one episode of ciguatera in their lifetime*.

*http://www.whoi.edu/science/B/redtide/illness/ciguatera_fish_poisoning.html).

7.5. Low oxygen zones

Another potentially serious consequence of algal blooms is oxygen depletion in bottom waters as dead algae sink to the seafloor and oxygen is used up as they decompose. Oxygen depletion is also enhanced by the input of organic matter (with high BOD and COD) from other sources. Permanent or seasonal zones that are depleted of dissolved oxygen occur naturally in some ocean areas, but their frequency, spatial extent, duration, and intensity is reported to be increasing globally (Breightburn et al., 2018a, 2018b). These hypoxic zones (or oxygen minimum zones) are also called "dead zones" because they are devoid of macrofauna such as fish and shrimp. In anoxic (no oxygen) conditions, the decomposition of organic matter leads to the production of hydrogen sulfide (Breightburn et al., 2018a), which is toxic to most marine organisms. However, these "dead zones" are actually inhabited by microorganisms that can withstand low oxygen conditions. Numerous hypoxic zones have been recorded in the WCR (Figure 7.3).

The largest hypoxic zone in this region is the seasonal hypoxic zone off the Louisiana-Texas coast in the northern Gulf of Mexico, which is promoted by nutrient enrichment from the Mississippi River Basin. In July 2017, this zone covered 22,720 km^2, the largest ever measured in this location,[34] In 2018, the extent of this zone decreased to 7,040 km^2. Variability in coastal conditions, such as wind, storms, and wave conditions, as well as rainfall and snowmeltl melt in the upper watershed, may contribute to the observed annual differences (Figure 7.4).

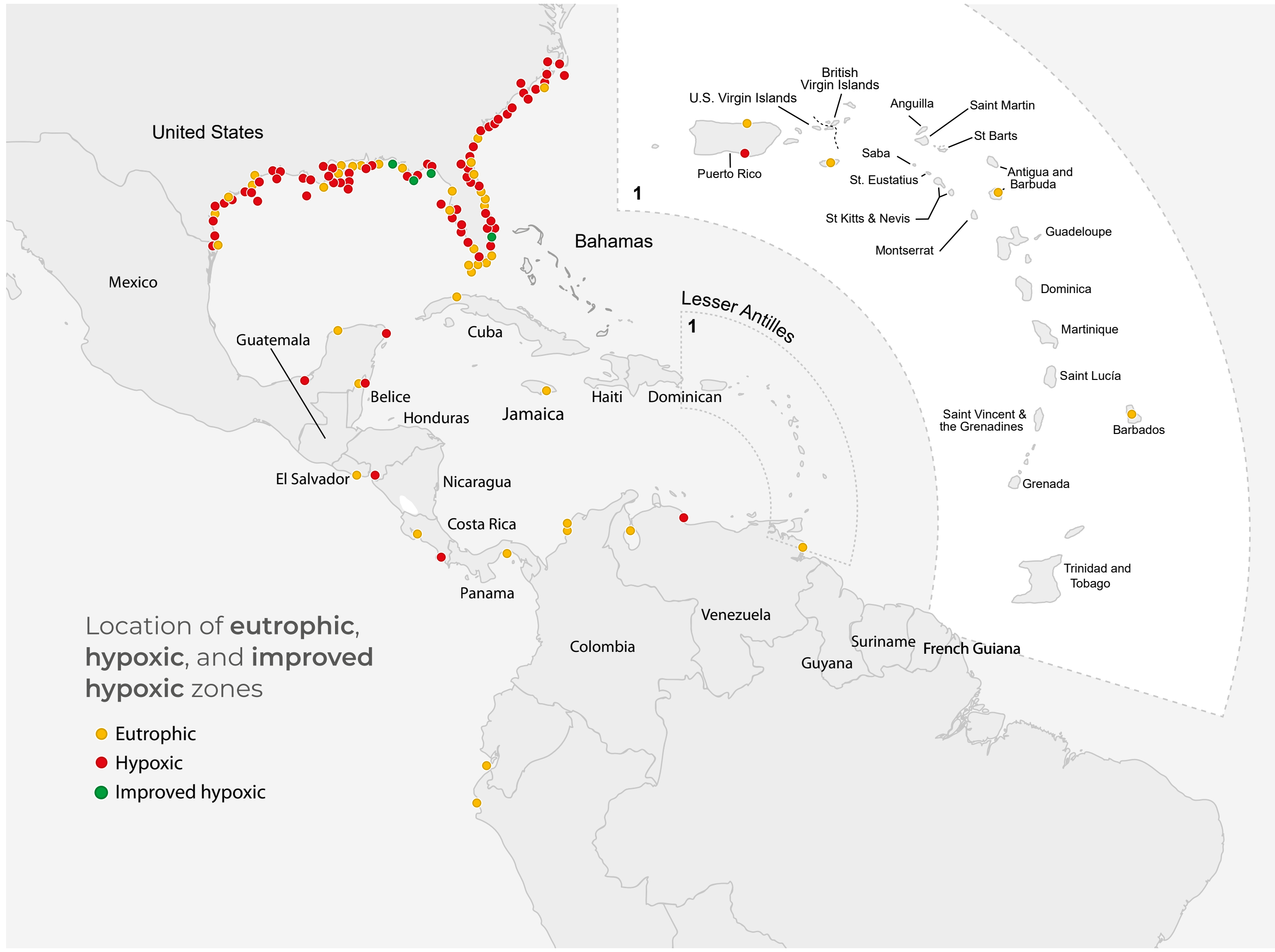


Figure 7.3. Location of eutrophic, hypoxic, and improved hypoxic zones throughout the Wider Caribbean.
(Selman et al., 2008).

The Mississippi River/Gulf of Mexico Hypoxia Task Force was established in 1997 to understand the causes and effects of eutrophication in the Gulf of Mexico, coordinate activities to reduce the size, severity, and duration of the seasonal hypoxic zone, and ameliorate the effects of hypoxia. In 2001, the Task Force released the *2001 Action Plan* (a national strategy to reduce Gulf hypoxia), followed by a revised action plan in 2008[35] to reduce, mitigate, and control hypoxia in the Northern Gulf of Mexico and improve water quality in the Mississippi River Basin.

Hypoxia can have profoundly adverse effects on marine communities and fisheries ,as well as on human communities. The United Nations Development Programme (UNDP) estimates that globally, the annual cost of damage from coastal hypoxia is between US$200 billion and US$800 billion per year, which represents a major drag on economic progress and poverty reduction (Hudson and

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[34] N. Rabalais, LSU/LUMCON; https://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured.

[35] https://www.epa.gov/ms-htf/gulf-hypoxia-action-plan-2008.

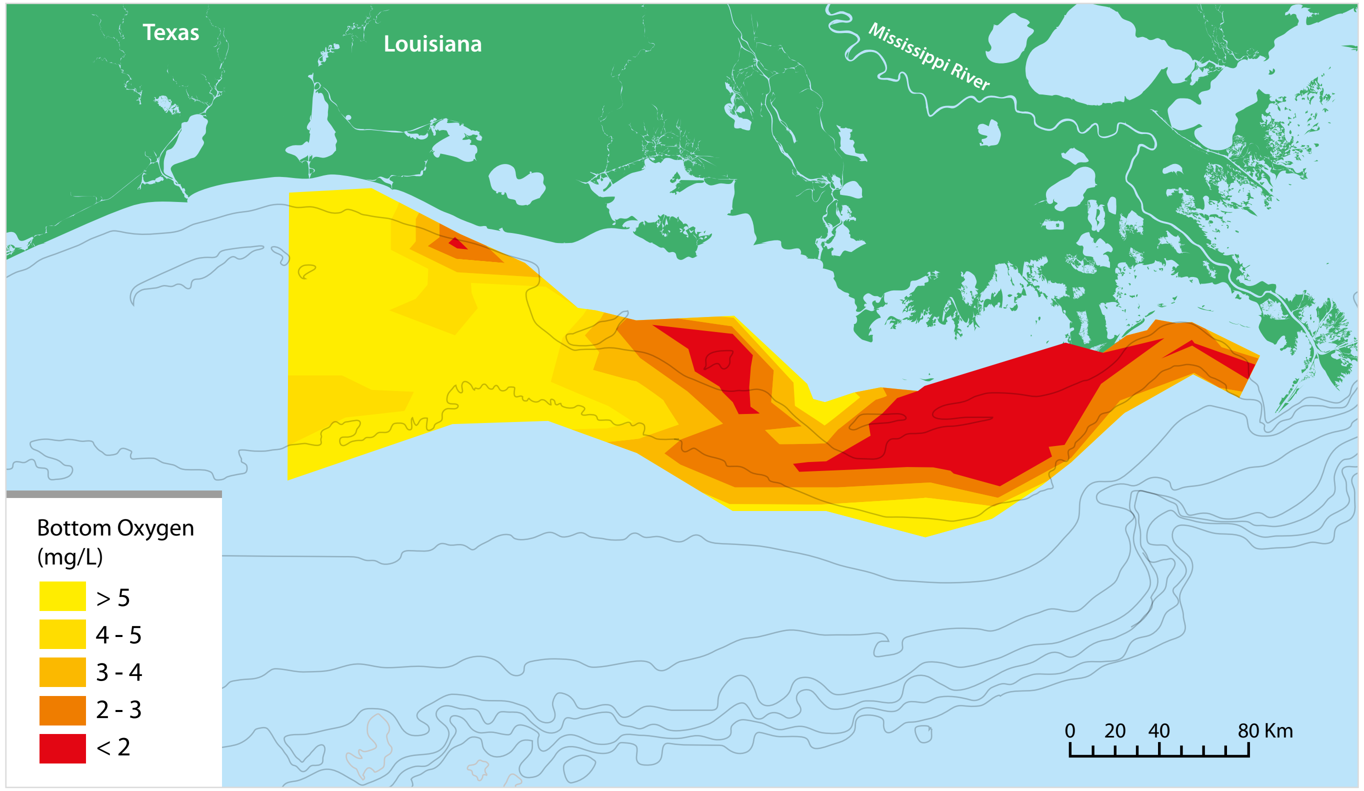


Figure 7.4. Gulf of Mexico bottom oxygen concentration on the Louisiana-Texas continental shelf, July 2018

(https://gulfhypoxia.net/).

Yannick Glemarec, 2012). Although difficult to quantify, the economic effects of hypoxia and HABs can also be serious at local and regional levels. For example, evidence linking Gulf of Mexico hypoxia to economic impacts revealed a recurring pattern of spikes in the price of large shrimp relative to small ones during months when hypoxic dead zones occurred in late spring and summer (Smith et al., 2017). In Cartagena Bay, Colombia, the drastic reductions in artisanal fisheries observed in recent decades by the bay's rural communities are likely related to hypoxic conditions in the bay (Tosic et al., 2017).

7.6. Coral reef decline

Anthropogenic nutrient enrichment of coastal waters is often associated with coral reef decline and has negative long-term consequences for corals (D'Angelo and Wiedenmann, 2014). After overfishing, high concentration of nutrients, primarily from inadequately treated sewage, is the main cause of widespread coral death and reduction in coral cover across the Caribbean region (Jackson et al., 2014). This is well-documented in many localities across the region (for examples, see Table 7.2), where effects include an increase in macroalgae on coral reefs and seagrass beds. Macroalgae overgrowth can smother corals, seagrasses, and sessile organisms. This is exacerbated by a reduced abundance of herbivorous fish (due to overfishing) that feed on submerged vegetation, including macroalgae. Eutrophication also reduces the ability of marine ecosystems to withstand threats from climate change.

Table 7.2. Examples of the impacts of nutrients, sewage, wastewater, and sediments on coral reefs and seagrass beds in the WCR.

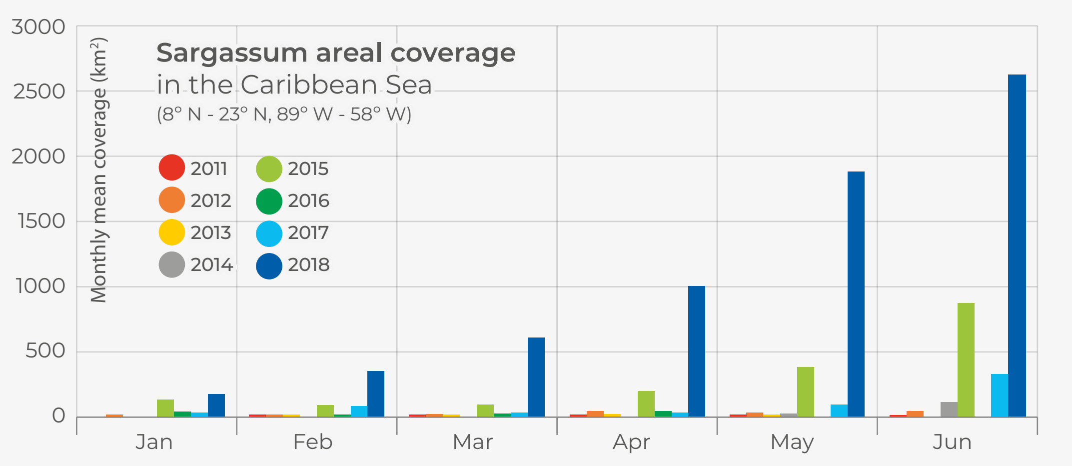
Country and/or location	Nutrients, agric. run-off	Sewage	Wastewater	Sediments	Description
Sint Maarten, Simpson Bay and Lagoon	✓	✓	✓		Nutrient run-off, sewage, overfishing, and climate change impacts, combined with tissue loss disease, are degrading coral reefs. HABs have been observed and nutrient indicator algae appeared in areas where previously it was largely absent (Sint Maarten Nature Foundation, 2019. http://list-serv.gcfi.org/scripts/wa-GCFI.exe?A2=ind1902&L=CAMPAM-L&P=R215694).
Jamaica, Negril	✓	✓			All coastal waters had nutrient and chlorophyll concentrations that exceeded thresholds for healthy coral reefs. Reefs had low coral cover and were smothered by eutrophic algae (Goreau and Goreau, http://www.globalcoral.org/_oldgcra/water_quality_in_the_negril_area.htm).
Jamaica, Negril	✓	✓			Blooms of macroalgae in shallow and deep reefs in 2001 correlated with increased nutrient enrichment from sewage discharges in the South Negril River (Lapointe et al., 2011).
Panama, Bocas del Toro	✓		✓		Eutrophication (as manifested by high Chl-a levels) and high turbidity are implicated in the loss of hard coral diversity. Hard coral cover within the bay declined to less than 10%, with extremely low diversities at some sites (Seemann et al., 2014).
Panama, Bocas del Toro (Bahia Almirante)	✓	✓			In 2010, coral bleaching and mass mortality of corals and other reef-associated organisms was caused by hypoxic (low oxygen) conditions and dead zones caused by nutrient inputs from agricultural run-off and untreated sewage (Altieri et al., 2017).
Trinidad & Tobago, Buccoo Reef	✓		✓		Nutrient enrichment has caused localized coral reef degradation (high macroalgae, low coral cover). Tobago's fringing coral reefs and Buccoo Reef Complex are affected locally by wastewater and stormwater, and regionally by the Orinoco River (Lapointe et al., 2010).
Bonaire, Curacao, Florida, Guadeloupe				✓	Degradation and mass mortality of coral reefs following dredging (Erftemeijer et al., 2012),
Colombia, Rosario Islands				✓	Increasing trends in sediment load coincided with the overall decline of healthy coral cover and water quality, as well as an associated increase in the percentage of algae cover in this national park (Restrepo et al., 2016).
Colombia, Cartagena Bay				✓	Of nearly 850 ha of seagrass existing in the Cartagena Bay in the 1930s, only 76 ha remained in 2001 (less than 8% of the original cover), which can be attributed to the impacts of heavy sediment loads and freshwater discharges (Restrepo et al., 2006).
USA, Florida	✓				Karenia brevis red tides are occurring with greater frequency, closer to shore, and during more months of the year. This can be attributed to greater nutrient inputs into coastal waters from increased agricultural run-off and sewage discharges. Fish kills caused by red tides are a common occurrence (Natural Resources Defense Council, 2014).
Saint Lucia				✓	Sites with a higher proportion of terrigenous sediment were associated with lower coral cover, higher macroalgal cover, and greater coral declines (Bégin, 2012),
Caribbean		✓			Sewage effluent has been identified as the source of the pathogen complex that causes white pox disease in Caribbean corals (Sutherland et al., 2010).

7.7. Sargassum blooms—the nutrient connection

Nutrient inputs to the ocean from land-based sources, along with other factors acting synergistically, have been implicated in the unprecedented Sargassum blooms that have been plaguing this region since 2011. Mass strandings of floating Sargassum have been observed almost yearly along the coast in many countries in the Caribbean, Brazil, and West Africa. Recent satellite images reveal increasing trends in Sargassum coverage in both the Caribbean (Figure 7.5) and the tropical Atlantic through 2018.

Figure 7.5. Monthly mean Sargassum areal coverage in the Caribbean Sea between 2011 and 2018

(University of South Florida Sargassum Watch System, https://optics.marine.usf.edu/projects/saws.html).

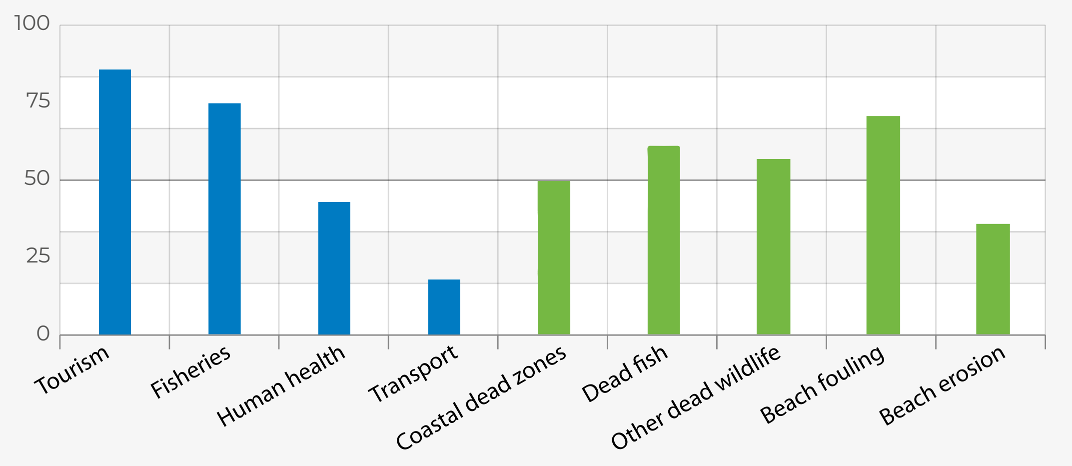


Researchers (e.g., Djakouré et al., 2017 and Sissini et al., 2017) have attributed the outbreaks to increases in nitrate and phosphate inputs by the Amazon River associated with deforestation and agro-industrial and urban sources, combined with warmer sea-surface temperatures observed in 2010–2011. Other factors that have been proposed include changes in ocean circulation, flow of nutrients from the Congo River in West Africa, and inputs of iron-rich dust from northwest Africa. However, the exact chemical, physical, or biological conditions responsible for the unusual periodic blooms of Sargassum in the region remain unclear and require further research.

The Sargassum proliferation has serious consequences for coastal and marine ecosystems, water quality, waterways, shorelines, fisheries, and tourism, as well as the health of the human population and the economy of the affected countries (Figure 7.6).

Figure 7.6. Percentage of territories where different economic sectors have been affected (blue bars), and where different ecological issues have occurred as a result of the outbreaks (orange bars).

Data from UNEP-CEP 2018, based on survey responses of national Focal Points from 28 territories in the Wider Caribbean.



While Sargassum itself is not toxic, the decay of large quantities can lead to anoxia and dead zones as well as the build-up of poisonous hydrogen sulfide, which is harmful to marine animals and humans. This can also trigger mortalities of fish and coastal invertebrates, and can severely impact local fisheries and aquaculture. The unprecedented scale of the Sargassum invasion has led to emergency conditions in several Caribbean countries (UNEP-CEP 2018). Some have experienced significant declines in tourism, such as the 30–35% drop in visitors during the early part of 2018 in Quintana Roo, Mexico (Arellano, 2018). There is an urgent need to develop regional cooperation on ocean governance and ensure an ecologically friendly management intervention, which can include using Sargassum as a resource (transformation and value-addition to animal feed and fertilizers, etc.) (UNEP-CEP, 2018).

7.8. Turbid waters

Corals are particularly vulnerable to increases in turbidity, which can cause smothering and burial of coral polyps, shading, tissue necrosis, and bacterial population explosions in coral mucus. Pollock et al. (2014) found that chronic exposure of coral reefs to dredging-associated sedimentation and turbidity significantly increased the prevalence of white syndromes—a devastating group of globally important coral diseases—and increased other signs of compromised coral health relative to reefs that have little or no sediment plume exposure. Minimizing sedimentation and turbidity associated with coastal development will provide an important management tool for controlling the outbreak of coral diseases.

Examples of case studies showing the impact of sedimentation and other stressors on coral reefs in the WCR are provided in Table 7.2. These studies underscore the importance of local stressors, such as run-off and dispersion of turbid plumes, compared to ocean warming, disease, and hurricanes, which have played a larger role on other coral reefs in the Caribbean (Restrepo et al., 2016). As a result, coral reef management across the WCR, especially in areas heavily influenced by continental fluxes, may only be effective when land- and marine-based stressors are simultaneously mitigated (Restrepo et al., 2016).

Another issue of major environmental concern regarding the inputs of sediments in coastal waters is the contamination of sediments with toxic chemicals. A wide variety of metals and organic substances, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), heavy metals, and pesticides, are discharged into coastal waters from urban, agricultural, and industrial sources. These contaminants adsorb onto suspended particles and eventually accumulate in depositional basins. Sediment, therefore, is a key means by which such pollutants are transported to water bodies (FAO, 2017). Bottom sediments from Cartagena Bay were found to have concentrations of mercury, cadmium, chromium, copper, and nickel in excess of the Threshold Effects Levels used as an indicator of potential impacts on marine life (Tosic et al., 2017). In the US Gulf of Mexico, sediment contaminants measured in coastal waters included elevated levels of metals, pesticides, PCBs, and, occasionally, PAHs (US EPA, 2012). These substances can become concentrated in marine organisms and pose a risk to organisms throughout the food web, including humans. Improved monitoring of contaminants in sediments and impacts on living marine organisms is needed in many of WCR countries.

7.9. The threat of sewage to ecosystems and humans

Discharge of untreated sewage can degrade marine ecosystems and render coastal waters unsuitable for recreational use and shellfish harvesting. Sewage is a major cause of coral reef deterioration worldwide (Wear and Vega Thurber, 2015). These authors found that 104 out of 112 coral reefs described in the World Atlas of Coral Reefs are impacted by sewage, including reefs in the WCR (Figure 7.7).

As shown in Table 7.2, degradation of coral reefs attributed to anthropogenic pressures, including sewage pollution, has been documented in several locations in the WCR.

One of the primary concerns of sewage pollution is the impact of fecal material and micro-organism contamination of recreational water and seafood (particularly shellfish, which are often consumed raw) on human health. These impacts include gastrointestinal illnesses and ear, eye, and skin infections). These issues are directly relevant to SDG Goal 3 (Ensure healthy lives and promote well-being for all at all ages), Goal 6 (Ensure availability and sustainable management of water and sanitation for all), Goal 11 (Make cities and human settlements inclusive, safe, resilient, and sustainable), and Goal 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development).

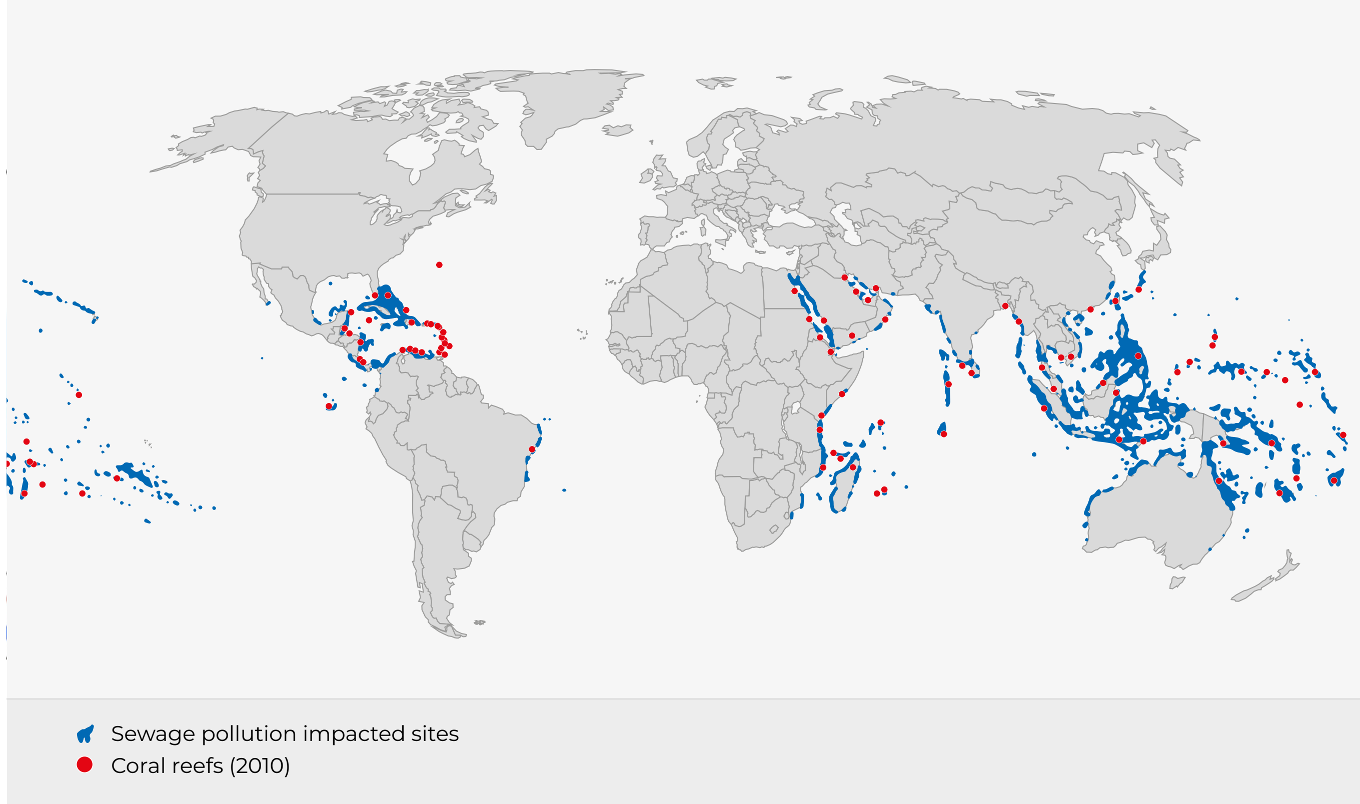


Figure 7.7. Coral reefs affected by sewage pollution worldwide
(Wear and Vega Thurber, 2015).

Data for the WCR is limited, but Shuval (2003) estimated that globally, there are over 120 million cases of gastrointestinal disease and over 50 million cases of more severe respiratory diseases caused by swimming and bathing in wastewater-polluted coastal waters each year. In addition, consuming raw or partially cooked shellfish harvested from polluted coastal waters causes about 4 million cases of infectious hepatitis A and E (with 40,000 deaths) and 40,000 cases of long-term disability, mainly chronic liver damage, annually. Preliminary estimates of the total global health impact of thalassogenic diseases (human infectious diseases associated with pathogenic microorganisms from land-based wastewater pollution of the seas) are about 3 million "disability-adjusted life years" (DALY) per year with an economic loss of some $12 billion per year. In addition to the water column, beach sand can also harbour fecal pathogens and other harmful microbes, posing yet another threat to humans.

Sewage pollution can have potentially severe socioeconomic consequences, including decreased livelihoods and revenue from tourism and seafood production. Availability of data from across the WCR is limited. Box 7.3 illustrates the magnitude of the economic losses that wastewater pollution can cause.

Box 7.3. Economic cost of wastewater pollution in the USA

In 2017, about 1,075 km^2 of shellfish beds were closed to harvesting in the Georgia Basin, and about 400 km^2 were closed in Puget Sound due to pollution of shellfish harvesting areas as a result of run-off from urban areas and farms, as well as uncontrolled sources of sewage and septic wastes (US EPA).

In 2016, several popular beaches in Florida, Mississippi, Louisiana, and Texas were subjected to swimming advisories due to high levels of harmful bacteria commonly found in fecal matter.

In the Machias Bay region of Maine (USA), temporary pollution closures from 2001 to 2009 contributed to the loss of $3.6 million in forgone revenue (2014 dollars), which was approximately 27.4% of total revenue (Evans et al., 2016). Closures linked to combined sewer overflows from the Machias wastewater system accounted for the majority of these losses ($2 million).

Other economic losses, such as decreased property values and tourism revenues have been linked to declines in water quality. Environmental degradation (including effects on live coral) caused by untreated wastewater can bring about severe economic consequences for people in the Caribbean, who are highly dependent on tourism and fisheries for jobs and income. Controlling land-based pollution at its source is a top priority for protecting the marine environment in the WCR.

8. MARINE LITTER AND PLASTIC

MARINE LITTER
AND PLASTIC

Key messages

The Wider Caribbean Sea has one of the highest plastic concentrations in the world ocean, and this is expected to increase. Over one million tonnes of plastic were introduced to the coastal waters of the WCR in 2015, mainly from land-based sources. Solid waste generation is expected to increase in the region as human populations continue to grow in the absence of more sustainable production and consumption patterns and adequate solid waste management.

Plastic pollution is gaining increased attention at all levels, although more needs to be done. Concern over plastic pollution of the ocean is explicitly expressed in SDG 14.1, and Contracting Parties to the Land-Based Sources Protocol have added marine litter as a priority pollutant. The large number of national, regional, and global programmes, as well as single-use plastic bans, demonstrates significant commitment. More attention to improving solid waste management, including prevention, reduction, and better recycling, is needed.

Plastic pollution poses significant risks to public health and marine life as well as to economic sectors such as tourism, fisheries, and shipping. Tourism in particular, which is a major source of foreign exchange for many island states and territories, can be severely affected. The long-term ecological and public health consequences of plastic are still largely unknown, given the product lifespans of up to 500 years and the diverse potential effects of different forms of plastic and the by-products of its recycling and incineration. Further investigations are required on the long-term impacts of plastic on human health, ecological health, and associated economic costs.

8.1. Changing composition of marine litter

While marine litter is a priority pollutant under the LBS Protocol, this chapter places the spotlight on plastic, which is currently high on the regional and global agenda. When the Interim LBS Monitoring and Assessment Working Group was engaged in the process of identifying the water quality parameters to be included in the SOCAR assessment, the issue of marine litter[36] was an emerging environmental concern. However, this has since changed, and plastic has been included under SDG 14. A significant increase in solid waste generation, accompanied by inadequate waste management in many countries and limited public awareness, are among the factors that have created what may be one of the biggest environmental concerns currently. Solid waste arises from various economic sectors and activities, either directly or indirectly. In addition, how citizens consume goods, their personal habits (e.g., use of plastic bags and packaging), and their waste practices (e.g., littering, poor household waste separation) contribute to the problem of marine litter (Figure 8.1).

Trash is now ubiquitous in the environment, including on beaches and the ocean, and poses significant risk to wildlife, public health, and economic sectors such as tourism, fisheries, and shipping. Land-based sources contribute 80% of marine litter, while sea-based sources contribute 20%. Plastics make up the majority of marine litter and it was estimated that in 2010, between 4.8–12.7 million metric tonnes of plastic entered the world's oceans (UNEP, 2016b) and could reach 250 million tonnes by 2025 (Jambeck et al., 2015).

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[36] Any manufactured or processed solid waste material that enters the marine environment from any source.

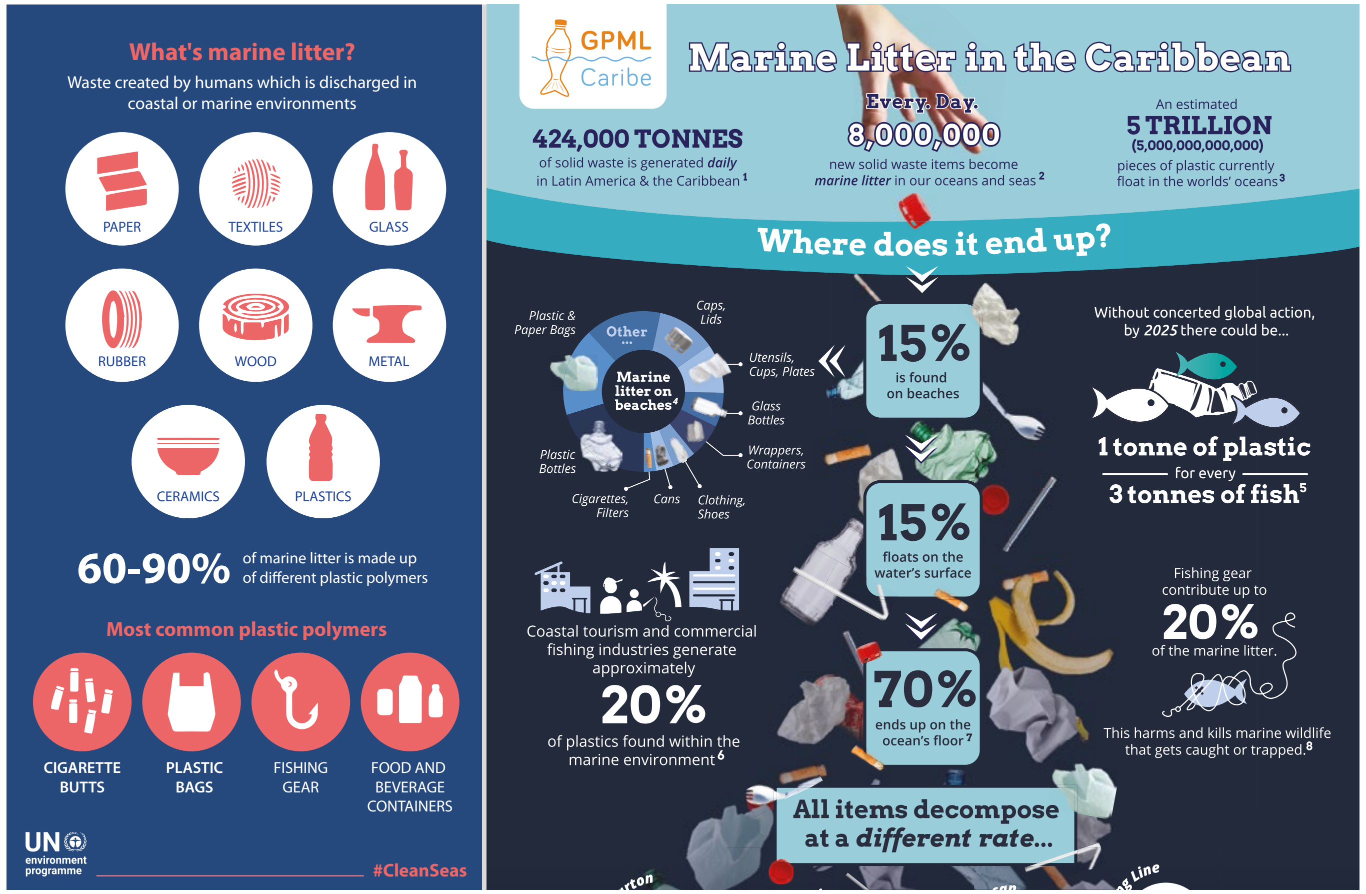

Figure 8.1. Impacts of marine litter and plastics

8.2. Solid waste, plastic, and microplastic

For this assessment, solid waste generation in the WCR was estimated using spatial resident population data for years 2015 and 2020, and published per capita solid waste production rates (Jambeck et al., 2015; Diez et al., 2019). The WCR's resident populations generated 79 million tonnes of solid waste in 2015, which is projected to increase to 84 million tonnes in 2020 (Figure 8.2). Additionally, plastics made up 13% of municipal waste in 2015, and because some waste is mismanaged, an estimated 1.3 million tonnes of plastics were introduced to coastal waters of the WCR in 2015 (Figure 8.2, bottom), with still unknown ecological consequences given the lifespans of these plastic materials can last up to 500 years. The highest volume of municipal waste is produced in sub-regions I and V, while the highest volume of mismanaged plastic waste is produced in sub-region V. See Annex 4.1 for technical notes and Annex 8.1 for additional results.

Freely available data on tourist numbers, disaggregated by type and originating country, were accessed from the Eastern Caribbean Currency Union (ECCU) Statistics Office to make a first estimate of tourism-generated solid waste in addition to that generated by resident populations (see Annex 4.1. for technical notes). The combined solid waste from resident populations of ECCU member countries[37] amounted to 663,000 tonnes in 2015. Tourists added another 49,000 tonnes, or 7% of total solid waste combined across the ECCU countries for the same year (see Annex 8.2). The growth rates of resident populations and expansion of tourism would need to be examined to determine if the coverage of waste management and services in these countries can cope with demand. To implement an evidence-based planning process, it would be prudent to conduct a similar assessment of tourism-generated waste in the other sub-regions and ensure that the expansion of tourism services is accompanied by the provision of smart waste management of sewage and solid waste, including problematic plastic waste.

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[37] Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines.

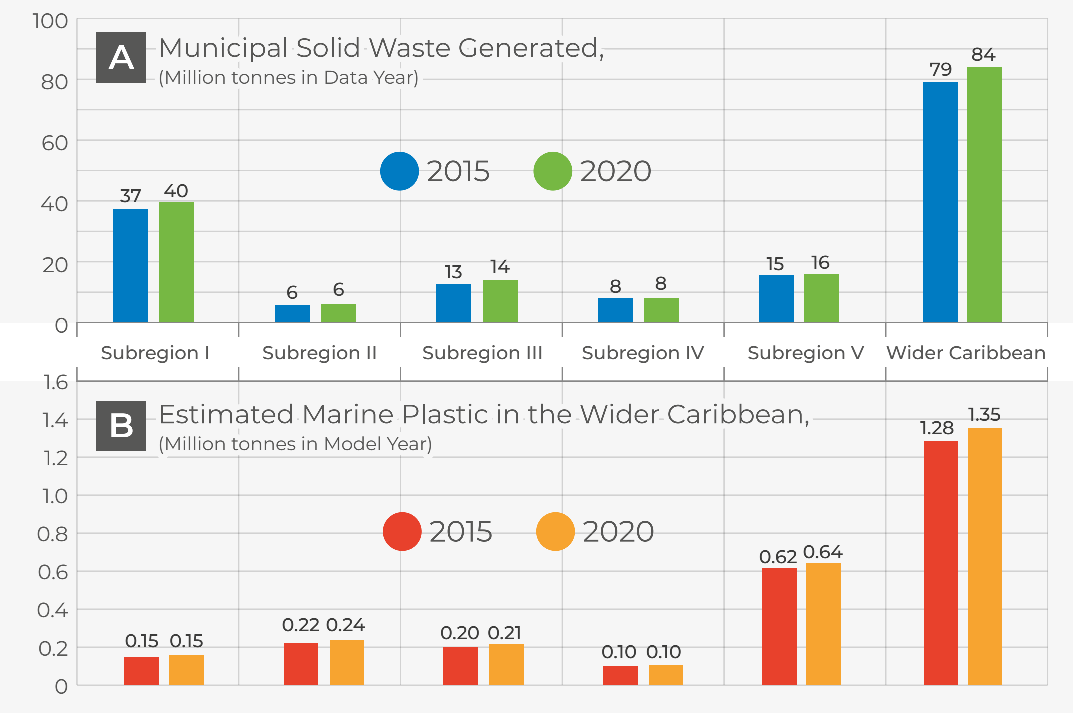

Figure 8.2. Municipal solid waste generated by the WCR's resident populations (8.2A) and concomitant mismanaged plastic waste (millions of tonnes) that have a high likelihood for being disposed in adjacent coastal waters (8.2B)

(see Annex 4.1 for technical notes and data sources).

With limited recycling and markets for solid waste, and space constraints in small islands, countries in the WCR are struggling to deal with the vast quantities of waste they produce. Currently, solid waste collection exists primarily in urban areas and in certain parts of cities and municipalities. Infrastructure is lacking, and fees collected are inadequate to expand services. A significant proportion of municipal solid waste is disposed in open dumpsites, which has severe consequences for humans and the environment. For instance, it was estimated that in the Latin America and the Caribbean region 145,000 tonnes per day of waste are disposed in open dumpsites, including 17,000 tonnes per day of plastic (UNEP, 2018).

When broken down, larger pieces of plastic contribute microplastics to the environment. Some microplastics are also specifically manufactured as microbeads for specific functions, such as use in industry as cleaning agents and in personal care and cosmetic products.

8.3. Floating micro- and macroplastic

While some plastic goes into controlled waste disposal, or is re-used or recycled within a circular economy, a significant proportion becomes waste that directly or indirectly reaches the sea. There are few reliable or accurate estimates of the nature and quantities of plastic involved, but it has been estimated that about 8 million metric tonnes of waste plastic enters the oceans every year. Large pieces of plastic (macroplastic) such as plastic bags and water bottles, as well as plastic micro-particles and nano-particles, are now ubiquitous in even the most ocean areas.

Modelled estimates of floating plastic abundance (items km^{-2}), for both microplastic (less than 4.75 mm) and macroplastic (greater than 4.75 mm) based on three proxy sources of litter (shipping density, coastal population density, and the level of urbanization within major watersheds) were generated for the world's LMEs by Kershaw and Lebreton (2016). The total number of floating microplastic and macroplastic in the four LMEs in this region (Southeast US Continental Shelf, Caribbean, Gulf of Mexico, and North Brazil Shelf) was about 82,000 and 5,000 pieces per square kilometre, respectively. These estimates place this region as among those with the highest plastic concentrations in the world. While the modelled estimates of floating plastics are in broad agreement with sea-based direct observations and shoreline surveys, there is a need to obtain empirical data for the WCR on the volume of plastic (floating and submerged), its sources, and its fate in the marine environment.

8.4. Impacts

Plastic is a problem at all stages of its life cycle, and there is growing documentation of the impacts of plastics on humans and marine ecosystems (see UNEP 2016 for a review). The impacts of macroplastics include reduced aesthetical value of beaches and the sea, with economic repercussions for the tourist industry; injury and death of marine fauna resulting from plastic entanglement and ingestion; transport of non-native marine species; and the smothering of benthic habitats. Plastic is also a hazard to marine industries (e.g., shipping, fishing, energy production, aquaculture) including through entanglement and damage of equipment (Figure 8.3). Images of beaches and sea surface areas blanketed with plastic litter, or of dead seabirds and marine mammals with their stomachs engorged with plastic, are becoming all too common. Microplastic poses a different set of dangers to humans and marine fauna (Box 8.1, Figure 8.3). The impacts of plastic, including microplastics, on humans and living marine organisms require further investigation.

The associated economic cost of plastic pollution is enormous, running into billions of dollars annually. The overall natural capital cost of plastic use in the consumer goods sector each year is US$75 billion—these are the financial impacts resulting from issues such as pollution of the marine environment or air pollution caused by incinerating plastic. Over 30% of the natural capital costs of plastic are due to greenhouse gas emissions from raw material extraction and processing. However, marine pollution is the largest downstream cost at US$13 billion, which is likely to be a significant underestimate (UNEP Year Book, 2014). According to UNEP, the total economic damage to the world's marine ecosystems from plastics is well over $15.5 billion every year, including losses to fisheries and tourism and the costs of beach cleaning.

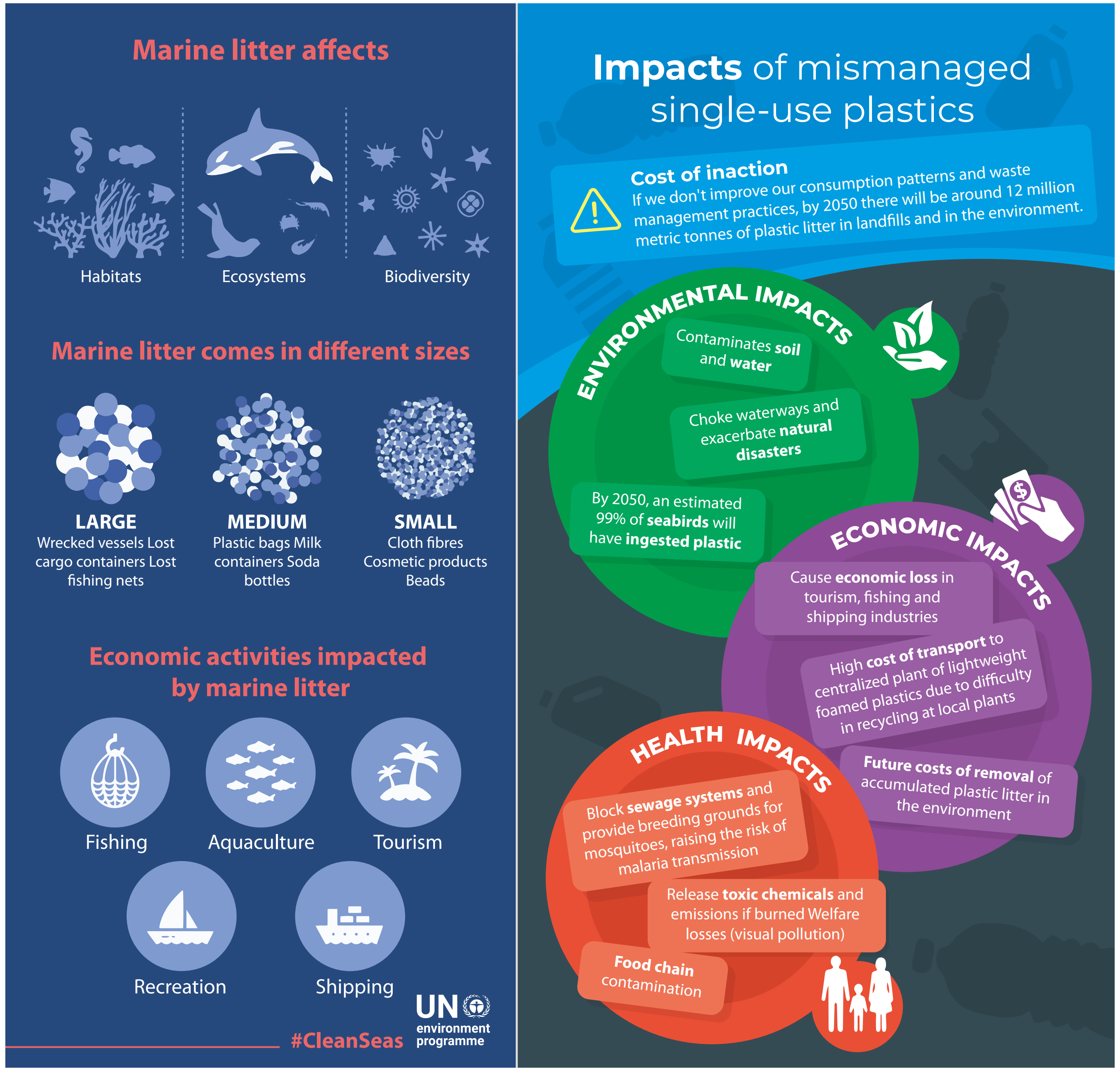

Figure 8.3. Impacts of marine litter and plastics

Box 8.1. Improving global governance for plastic

Efforts to address the plastic crisis continue to focus on waste management and recycling, but there is compelling evidence that plastic recycling is posing great risk to the environment and public health through air pollution, toxic ash, and other externalities. Findings by the UN Environment Ad Hoc Open-Ended Expert Group, bolstered by multiple UN-sponsored analyses and independent reports, point to major gaps and inadequate coordination in current governance structures. The Expert Group's recommendations have given significant momentum to the push for a new global framework to reduce the production and consumption of plastic. At the Fourth UN Environment Assembly (UNEA-4), Norway proposed a resolution calling for stronger global governance structures to address marine litter and microplastics.

(Source: L. Fuhr and J. Patton, Project Syndicate, 6 March 2019)

8.5. Addressing plastic pollution

Concern over the effects of plastics has ignited an unprecedented environmental revolution across the world. In March 2017 at the 17th Intergovernmental Meeting of the Parties to the Cartagena Convention (Cayenne, French Guiana), countries agreed to add marine litter as a priority pollutant under the Land-Based Sources Protocol as a result of growing concern about plastics.

Although there are some successful initiatives that aim to tackle other types of single-use plastics, the recent drive for action by governments largely focuses on plastic bags and, to a certain extent, foamed plastic products. Bans on single-use plastic bags and polystyrene foam products have swept across the region in the last year alone (Figure 8.4).

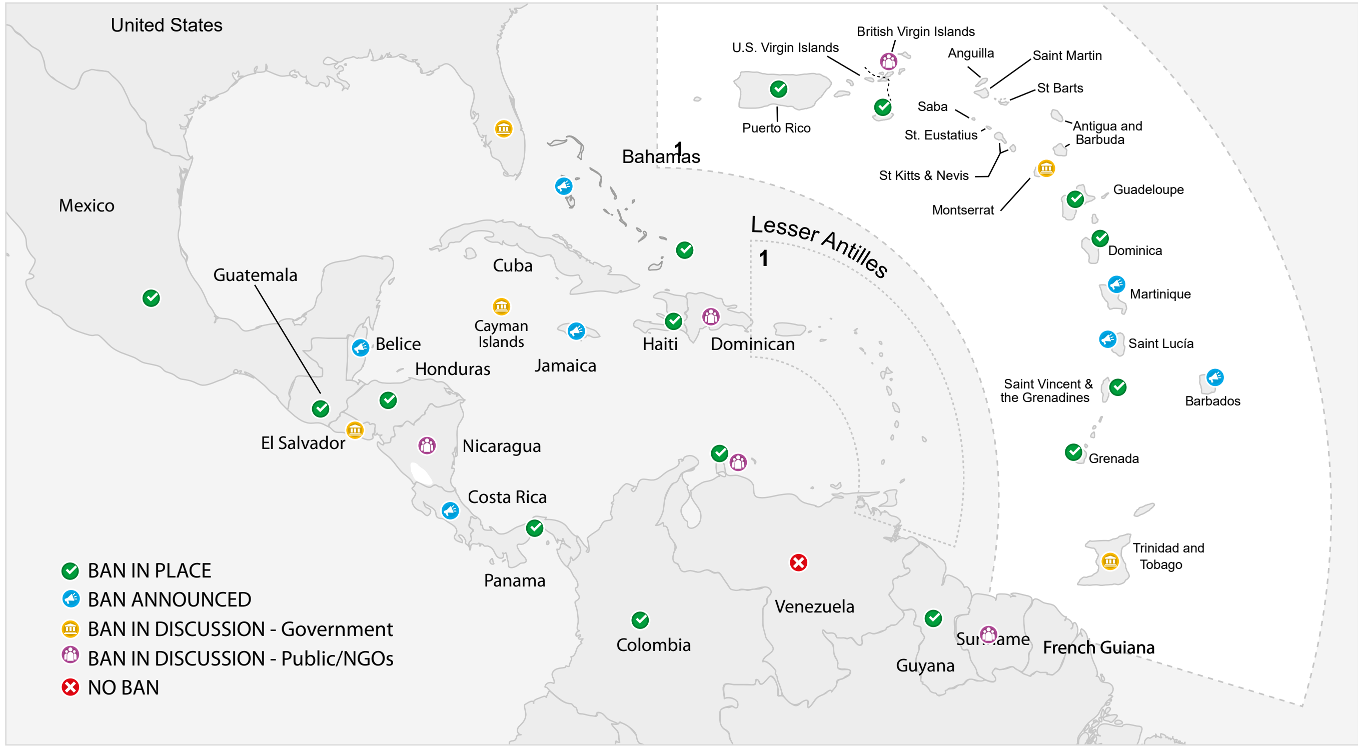

Figure 8.4. ~~Figure 8.3.~~ Bans on single-use plastic bags and polystyrene foam products in the Caribbean

(UN Environment CEP, April 2019).

In addition, a number of regional and global programmes and initiatives have been developed to address the marine litter problem:

- **Break Free From Plastic**, a growing global movement of non-governmental organizations, has been working to inform governments of the risks associated with new plastic production. Since its launch in 2016, almost 1,300 organizations from across the world have joined the movement.
- The **Regional Action Plan for Marine Litter (RAPMaLi) for the Wider Caribbean Region** is meant to directly address marine litter and plastic pollution. To drive the implementation of RAPMaLi, the Caribbean Node of the Global Partnership for Marine Litter (GCFI-CN) was created.
- **Trash Free Waters Partnership:** UNEP-CEP and UNEP Regional Office for Latin America and the Caribbean (ROLAC) have been working in Jamaica and Panama on this partnership that engages national and community stakeholders in implementing marine litter projects. Jamaica's National Environment Protection Authority established a partnership with Sandals Foundation and Peace Corps Jamaica to engage communities in a tourist area to collect and separate waste, sell the organic waste as compost, and install a trash boom in a gully to trap trash going down the nearby stream.
- **Phasing out single-use plastics:** towards clean seas and sustainable tourism in the Caribbean: ROLAC is leading this initiative, which aims at reducing the consumption and disposal of plastics in the Caribbean Sea by improving the capacity of the tourism sector in implementing sustainable alternatives and eco-innovative solutions. The project, which is funded by the Norwegian Government, is being conducted in Saint Lucia and the Dominican Republic. The project itself will target multiple actors in the tourism sector: hoteliers, tourism associations, tour operators, procurers and staff, and tourists. The main objective of the project is to develop a market readiness analysis to measure the maturity of the market for sustainable alternatives to use single-use plastic products, and provide technical support in the substitution of single-use plastics.
- **International Coastal Clean-Ups** continue to be held annually in many Caribbean countries to raise awareness of the prevalence of marine litter on beaches and sensitive coastal areas.
- **CleanSeas Campaign,** which was launched in 2017 by UNEP, aims at engaging stakeholders in addressing marine litter. In October 2018, , Guatemala introduced the installation of bio-fences to trap plastic trash in rivers under the CleanSeas Campaign. Some of the bio-fences are constructed of recovered plastic waste, and communities are generating income from recycling and upcycling plastic. Similar projects are being implemented in Honduras, Panama, and the Dominican Republic. In Panama, the Ministry of the Environment, in partnership with ANCON Panama, installed trash booms on two major rivers in Panama City and conducted awareness raising campaigns in nearby schools.
- **Zero Waste:** an initiative that is gaining momentum worldwide, seeks to curb waste production at its source and use trash as raw material for re-use in economic production and ecological cycles. In this region, Colombia, for example, has joined the Zero Waste Initiative with its own NGO ”Basura Cero Colombia.”
- **Blue Flag Programme:** a voluntary eco-labelling scheme that sets standards for water quality, environmental management, information provision, safety and services. The need to maintain Blue Flag status has been an important factor motivating clean-up efforts in countries in the Caribbean and across the world.
- **Plastic recycling:** Addressing marine litter using the circular economy approach is gaining momentum in the region. The end goal is that the production and consumption of material goods results in minimal environmental impacts, and contributes to both the economic and social well-being of dependent human communities as a result. However, the by-products of plastic recycling can be just as harmful, or even more harmful, than the plastic itself. There is a growing recognition of the need to reduce the production of new plastic (see Box 8.2).

Box 8.2. Improving global governance for plastic

Efforts to address the plastic crisis continue to focus on waste management and recycling, but there is compelling evidence that plastic recycling is posing great risk to the environment and public health through air pollution, toxic ash, and other externalities. Findings by the UN Environment Ad Hoc Open-Ended Expert Group, bolstered by multiple UN-sponsored analyses and independent reports, point to major gaps and inadequate coordination in current governance structures. The Expert Group's recommendations have given significant momentum to the push for a new global framework to reduce the production and consumption of plastic. At the Fourth UN Environment Assembly (UNEA-4), Norway proposed a resolution calling for stronger global governance structures to address marine litter and microplastics.

(Source: L. Fuhr and J. Patton, Project Syndicate, 6 March 2019)

Future guidance for addressing marine litter within the Cartagena Convention and the Land-Based Sources Protocol

Contracting Parties to the LBS Protocol can consider working jointly to address marine litter by building awareness, advancing initiatives on marine litter (including solid waste management improvements, policy development, and national monitoring programmes), and reporting these achievements to the Secretariat. Using the Intergovernmental Meetings, LBS Conference of the Parties, and LBS Scientific and Technical Advisory Committee meetings, Contracting and Non-Contracting Parties can share ongoing initiatives, policy changes, and action plans with other member states and the Secretariat.

MERCURY

9. MERCURY

Key messages

Humans are exposed to highly toxic mercury through different pathways, including bio-accumulation and bio-magnification in the marine food chain followed by consumption of contaminated seafood. A recent study in several Caribbean SIDS found high concentrations of mercury in human hair samples in most of the Caribbean locations. This was attributed to the consumption of predatory fish, which can have major implications for countries and territories, particularly those that are islands, where fish is an important protein source.

Mercury hotspots are likely to exist in the WCR. Several countries engage in industrial activities that are known to contribute to mercury releases, such as the oil and gas extraction and refining, bauxite mining, and artisanal and small-scale gold mining. Caribbean countries also face similar challenges related to the use and disposal of mercury-added products, including a general lack of environmentally sound disposal methods. Inadequate management of mercury emissions, as well as use and disposal of mercury products, create the potential for mercury hotspots in the region.

9.1. Dangers of mercury

This assessment includes a brief review of mercury, due to grave concern about its high toxicity to both humans and animals, and their exposure to mercury in the environment (Box 9.1). Mercury in water becomes more hazardous than mercury on land, since natural bacterial processes in seawater and in coastal sediments convert inorganic mercury to methylmercury, the most dangerous form of this element. Bio-accumulation and bio-magnification of methylmercury in the marine food chain is the major pathway for exposure of humans and the main cause for concern.

Box 9.1. Dangers of mercury to humans and wildlife

Mercury is considered by the World Health Organization to be one of the top ten chemicals or groups of chemicals of major public health concern, owing to its high toxicity.

Exposure to mercury, especially in its methylated form, may cause serious health effects compared to inorganic mercury.

Mercury can cause permanent changes in the nervous system (particularly the developing nervous system of the fetus), digestive and immune systems, as well as lungs and kidneys. It can even cause death. Because of this, and the fact that mercury can be transferred from a mother to her fetus, infants, and children, pregnant women are considered the most vulnerable populations.

Mercury can also cause reproductive impairment and other harmful effects in wildlife, such as birds and predatory mammals.

9.2. Emissions and releases of mercury to the ocean

Mercury emissions and releases[38] to land and water originate from a diverse range of human activities, including coal burning, mining and smelting of iron and non-ferrous metals, cement production, oil refining, artisanal and small-scale gold mining, burning of consumer products, slow degradation of consumer products in landfills, use of dental amalgam, and chlor-alkali production (UNEP, 2013). Direct deposition from the atmosphere is the dominant pathway by which mercury reaches the oceans (Figure 9.1, UNEP, 2013). The exceptions are smaller, semi-enclosed basins, where river run-off, coastal erosion, and ocean currents account for about half of mercury inputs. The most recent modelling effort (UNEP, 2013) suggests that total deposition input of mercury to the oceans in 2008 was 3,700 tonnes. Rivers are estimated to carry more than 2,800 tonnes of mercury each year, of which only about 380 tonnes are transported offshore, with the rest trapped in estuaries. In addition, groundwater and re-mobilization from sediments releases 100–800 tonnes of mercury into the ocean each year.

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[38] In the Minamata Convention, "emissions" refers to mercury emitted to the air, while "releases" refers to mercury released to land and water

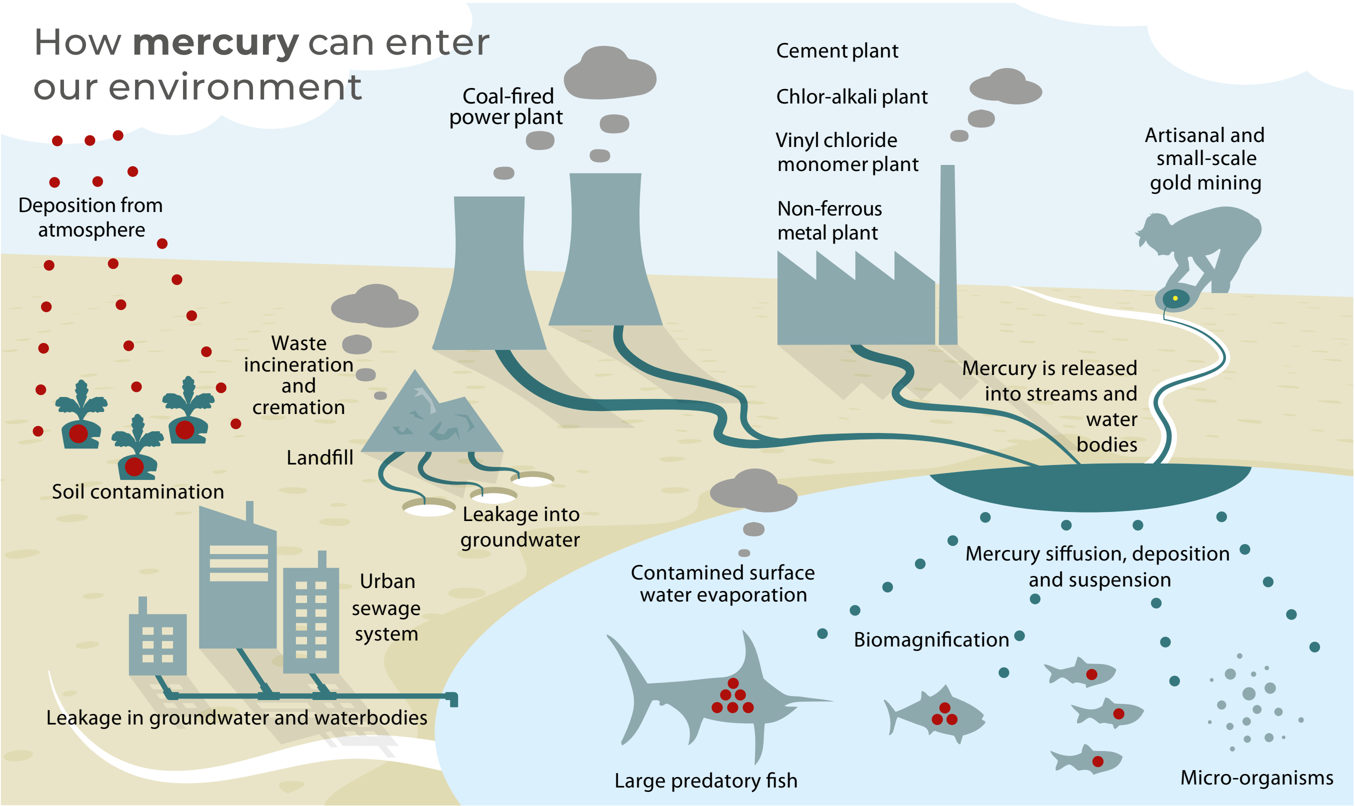
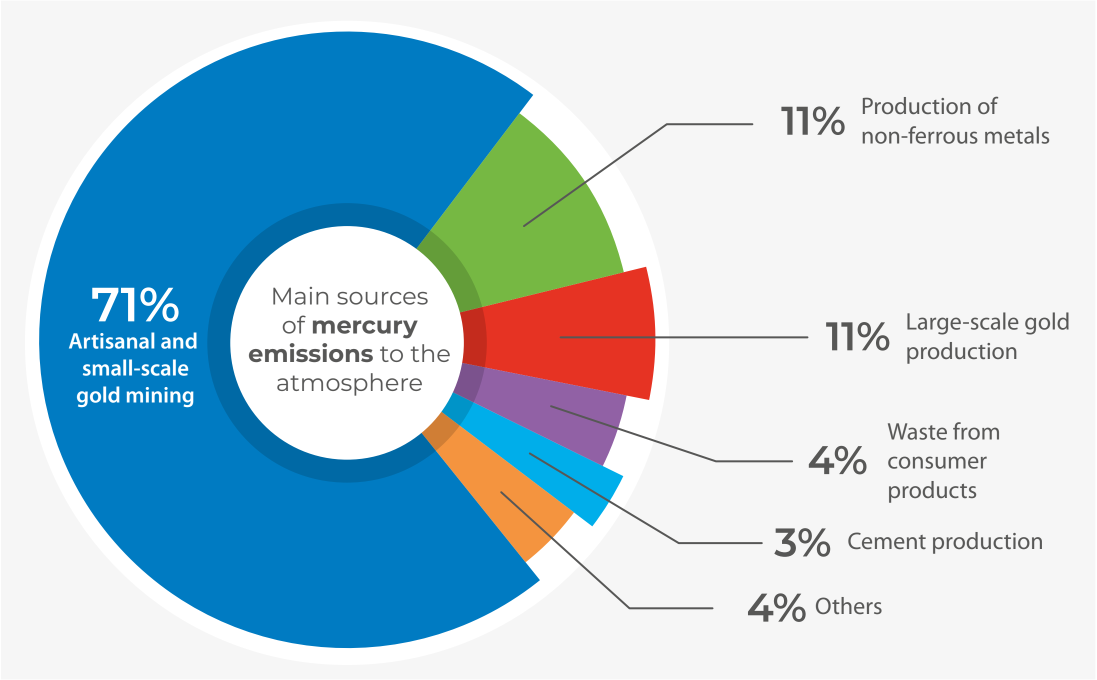


Figure 9.1. Sources of mercury and pathways to the marine environment.
(Downloaded from https://www.unenvironment.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-general-information.)

In 2010, the LAC region accounted for about 15% of the global anthropogenic emissions of mercury to the atmosphere, compared with 48% by Asia, 17% by Africa, 11% by Europe, and 3% by North America (Basel Convention Coordinating Centre, Stockholm Convention Regional Centre for LAC and UNEP, 2014). Artisanal and small-scale gold mining accounted for 71% of all mercury emissions in this region (Figure 9.2).

Figure 9.2. Main sources of mercury emissions to the atmosphere in Latin America and the Caribbean in 2010
(Source: Basel Convention Coordinating Centre, Stockholm Convention Regional Centre for LAC and UNEP, 2014).



The updated global mercury assessment (UNEP, 2019) shows that in 2015, nearly 500 tonnes of mercury were emitted to the atmosphere by countries in the Americas, with South America accounting for over 80%, mainly from gold mining (Table 9.1).

Table 9.1. Emissions of mercury (tonnes) from main sources to the atmosphere in the Americas in 2015 (UNEP, 2019).

Region	Fuel combustion	Industry sectors	Intentional use (including product waste)	Artisanal and small-scale gold mining	Regional total	% world total
Central America & Caribbean	5.69	19.1	6.71	14.3	45.8	2.1
South America	8.25	47.3	13.5	340.0	409.0	18.4
North America	27.0	7.63	5.77	0.0	40.4	1.8

The Basel Convention Regional Centre (BCRC-Caribbean) recently completed four initial mercury assessments[39] in Jamaica, St. Kitts and Nevis, Saint Lucia, and Trinidad and Tobago, and is currently conducting assessments in Antigua and Barbuda, Belize, Dominica, Grenada, and St. Vincent and the Grenadines. The initial assessments for the first four countries identified the major sources of mercury releases to all potential pathways—air, water, land, sector-specific disposal, by-products, and impurities (Table 9.2). Over time, these releases may be eventually deposited directly or indirectly to the ocean.

Table 9.2. Major sources of mercury releases in four Caribbean countries (BCRC-Caribbean).

Country	Top sources of mercury release
Trinidad and Tobago	Extraction and use of fuels/energy sources
	Waste incineration and burning
	Use and disposal of consumer products with mercury
Saint Lucia	Products and processes with intentional use of mercury (dental amalgam, manometers, etc.)
	Use and disposal consumer products with mercury
	Waste landfilling and wastewater system
Saint Kitts and Nevis	Use and disposal of consumer products with mercury
	Products and processes with intentional use of mercury (dental amalgam, manometers, etc.)
	Waste landfilling and wastewater system
Jamaica	Bauxite production
	Use and disposal of consumer products with mercury
	Waste landfilling and wastewater system

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[39] Reports are available at: http://www.bcrc-caribbean.org/minamata-convention-on-mercury/.

Most Caribbean countries have similar issues related to mercury, especially the use and disposal of mercury-added products (e.g., thermometers, batteries, switches and relays, dental amalgam, and light sources) accompanied by general lack of environmentally sound disposal methods. In addition, several countries in this region have industrial activities known to contribute to mercury releases, such as the oil and gas industry extraction and refining, bauxite production, and artisanal and small-scale gold mining.

9.3. Mercury in our food chain

The World Health Organization (WHO), the US Environmental Protection Agency (EPA,) and the European Commission, among others, have examined fish mercury concentrations to identify the types of fish that are likely to have higher mercury content. This information has contributed to the development of consumption guidelines that indicate the number of seafood meals that could be eaten while staying within recommended exposure limits (BCRC-Caribbean, 2018). Typically, larger and older predatory fish, such as shark and swordfish, are expected to have higher mercury concentrations. Continuous consumption over time, especially by the more vulnerable populations like children and pregnant women, may have negative health effects.

Analyses to assess how mercury accumulates in the human body include hair sample testing. A recent study estimated mercury levels in the hair of women of childbearing age in 21 countries, including nine Caribbean SIDS (Bell et al., 2018). Results were assessed against the internationally recognized reference level of 1 ppm total mercury, above which health effects to the developing fetus may occur, and a more recent, science-based threshold of 0.58 ppm based on data indicating harmful effects at lower levels of exposure. In Caribbean locations, 35% of all participants exceeded the 1 ppm total mercury reference level and 58% exceeded the proposed reference level of 0.58 ppm. The results for Caribbean SIDS are shown in Figure 9.3.

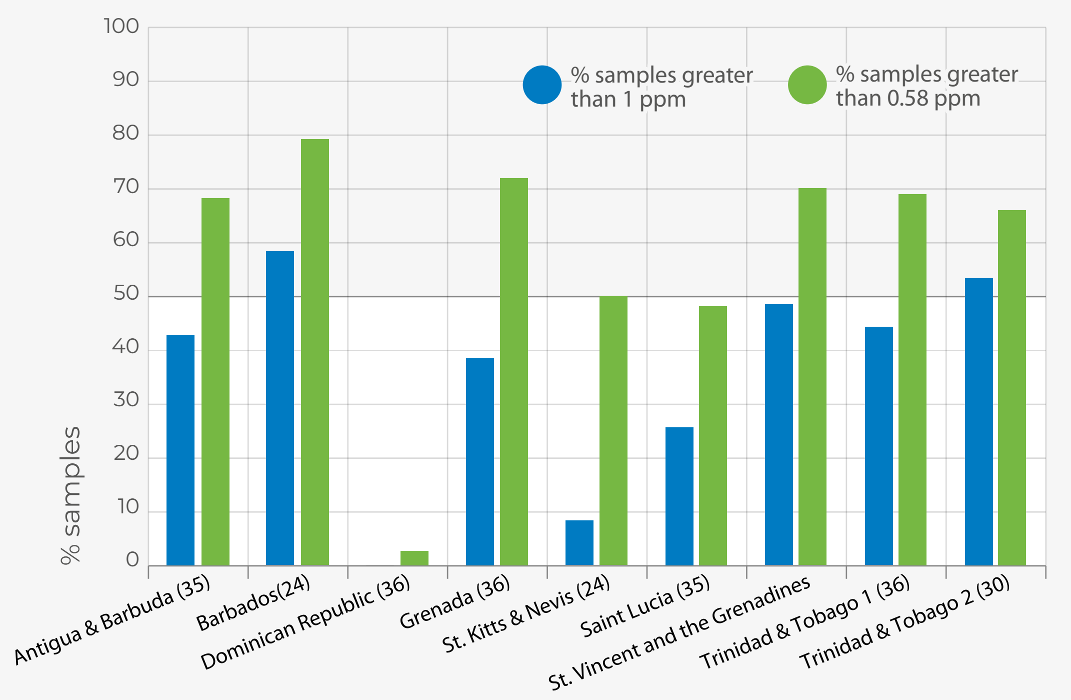

Figure 9.3. Proportions of all participants in Caribbean locations with a mercury level. Mercury level (ppm) greater than the 1 ppm (blue) and 0.58 ppm (green) reference levels (based on data in Bell, 2018). The number in brackets after the country name is the sample size.

Mean concentrations of mercury were elevated in the hair samples from most of the Caribbean locations, with the notable exception of the Dominican Republic. Based on questionnaire responses from participants, the preliminary assumption was that elevated body burdens of mercury were linked to the consumption of predatory fish such as mahi-mahi, kingfish, tuna, mackerel, shark, barracuda, and marlin, which might have accumulated mercury in their tissues through the food chain. On the other hand, study participants in the Dominican Republic reportedly ate fish infrequently (or in some cases, not at all), and that those who did consume fish predominantly ate sardines (which are low trophic level fish) and salted cod.

Except for Trinidad and Tobago, which has a well-developed industrial sector, including oil and gas production, the Caribbean SIDS included in the study are generally remote from heavy industrial development or other mercury pollution sources that could significantly influence mercury levels in women of childbearing age. Some studies have indicated heavy metal contamination of localized marine areas around Trinidad and Tobago, with speculation that dental amalgam waste and industrial sources may be influencing water quality. According to the Bell study, distant air emissions of mercury from industrial sources, such as coal-fired power plants, mercury use in small-scale gold mining, and emissions from other sources can contaminate ocean fish that serve as a primary protein source for SIDS populations.

An important consideration (not pointed out in the Bell study) is the fact that some of the fish mentioned in the study are highly migratory pelagic species with very broad geographic ranges. The other species, such as snappers and groupers, are known to also undertake migrations for spawning, and form large spawning aggregations in the region. Therefore, fish can be exposed to mercury when they migrate through contaminated waters.

It is important to note that the Bell study was based on relatively small sample sizes (approximately 30 hair samples per country) and interpretation of the results on questionnaire responses from participants. Further detailed research is required to correlate potential mercury sources with fish contamination levels, and mercury body burden with dietary habits in the region. Monitoring of mercury levels in humans should be continued in other WCR countries.

Given the widespread concern about the impact of mercury, the UNEP Global Mercury Partnership was created in 2005. The Minamata Convention on Mercury was adopted in October 2013 and entered into force in August 2017. In May 2019, the number of Signatories stood at 128 and the number of Parties at 107, among which are several WCR countries. The Convention seeks to protect human health and the environment from anthropogenic emissions and releases of mercury and its compounds. It includes a range of measures aimed to control emissions and releases of mercury throughout its life cycle.

RESPONSES:
ADDRESSING
LAND-BASED
POLLUTION

10. RESPONSES: ADDRESSING LAND-BASED POLLUTION

Key messages

Significant progress is being made to address land-based pollution at the national, sub-regional, and regional levels. There are several institutions, legal frameworks, action plans, programmes, and projects within the WCR related to marine pollution at the national and regional levels. Countries are implementing measures to improve wastewater and solid waste management. The level of awareness of marine environmental issues and impacts is also growing in the region.

Challenges faced by WCR countries to address land-based pollution and fulfil their obligations (Contracting Parties) under the Land-Based Sources Protocol persist. Despite considerable advances and achievements, countries continue to face similar problems that existed decades ago. The approach to addressing land-based pollution remains generally inadequate, uncoordinated, and fragmented across the region. The complex and multifaceted nature of land-based pollution requires an integrated, cross-sectoral approach and private sector engagement to effectively tackle this issue.

Ratification and implementation of the Land-Based Sources Protocol by WCR countries needs to be improved. Countries show a lower level of engagement in non-binding multilateral agreements than in binding agreements such as the LBS Protocol. This may be related to the effort needed by countries engaged in binding agreements to comply with the obligations, and the low accountability of pollution frameworks with no repercussions for lack of compliance.

Preventing pollution is more cost-effective than addressing its impacts. Controlling land-based pollution at its source should be a top priority for protecting the marine environment in the WCR. Improving solid, liquid, and hazardous waste management presents many opportunities for generating livelihoods and revenue while reducing pollution. One example is adopting a circular economy approach to waste management.

Governments and other stakeholders need to adopt a different approach to addressing land-based pollution. An extensive range of on-the-ground actions and concrete measures to reduce pollution loads at the source are available and various sustainable financial mechanisms have been developed. There is an urgent need for governments to adapt and scale up existing experiences, best practices, and technologies, and undertake the required institutional, policy, legislative, and budgetary reforms to address land-based pollution, particularly at its source.

10.1. Environmental governance

In the context of this assessment, "responses" are actions taken by society to address land-based pollution and its impacts. Responses can be viewed within the broader realm of environmental governance. UNEP defines *environmental governance* as "the set of processes and institutions, both formal and informal, and including rules and values, behaviours and organizational modes, through which citizens, organizations and social movements, as well as the various stakeholders, articulate their interests, mediate their differences and exercise their rights and obligations in connection with access and use of natural resources."

This chapter provides an overview of the institutional framework or arrangements and processes that exist in the WCR to address marine environmental pollution. It also highlights specific on-the-ground actions (stress reduction measures) and best practices to reduce land-based pollution.

10.2. Institutional arrangements and processes

Several institutions, legal frameworks, international non-binding and binding agreements, action plans, programmes, legislation and regulations, and projects exist within the WCR at the global, regional, sub-regional, national, and community/municipality levels related to marine pollution. This underscores the need for improved coordination at all levels. In addition, countries have developed, or are developing and enacting policies, legislation, national strategies and action plans, and other measures to improve wastewater and solid waste management. All WCR countries have laws that govern environmental protection (including pollution), as well as responsibility for the water and wastewater sector (GEF CReW, 2016). However, harmonization among the different pieces of legislation, some of which are outdated, is generally lacking. Additionally, in most countries enforcement of existing laws is inadequate, some lack water quality and effluent standards, and water quality monitoring is generally insufficient. For a review of the status within selected countries with respect to policies and legislation for marine pollution, see relevant GEF CReW project publications and UNEP-CEP (2010b).

Table 10.1 presents a snapshot, with examples, of the institutional frameworks and processes in the WCR related to marine environmental pollution.

Table 10.1. Overview of the institutional frameworks and processes in the WCR related to land-based marine environmental pollution.

(Note: The material presented in this table provides a group of examples only and is not intended to be an exhaustive list; the institutions listed under the column heading Institutional frameworks are not necessarily linked to the processes in the same row, and the table should be read vertically instead of horizontally.)

Level	Institutional frameworks	Processes			
	Institutions, Associations, and Geopolitical Arrangements*	Agreements/ Frameworks	Programmes/Strategies/ Action Plans	Projects	Monitoring and Assessment/ Standards
Global	UN	UNCLOS, SDG Goals, SAMOA Pathway, Sendai Framework for Disaster Risk Reduction	BPOA (SIDS)		WOA, SDG national reporting and indicators
	UN Environment Programme, UNDP, IMO, donor agencies (e.g., GEF, World Bank)	GPA, MEAs (e.g., Marpol, Minamata, Basel, Rotterdam, Stockholm Conventions)	Regional Seas Programme, Global Partnership on Nutrient Management (GPNM); Global Partnership on Marine Litter (GPML); Global Wastewater Initiative (GWI); Global Waste Mnagement Partnership (GWM), CleanSeas Campaign on Marine Litter	Trash Free Waters International; Addressing Marine Plastics—A Systemic Approach	GEO, Mercury Assessment
	IOC-UNESCO/IOCARIBE		HABs programme		GOOS
	UNICEF-WHO				Joint Monitoring Programme for Water Supply and Sanitation
	GESAMP (Working Groups)				Working Groups conduct assessments on specific substances or issues (e.g., coastal pollution, plastics)
Regional	UNEP-(CEP) (Regional Seas); LBS Regional Activity Centres (CIMAB & IMA); Regional Activity Network, Caribbean Sea Commission Gulf and Caribbean Fisheries Institute (GCFI)	Cartagena Convention (LBS, SPAW, and Oil Spill Protocols)	Assessment and Management of Environmental Pollution Programme (AMEP), CLME+ Strategic Action Programme (SAP), Gulf of Mexico SAP, Regional Action Plan on Marine Litter Management (RAPMaLi), Nutrient Reduction Strategy and Action Plan/ Investment Plan, Caribbean Regional Node for Marine Litter Management, Sub-Regional Action Plan for Marine Litter (Central America)	RepCar, CEPPOL, IWCAM, CReW, IWEco, CLMEE and CLME+ projects, Gulf of Mexico LME Project, Trash Free Waters–Caribbean	GEO LAC, CARICOMP, SOCAR LBS parameters, and assessment ranges (thresholds)
	Caribbean Water and Wastewater Association (NGO) Caribbean Water & Sewerage Association North American Marine Environment Protection Association Caribbean Marine Environment Protection Association				
Sub-regional	*CARICOM *OECS *SICA-CCAD	St. George's Declaration (OECS)		MAR2R (CCAD)	
	CARPHA				Epidemiological studies, Environmental assessments, Environmental Health Laboratory
National	Government Environment ministries/ departments; National environmental management/ protection agencies and authorities; private sector	Policies, legislation, regulations, clean water act	National action plans (e.g., Gulf of Mexico Hypoxia Action Plan, Mississippi River/Gulf of Mexico Watershed Nutrient Task Force)	Projects developed at a national level, participation in regional projects	National effluent and water quality standards, monitoring programmes, Colombia REDCAM, US EPA Coastal Condition report, National State of the Environment (SOE) reports, national reporting for SDGs and MEAs
	Technical institutions: CIMAB (Cuba) INVEMAR (Colombia) IMA (T&T) NOAA (USA) Analytical laboratories				
All levels	NGOs				

10.2.1. Regional framework: Cartagena Convention and LBS Protocol

As previously mentioned in Chapter 1 of this report, the most important regional legal framework regarding marine environmental pollution is the Cartagena Convention and its three Protocols. The Convention entered into force in 1986 and is a legally binding, regional multilateral environmental agreement (MEA) for protecting and developing the WCR. (For details on the Cartagena Convention and Protocols see http://cep.unep.org/cartagena-convention.) To date, 26 countries have ratified or acceded to the Convention and 14 have ratified the LBS Protocol (Figure 1.3).

National barriers to LBS Protocol ratification and implementation

An assessment of the status of the LBS Protocol in selected Caribbean countries, conducted in 2013 under the GEF CReW project, revealed a great disparity among these countries (Corbin, 2013). While many of them have sought, to prevent, reduce, and control pollution of the marine environment from land-based sources and activities, some have made more progress than others. In addition, the assessment also confirmed that even those countries that have not yet acceded to the Protocol are already undertaking related activities but without adequate coordination. While the LBS Protocol provides such a coordinating mechanism and common framework, ratification and implementation of the Protocol needs to be improved.

The study also found that these countries generally face the same challenges and constraints in their efforts to fulfil their obligations under the Protocol (Box 10.1). Many of these challenges are identical to those recognized when the LBS Protocol was first developed in 1999. In addition, responses to a survey undertaken in 2017 by the Secretariat in preparation of this report revealed that while considerable progress has been made, many of the same challenges and needs have persisted in some WCR countries.

Box 10.1. Country challenges and needs related to meeting their obligations under the LBS Protocol (GEF CReW Project; Corbin, 2013)

Challenges

- Lack of financing
- Inadequate (and sometimes uncoordinated) policy, legislative, and institutional frameworks
- Lack of human, financial, and technical resources
- Old infrastructure leading to increased pollution of the environment
- Lack of adequate maintenance and poor operational wastewater systems
- A need for sustained water quality monitoring programmes and more comprehensive information management systems
- A need for more focused public awareness and environmental education programmes

Needs

- Funding for the development of laboratory capacity in support of monitoring programmes
- Formulation and implementation of relevant policies
- Enhancing institutional capacity through training and the provision of technical and other assistance
- Review of national legislative and regulatory frameworks, including drafting of legislation to address the weaknesses and gaps identified
- Design and implementation of public awareness and environmental educational programmes
- Access to and adoption of more appropriate and cost-effective technologies
- Establishment of data management systems both for national analytical purposes and for facilitating the exchange of information at national and regional levels
- Valuation of the economic impacts of pollution resulting from nutrients and wastewater
- The provision of "easy" financial arrangements to assist industries in upgrading their treatment
- Guidance on the development of wastewater permitting systems

The challenges listed in Box 10.1, among others, are described in many reports and publications produced in past years by UNEP, the World Bank, and others. Addressing these challenges in a coherent and coordinated manner across the region should be priorities for governments and intergovernmental organizations in addressing land-based pollution in the region.

10.2.2. Global frameworks and initiatives

Several global or international frameworks (including multilateral environment agreements), programmes, and initiatives have been developed, and WCR countries participate in them to varying degrees. The key frameworks and initiatives relevant to land-based pollution include:

- United Nations Convention on the Law of the Sea (UNCLOS) (http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm)
- MARPOL International Convention for the Prevention of Pollution from Ships (www.imo.org)
- Basel Convention on the Transboundary Movements of Hazardous Waste and their Disposal (www.basel.int)
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (www.pic.int)
- Stockholm Convention on Persistent Organic Pollutants (chm.pops.int)
- Minamata Convention on Mercury (www.mercuryconvention.org)
- Global Programme of Action for the Protection of the Marine Environment from Land-Base Activities (GPA)
- Global Partnership on Nutrient Management (www.unenvironment.org)
- Global Partnership on Marine Litter (www.unenvironment.org)
- Global Wastewater Initiative (www.unenvironment.org)
- Global Partnership on Waste Management (www.unenvironment.org)
- CleanSeas Campaign on Marine Litter (www.cleanseas.org)

10.2.3. Assessment of transboundary governance arrangements for pollution

Fanning et al. (2016) conducted an assessment of transboundary governance arrangements (agreements) and their associated architectures (institutional frameworks) relevant to pollution, fisheries, and biodiversity and habitat destruction in 50 transboundary LMEs (shared by two or more coastal states) including the Caribbean Sea, Gulf of Mexico, and North Brazil Shelf LMEs. Some key findings are provided in Box 10.2. These highlight several factors that should be addressed to improve governance related to pollution in the region.

Box 10.2. Assessment of transboundary governance arrangements relevant to pollution.
(Fanning et al., 2016)

- Pollution arrangements are low in accountability: few arrangements have repercussions for lack of compliance.
- Improvements in the design of transboundary governance for LMEs can be achieved by ensuring that current and new agreements have policy-cycle mechanisms in place that include a wide array of data and information providers; provide for a strong, knowledge-based policy interface; hold decision-makers and those responsible for implementation accountable; and ensure that monitoring and evaluation mechanisms are implemented to facilitate adaptive management.
- There is a significant disconnection between organizations involved with fisheries issues and those involved with pollution and biodiversity issues, which points to a need to focus efforts on collaboration between these organizations, and/or the creation of overarching integrating mechanisms. *In the LMEs within the WCR, governance arrangements for pollution and biodiversity are closely integrated within the Cartagena Convention. There may be interaction with fisheries governance arrangements through participation in each other's meetings, but this appears to be informal.*
- Countries have a high level of commitment towards participation in agreements addressing transboundary issues. Nevertheless, binding agreements (as are all agreements for pollution) have a lower level of engagement than non-binding agreements. The effort needed by countries engaged in binding agreements to comply with the conditions of the agreement may explain this finding (but this needs to be verified).

10.2.4. Sustainable Development Goals

Multiple SDGs and Targets are pertinent to marine environmental pollution, particularly SDG 14, Target 14.1 (By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution). SDG 14 is complemented by several other SDGs and their Targets (See Box 1.2 in Chapter 1 of this report).

10.2.5. Regional programmes and projects

Regional Seas Programme – Caribbean Environment Programme

In 1981, UNEP established the Caribbean Environment Programme (CEP) as one of its Regional Seas programmes in recognition of the importance and value of the WCR's fragile and vulnerable coastal and marine ecosystems and endemic biodiversity. The Caribbean Regional Coordinating Unit (CAR/RCU) serves as the Secretariat for the Caribbean Environment Programme and the Cartagena Convention. Projects and activities take place under three programme areas: Assessment and Management of Environment Pollution (AMEP), Specially Protected Areas and Wildlife (SPAW), and Communication, Education, Training and Awareness (CETA). (https://www.unenvironment.org/cep/)

CLME+ Strategic Action Programme

The UNDP/GEF Project "Catalysing the Implementation of the Strategic Action Programme for the Sustainable Management of Shared Living Marine Resources in the Caribbean and North Brazil Shelf Large Marine Ecosystems" (CLME+ project) is implementing a Strategic Action Programme (SAP) to address three priority issues in the region (pollution, unsustainable fisheries, and habitat degradation). The SAP was politically endorsed by over 30 government ministers representing 26 countries and 6 overseas territories in the CLME+ region. SAP Strategy 1 relates to protection of the marine environment with respect to the three priority issues (www.clme-project.org).

Regional Nutrient Reduction Strategy, Investment Plan, and Action Plan

With support from the UNDP/GEF CLME+ Project, UNEP-CEP is leading the development of a Regional Nutrient Reduction Strategy and associated Investment Plan and Action Plan (ongoing). This activity will be informed by the information on nutrients in this report. A similar framework is also being developed in parallel (but linked) for habitat restoration.

Regional Action Plan for Marine Litter (RAPMaLi) for the Wider Caribbean Region

RAPMaLi was originally developed in 2007 as a project under the direction of UNEP (through its Regional Seas Programme) in response to growing global concerns about litter accumulation in the oceans. RAPMaLi is designed to serve as a comprehensive toolkit to assist SIDS incorporate components of proper waste management across all sectors.

Projects

Examples of recent and ongoing GEF-funded projects that are relevant to marine environmental pollution in the WCR include:

- Caribbean Regional Fund for Wastewater Management (CReW) http://www.gefcrew.org/index.php/about-gef-crew
- Integrating Water, Land and Ecosystems Management in Caribbean SIDS (IWEco)
- http://www.cep.unep.org/gef-iweco-1/gef-iweco
- CLME+ project and Strategic Action Programme
- https://clmeplus.org/
- Integrated Ridge-to-Reef Management of the Mesoamerican Reef project (MAR2R) https://www.thegef.org/news/belize-guatemala-honduras-mexico-ccad-and-gef-join-forces-conservation-mesoamerican-reef

10.2.6. Governance Effectiveness Assessment Framework

Assessing environmental governance includes reviewing governance arrangements and processes, as well as outcomes and impacts (Fanning and Mahon, 2018). Mahon et al. (2012) developed a Governance Effectiveness Assessment Framework (GEAF) that consists of seven categories of indicators (Figure 10.1) aimed at assessing whether good governance arrangements are in place and whether they are effective at achieving what they set out to do. The GEAF links improved socioeconomic and ecosystem conditions with enhanced governance arrangements and more effective policy cycle implementation.

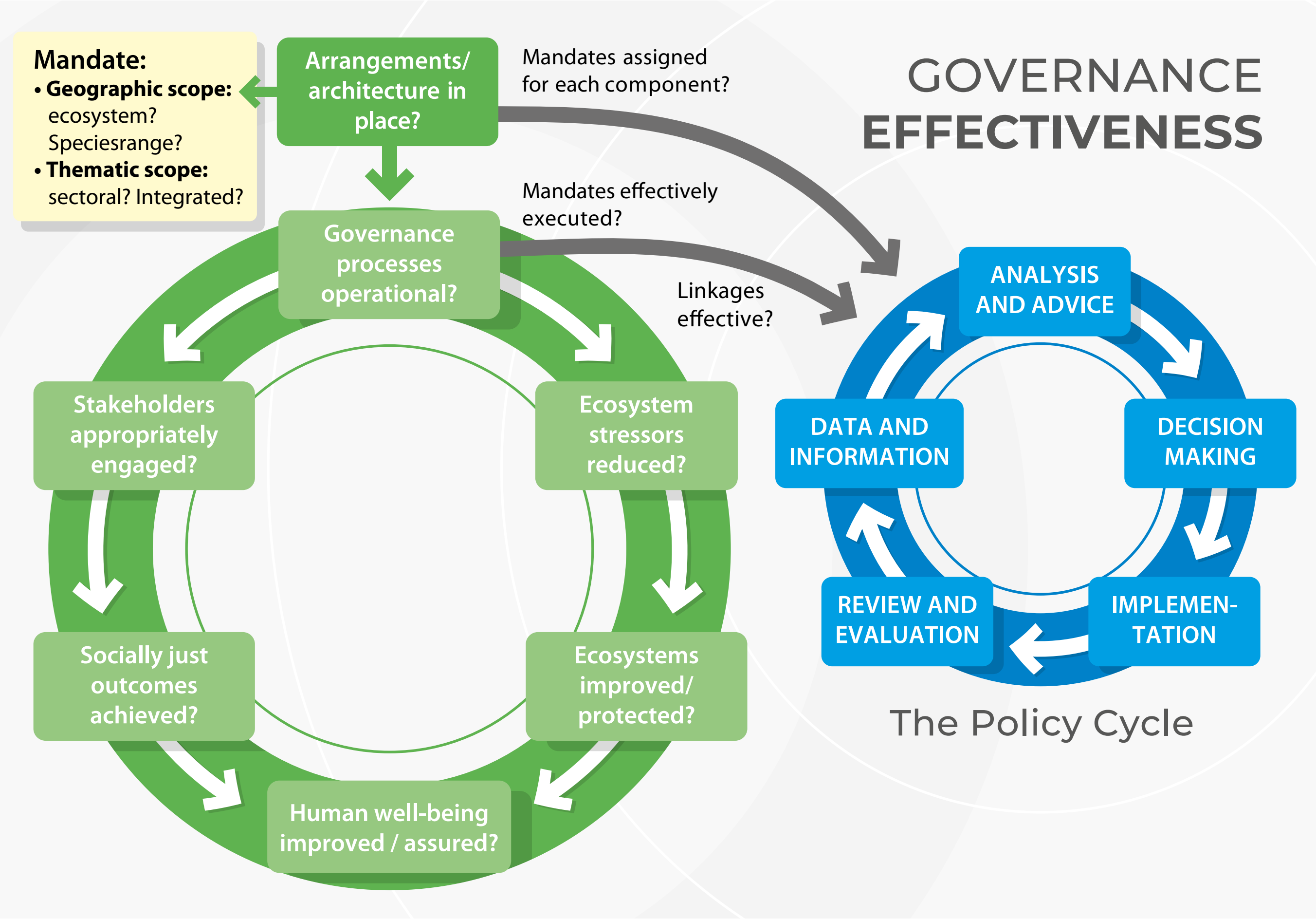

Figure 10.1. Governance Effectiveness Assessment Framework
(Mahon et al., 2012; Fanning and Mahon, 2018).

The GEAF has been adopted by the countries and intergovernmental organizations participating in the UNDP/GEF CLME+ Project for monitoring and evaluatiing the regional Strategic Action Programme. Under this Project, Fanning and Mahon (2018) developed a set of GEAF indicators for marine pollution, fisheries, and habitats. These indicators are being applied in the ongoing governance assessments being conducted under the project.

A quantitative governance assessment using the complete GEAF for land-based pollution is beyond the scope of this report. However, the assessment of pressures and state in this report can contribute to the baseline for assessing the elements of the GEAF related to ecosystems and human well-being.

10.3. Stress reduction measures and best practices

There is an extensive range of stress reduction measures (i.e., measures to reduce pollution loads at the source or prevent them from reaching the marine environment), experiences, and best practices that WCR countries can adapt to local circumstances. Reviews of regional and international best practices for wastewater management are presented in the UNEP-CEP Technical Reports 64 (UNEP-CEP, 2010b) and 65 (UNEP-CEP, 2010c), respectively. Also refer to UNEP 2018 for case studies and examples of (solid) waste management practices in the region, and the UNEP Division of Technology, Industry, and Economics, Sustainable Consumption & Production Branch http://www.unep.fr/scp/cp) for Resource Efficient and Cleaner Production programmes. Generic stress reduction measures and best practices to address land-based pollution, with examples from the region, are described below (stress reduction measures are also given in preceding chapters of this report).

10.3.1. Nature-based solutions (soft engineering)

"Soft Engineering" technologies are based on ecological principles and practices that use vegetation and ecosystems (forests, wetlands and grasslands, crops, and soils) as biofilters due to their natural ability to facilitate effluent filtration and pollutant absorption. When managed properly, natural biofilters can provide high-value "green infrastructure" for regulating water flows and maintaining water quality by reducing sediment loadings, preventing soil erosion, and capturing and retaining pollutants. Soft engineering technology has been adopted in several countries. For example, wetlands to remove nutrients and contaminants from the wastewater in the Fond D'Or Watershed in Saint Lucia; and an artificial wetland system to filter wastewater from a fish processing plant in Tobago (Trinidad and Tobago). In deploying these natural systems, attention must be paid to ensuring that their carrying capacity is not exceeded and that they are adequately protected.

10.3.2. Circular economy approaches

The main objective of the circular economy is to make maximum use of resources while preventing waste generation. This contributes to environmental and financial benefits and sustainability, as opposed to the "cradle-to-grave" linear model for materials, which begins with resource extraction, moves to product manufacturing, and ends where the used product is disposed of in a landfill. Waste is increasingly being seen as a potential resource that offers opportunities to develop a circular economy. An initiative gaining momentum worldwide—Zero Waste—seeks to curb waste production at its source and redefine trash as raw material, fit for re-use in economic production and ecological cycles. Colombia, for example, has joined the Zero Waste initiative (https://www.no-burn.org/introduccion-al-concepto-de-basura-cero/) with its own project and NGO (Basura Cero Colombia). Colombia has adopted a holistic programme for trash management based on a circular economy approach. The approach, which is supported by Colombia's National Policy for the Integrated Management of Solid Waste and a Zero Waste Systems Certification, allows organizations to implement strategies to reduce, re-use, use, and recover waste and even energy. Among 11 countries in Latin America and the Caribbean surveyed in a recent study, Colombia has the highest rate of recycling at nearly 18% (UNEP, 2018).

10.3.3. Reduce/re-use/recycle/

This approach can be viewed as part of a wider circular economy approach. Waste minimization, in-plant refinement of raw materials and production processes, recycling of waste products, and so on, are given priority over traditional end-of-pipe treatments.

Recycling and re-using sanitation waste has vast potential to benefit the water, agriculture, and energy sectors in the WCR. Treated wastewater can be used for several different purposes, such as agricultural irrigation, aquaculture, industrial cooling, and low-quality applications such as toilet flushing. One of the main challenges is selecting an appropriate treatment system that ensures that the effluent is of acceptable microbiological and chemical quality. In many of the islands in the Eastern Caribbean, the larger hotels have on-site wastewater treatment plants and re-use wastewater for irrigation (Peters, 2015). In Trinidad (Trinidad and Tobago), the Beetham wastewater treatment plant provides some 20 million gallons per day of high-quality industrial water that is transported via submarine pipeline to Point Lisas for use in the Point Lisas Industrial Estate.

Guatemala announced a commitment to reduce plastic pollution in the oceans as part of the UNEP CleanSeas Campaign. This country has installed bio-fences made from recovered plastic debris in rivers across the country to trap and collect macroplastic waste. This makes it easier for communities to recycle or properly dispose of the waste. Community residents have generated additional income through recycling and upcycling. Honduras, the Dominican Republic, and Panama have adopted the Guatemalan bio-fences to trap plastics in their rivers.

10.3.4. Sustainable agricultural practices

For diffuse sources such as agricultural run-off, best environmental practices/sustainable agricultural practices are implemented to minimize non-point sources (for example, more efficient use of fertilizers, manure, and pesticides). Following the introduction of technological innovation and good agricultural practices under the GEF-REPCar demonstration projects, a significant reduction (up to 50% in some cases) was achieved in the use of synthetic pesticides on the pineapple and banana demonstration crops in Costa Rica, on banana and plantains in Colombia, and on beans and oil palm in Nicaragua. Farmers also benefited economically since they spent less of their income purchasing fertilizers. Emerging technology systems and agricultural innovations have an important role in developing sustainable agriculture (for example, see www.edf.org/ecosystems/sustainable-agriculture/precision-agriculture; http://www.pnas.org/agricultural_innovations; and http://www.ayokasystems.com/news/emerging-agriculture-technologies/).

10.3.5. Environmentally sound technologies

Environmentally sound technologies protect the environment by using all resources in a more sustainable manner, recycling more of the waste products, and appropriately handling residual wastes. These include on-site wastewater treatment systems and off-site centralized treatment technologies. A recent cost-effective innovation is Chemically Enhanced Primary Treatment (CEPT) used to enhance the first step in urban wastewater management. One of the major treatment objectives is low-cost phosphorus removal. Tests of CEPT in Brazil showed that it is possible to remove about 90% of the phosphate and substantially reduce total suspended solids and biological oxygen demand. The first two CEPT treatment plants in Rio de Janeiro have been constructed and have commenced operation. Ongoing studies are aimed at reducing the cost and increasing the efficiency of wastewater treatment lagoons frequently used in small cities by combining CEPT and lagoon treatment technologies.

Detailed descriptions of the technologies are included in the report, Assessment of Wastewater Management Technologies in the Wider Caribbean Region (UNEP-CEP, 2010c).

10.4. Sustainable financial mechanisms

A recurring challenge is the lack of adequate financial resources for WCR countries to implement effective solutions to pollution. Most countries in the region have failed to take a long-term, integrated approach to wastewater management and few have made adequate budgetary provisions to invest in sewerage infrastructure, policy reform, and public education (UNEP-CEP, 2010b). As a result, WCR countries often rely on funding from donors or governments, and not on best value and net economic benefit. Therefore, the development of innovative financial mechanisms and affordable financing to assist countries within the WCR constitutes a very high priority.

The GEF CReW project worked with the World Resources Institute (WRI) to develop and test an economic valuation resource guide to assist countries in making a stronger case for investments in wastewater treatment. The guide can also help decision-makers weigh the trade-offs between wastewater infrastructure investment types, such as natural infrastructure (e.g., conservation of wetlands) versus engineered infrastructure (e.g., wastewater treatment facilities).

Diverse financial mechanisms have been developed, including payments for environmental services (PES) schemes often using innovative public–private partnerships, debt-for-nature swaps, and various other types of funds and mechanisms. For example, under the GEF CReW project, a financial mechanism was established in Belize, where a National Wastewater Revolving Fund worth $5 million provided below-market interest rate loans for wastewater treatment projects. In Jamaica, the Jamaica Credit Enhancement Facility (JCEF), which is worth $3 million, provides credit enhancement for local commercial bank financing of wastewater projects. JCEF is a reserve account used as collateral for local banks interested in acquiring financing for wastewater projects. The Government of Jamaica pledged an additional $12 million, with total financing expected to grow substantially. The initial project proposal intially expected GEF CReW funds to leverage $7 million for the Jamaica National Water Commission (NWC) to execute 11 small projects. Since 2008, the Office of Utility Regulation has authorized the NWC to collect a monthly wastewater utility surcharge called the K-factor, which capitalizes a special account for priority water and wastewater investment projects. The K-factor, together with the reserve guarantee from GEF CReW, contributed to the NWC securing its first commercial loan for $12 million, without a sovereign guarantee.

In conclusion, considerable progress has been made at all levels within the WCR to develop institutional and policy frameworks and initiatives that address a range of environmental issues, including marine environmental pollution. Furthermore, diverse and innovative technologies for pollution control and management are available, as are a range of sustainable financial mechanisms. Nevertheless, the approach to addressing land-based pollution remains generally inadequate, uncoordinated, and fragmented across the region, although there are numerous impressive successes and achievements in specific locations.

There is an urgent need for WCR governments to adapt and scale up existing experiences, best practices, and technologies, and undertake the required institutional, policy, legislative, and budgetary reforms, necessary to address land-based pollution, particularly at its source. Furthermore, the complex and multifaceted nature of land-based pollution (reflected by, for example, multiple sectors and sources, potential interactions between contaminants in the environment, and wide-ranging impacts on both human and environmental health) means that an integrated, cross-sectoral approach (including private sector engagement) is required to effectively tackle land-based pollution.

11. CONCLUSION AND RECOMMENDATIONS

11.1. Conclusion

This assessment clearly shows that the region still has a long way to go to achieve the Sustainable Development Goals and Targets related to pollution (particularly nutrients and plastic, which are explicitly addressed in SDG 14.1), and other relevant targets.

Moreover, the impacts of pollution arising from land-based sources and activities on human health and economies will seriously compromise our ability to achieve the remaining SDGs and other societal goals and targets.

Although substantial data and information gaps remain to be addressed, this assessment corroborates what is widely acknowledged in the region about the issue of land-based pollution, using empirical water quality data from WCRcountries, updated estimates of domestic wastewater and nutrient loads, and information from published sources.

Human populations and their production and consumption patterns are major drivers of change in the condition of the marine environment and its ecosystems. In the WCR, population, urbanization, and important economic sectors such as tourism—which are all concentrated in coastal areas—are projected to continue to grow over the coming decades. This will intensify pressures on the marine environment from land-based sources and activities under a "business as usual" scenario of poor urban planning, inadequate wastewater treatment facilities and solid waste management, and unsustainable land use and agricultural practices. The region's coastal waters continue to receive discharges of substantial volumes of untreated domestic wastewater and agricultural run-off, which introduce significant loads of sewage, nutrients, and other potentially harmful substances to coastal waters. These discharges, together with the input of high quantities of sediments and solid waste (particularly plastics), are major pressures exerted on the region's marine environment.

These pressures have caused deterioration in the state of coastal waters in many localities throughout the region with respect to the eight core water quality indicators that were assessed. Six of these indicators—dissolved inorganic nitrogen, dissolved inorganic phosphorus, and chlorophyll-a (nutrient pollution); *E.coli* and *Enterococcus* (fecal contamination); and turbidity (sediment pollution)—showed a high proportion of sampling sites with poor environmental status, which was particularly pronounced during the rainy season and in areas affected by river discharge. Land-based pollution hotspots may be present in several locations, and improved monitoring and remedial actions are urgently needed in these areas. Marine litter, particularly plastics, and contamination of the marine food chain by mercury are also of growing concern in the region.

There is documented evidence that land-based pollution is degrading the region's ecologically and economically valuable marine ecosystems such as coral reefs and seagrass beds. Because of the region's high dependency on marine ecosystem goods and services, a threat to its marine ecosystems is a direct threat to its socioeconomic development and the well-being of its people. Land-based pollution poses significant direct and indirect threats to public health, livelihoods, and important economic sectors such as tourism and fisheries, and hinders development of a blue economy by reducing its natural resource base. Further, the associated economic costs can exceed tens of billions of dollars annually.

Considerable advances have been made at national, sub-regional, and regional levels in the WCR to address land-based pollution. Nevertheless, overall progress has been slow, with many historical challenges continuing to persist. There is an urgent need for WCR governments to adapt and scale up existing experiences, best practices, and technologies, and undertake the required institutional, policy, legislative, and budgetary reforms to address land-based pollution, particularly at its source.

11.2. Recommendations

The following recommendations are organized according to five themes and directed to either Contracting Parties of the Land-Based Sources Protocol or to the Convention Secretariat.

1. Technical/Monitoring and Assessment

Contracting Parties:

1. Standardize data collection protocols, analytical procedures and reporting of water quality results.
2. When developing and/or enhancing national monitoring and assessment programmes:
   a. Measure the accumulation of priority contaminants in marine biota, particularly species consumed by humans.
   b. Monitor and evaluate the impacts of emerging issues such as Sargassum blooms, ocean acidification, electronic waste, marine litter and microplastics on the marine environment and human health, including the identification of causes and sources, movements, sinks, and hot spots.
   c. Quantify the economic impact of pollution due to loss of ecosystem goods and services and in so doing assess the costs and benefits of "business as usual" scenarios versus the implementation of pollution prevention and reduction measures.
   d. Use the data from the SOCAR, the conceptual framework of the economic burden of disease developed by the WHO (WHO, 2009) and other sources to obtain a more comprehensive analysis of the environmental, social, and economic impacts of pollution on the coastal and marine environment.
   e. Assess the source categories of pollution(including specific industrial sources) by sub-region, quantify the pollution loads, and establish causal linkages with the monitoring data, thereby allowing for a regional determination of the pollution impact by category.
   f. Establish a set of core monitoring parameters that could form the basis of a minimum assessment of coastal marine water quality and be used to develop a pollution index that would assist countries in assessing potential pollution risk to the coastal and marine environment.
   g. Develop a standardized template for recording and reporting monitoring data and metadata, to be used by all Contracting Parties.
   h. Use geo-referenced data as much as possible for identification of sample sites.

The Secretariat:

3. Facilitate greater synergies with the Cluster of Chemical Conventions on the assessment of chemical contaminants such as persistent organic pollutants (POPs) and heavy metals in particular, and promote monitoring of these contaminants by Contracting Parties.
4. Assess the existing reporting requirements under the Cartagena Convention in accordance with Article XII and facilitate the alignment of SOCAR with other reporting requirements and mechanisms such as the *The State of Nearshore Marine Habitats in the Wider Caribbean* report, SOMEE, and reporting on international goals such as the SDGs (in particular 14) and the Aichi Targets (in particular 8 on pollution and 14 on ecosystem services).
5. Work with Contracting Parties to gather information and data specific to the development of the SOCAR assessment on an ongoing basis and develop periodic interim information products

for submission to the Scientific and Technical Advisory Committees (STACs) and Conferences of Parties (COPs), as appropriate.

6. Work with Contracting Parties and partner agencies to better monitor and document the effects of pollutants in the coastal and marine environment on human health, including the collection of epidemiological data and application of the International Health Regulations (IHR).

2. Capacity Building and Training

Contracting Parties:

1. Develop sufficient laboratory capacity to monitor microplastics and coastal acidification through the use of the Regional Activity Centres (RACs), Regional Activity Network (RAN), and other measures, with support from other regional and international laboratories.
2. Consider including national data on plastics and/or microplastics in future SOCAR assessments.

The Secretariat:

3. Conduct a comprehensive needs assessment of Contracting Parties for future reporting on the State of Convention Area that would inform the development of a capacity building programme to be endorsed by Contracting Parties.
4. Work with Contracting Parties and Donor agencies to facilitate laboratory capacity building including :
    a. Enhancing laboratory quality assurance (QA) and quality control (QC) measures;
    b. Facilitating a programme for the gradual accreditation of laboratories, including the development of partnerships with the national bodies responsible for implementation of the ISO 17025 standard;
    c. Compiling a compendium of methods, inclusive of QA and QC criteria, to guide the analysis of SOCAR pollution parameters and to facilitate comparability of generated data; and
    d. Developing a standard format for the executing national coastal marine surveys to ensure the collection of SOCAR-related data.
5. Work with the RACs and RAN to facilitate training in geographic information systems (GIS), and data management and analysis to ensure that Parties are equipped with the necessary capacity to assess environmental risks resulting from coastal and marine pollution.

3. Governance: Institutional, Policy, and Legal frameworks

Contracting Parties:

1. Establish partnerships, including through Memoranda of Understanding (MOUs) with universities, research institutes, private sector organizations, and non-governmental agencies to assist in data collection for future SOCAR assessments.
2. Ensure partnership agreements for data generation include requirements for the use of such data and its dissemination.
3. Develop National Pollution Prevention Action Plans to assist in implementing the Cartagena Convention and the LBS Protocol.

4. Consider providing technical support to other Contracting Parties through offers of training, professional exchanges, coordination of quality assurance activities, serving as reference laboratories, and designing and implementing national and/or regional monitoring programmes.

4. Knowledge Management, Communication, and Stakeholder Engagement

Contracting Parties:

1. Fully engage in future national, sub-regional, and regional assessments that support development of future SOCAR assessments to ensure buy-in and ownership of the assessment and increase the likelihood that the results will be used in decision-making.

The Secretariat:

2. Ensure that high-level policy briefs are provided to relevant regional and sub-regional intergovernmental bodies such as CARICOM, OECS, and CCAD as part of the dissemination of the SOCAR results.
3. Establish a central database and clearing house to house SOCAR data, information, and other relevant resources.
4. Develop guidance for reporting on the state of monitoring programmes implemented by Contracting Parties, in accordance with Article VI of the LBS Protocol, with support from the RACs and the Working Group on Monitoring and Assessment, including how to assess the challenges in sharing sensitive water quality data.

5. Sustainability

Contracting Parties:

1. Establish a policy identifying the role of intergovernmental organizations (IGOs) as partners in the development of future SOCAR reports and in the overall implementation of the LBS Protocol.
2. Continue discussions on additional monitoring parameters, through the Working Group, STAC, and other entities, to ensure that focal areas within the LBS Protocol are addressed and all classes of pollution are adequately considered.
3. Review Annex 1C of the Protocol to provide insights on additional pollutants of concern based on available scientific data and the results of national and regional monitoring programmes.
4. Develop sustainability measures for national laboratories, which should include the institutionalization and legal designation of the laboratory, and the establishment of a financial mechanism for laboratory operations.
5. Review, develop, and strengthen national environmental legislation, including generation and sharing of pollution-related data and information.

The Secretariat:

6. Document lessons learned and best practices from pollution prevention projects and activities, and work with Contracting Parties to scale up and implement solutions to address LBS pollution, particularly in pollution hotspots, through innovative national financial mechanisms and as part of donor-funded projects.

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ANNEXES

ANNEXES

Annex 1.1. LBS Working Group Members

NAME	JOB TITLE	ORGANIZATION
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Akhidenor Eromonselle	Research Officer, Planning Evaluation and Research Branch	National Environment and Planning Agency, Jamaica
Andrew Horan	Global Affairs and Policy, Office of International and Tribal Affairs	US Environmental Protection Agency, USA
Arelys Fuentes Castillo/ Yamil Danil Sanchez Pena	Laboratorio de Agua	Ministerio de Ambiente, Panamá
Linroy Christian	Microbiologist	Ministry of Agriculture, Lands, Marine Resources and Agro Industry, Antigua and Barbuda
John Bowleg	Department Head, Water Resources Management Unit	Water & Sewerage Corporation, The Bahamas
Anthony Headley	Director (Ag), Environmental Protection Department	Ministry of Environment and Drainage, Barbados
Marlen Perez	Investigadora Auxiliar, Division de Contaminación	Centro de Ingeniería y Manejo Ambiental de Bahias, Cuba
Frank Grogan	Environmental Officer II, Water Quality Unit	Environmental Management Permitting Division, Environmental Protection Agency, Guyana
Felicia Adams-Kellman	Senior Environmental Officer	Environmental Protection Agency, Guyana
Marko Tosic	Associate Researcher	Department of Earth Sciences, EAFIT University, Colombia
Daryll Banjoo	Senior Research Officer	Institute of Marine Affairs, Trinidad & Tobago
Stephanie Adrian	Global Affairs and Policy, Office of International and Tribal Affairs	US Environmental Protection Agency, USA
Hugh Sullivan	Acting Lead	Office of Water, National Coastal Condition Assessment, US Environmental Protection Agency, USA
Lyndon Robertson	Head of Department, Environmental Health and Sustainable Development	Caribbean Public Health Agency (CARPHA), Saint Lucia
Andrea Salinas	Environmental Mapping and Reporting Specialist (former)	CLME+ Project (UNDP/GEF), Colombia
John Knowles	Mapping & Monitoring Specialist	CLME+ Project (UNDP/GEF), USA
Patrick Debels	Regional Project Coordinator	CLME+ Project (UNDP/GEF), Colombia
Morten Soerensen	Senior Advisor, Marine Programme	GRID-Arendal, A Centre, Norway
Luisa Espinosa Diaz	Coordinadora Programa Calidad Ambiental Marina	INVEMAR, Colombia
Andrea Jones-Bennett	Director, Projects and Enforcement, Environment and Risk Reduction Division	Ministry of Economic Growth and Job Creation, Jamaica
Gillian Guthrie	Senior Director, Environment and Risk Management Division	Ministry of Economic Growth and Job Creation, Jamaica
Nicole Oreggio	Director, Pollution Control, Environment and Risk Reduction Division	Ministry of Economic Growth and Job Creation, Jamaica
Dannielle Townsend	Coordinator - Pollution, Monitoring & Assessment Branch	National Environment and Planning Agency, Jamaica
Loureene Jones-Smith	Coordination - Ecosystems Management Branch	National Environment and Planning Agency, Jamaica
Paulette Kolbusch	Senior Manager, Environmental Management Subdivision	National Environment and Planning Agency, Jamaica
Richard Nelson	Senior Manager, Environmental Management Subdivision	National Environment and Planning Agency, Jamaica
Lisa Kirkland	Manager, Environmental Management Subdivision	National Environment and Planning Agency, Jamaica
Troy Pierce	Chief Scientist	U.S. EPA Gulf of Mexico Program, USA

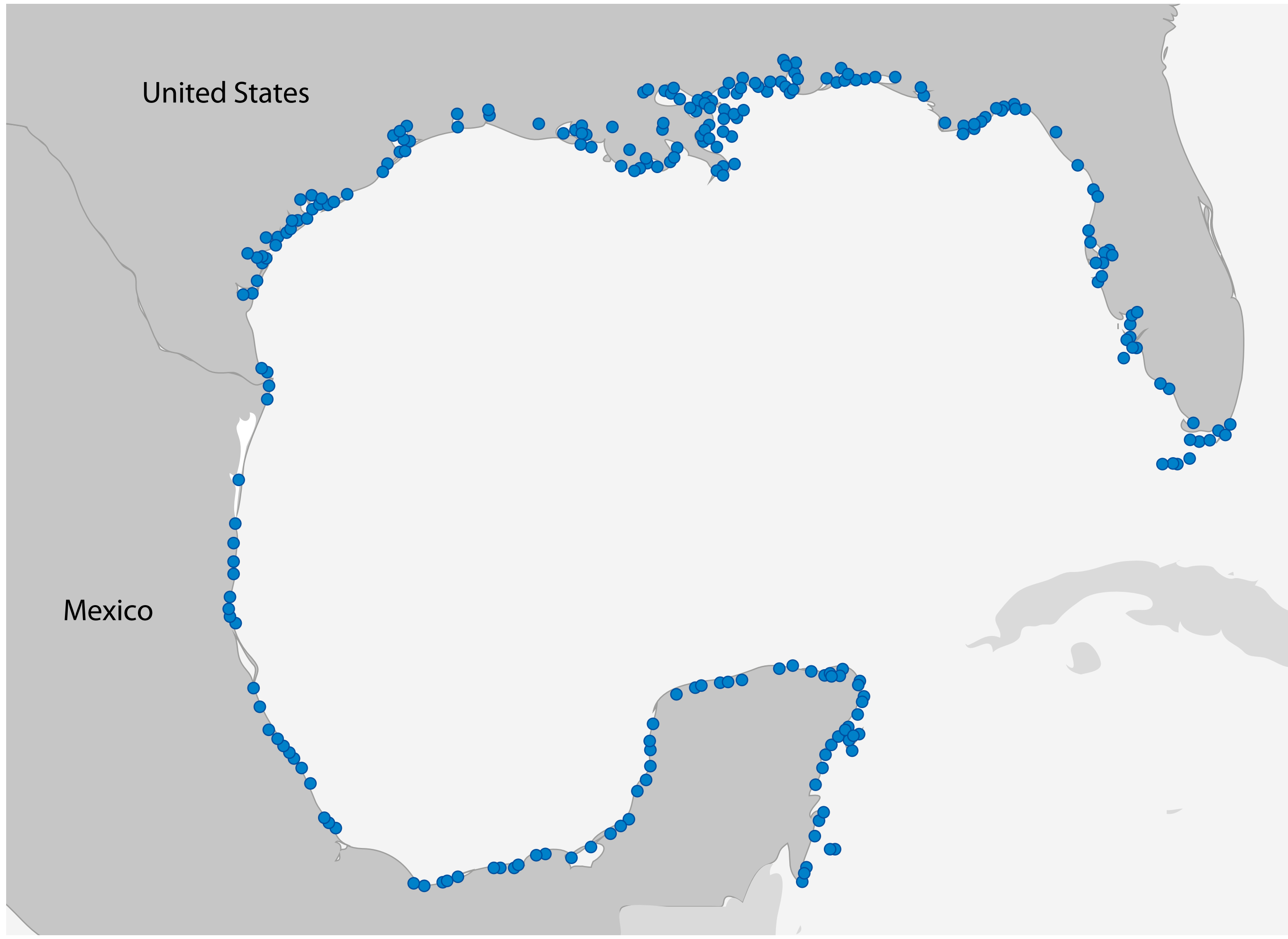
Annex 3.1. Countries and territories that submitted water quality data for SOCAR and the main parameters covered. No data was submitted from sub-region II. (Note: DIN measurements were covered only by the USA. DIN was determined as the sum of NH4, NH3, and NO2 for the countries and territories that submitted such data.)

Sub-region	**I**		**II**	**III**				**IV**									**V**			
Parameter (*assessed for SOCAR)	Mexico	USA	No data	Aruba	Colombia	French Guiana	Guyana (effluent data only)	Antigua & Barbuda	Grenada	Trinidad & Tobago	Guadeloupe	Martinique	USVI	Dominica	Saint Lucia	St. Vincent & The Grenadines	Dominican Republic	The Bahamas	Jamaica	Puerto Rico
*Chlorophyll-a	X	X			X					X	X	X								
*Dissolved oxygen (DO)	X	X		X	X		X		X	X	X	X					X	X		
*Dissolved inorganic nitrogen (DIN)		X			X					X	X	X					X			X
*Dissolved inorganic phosphorus (DIP)		X			X					X	X	X					X		X	
*Turbidity	X				X	X			X	X	X	X					X	X	X	
*pH	X	X		X	X		X	X		X	X	X					X	X	X	
**Enterococcus*	X			X	X			X	X	X			X	X	X	X				X
**E. coli*				X					x	X			X	X	X	X		X		
Salinity	X	X			X	X			X	X	X	X					X	X		
Temperature	X	X			X	X			X	X	X	X					X			
Total suspended solids	X				X		X			X							X		X	

Annex 3.2. Water quality sampling sites by country/territory

Note: the following maps are not to scale.

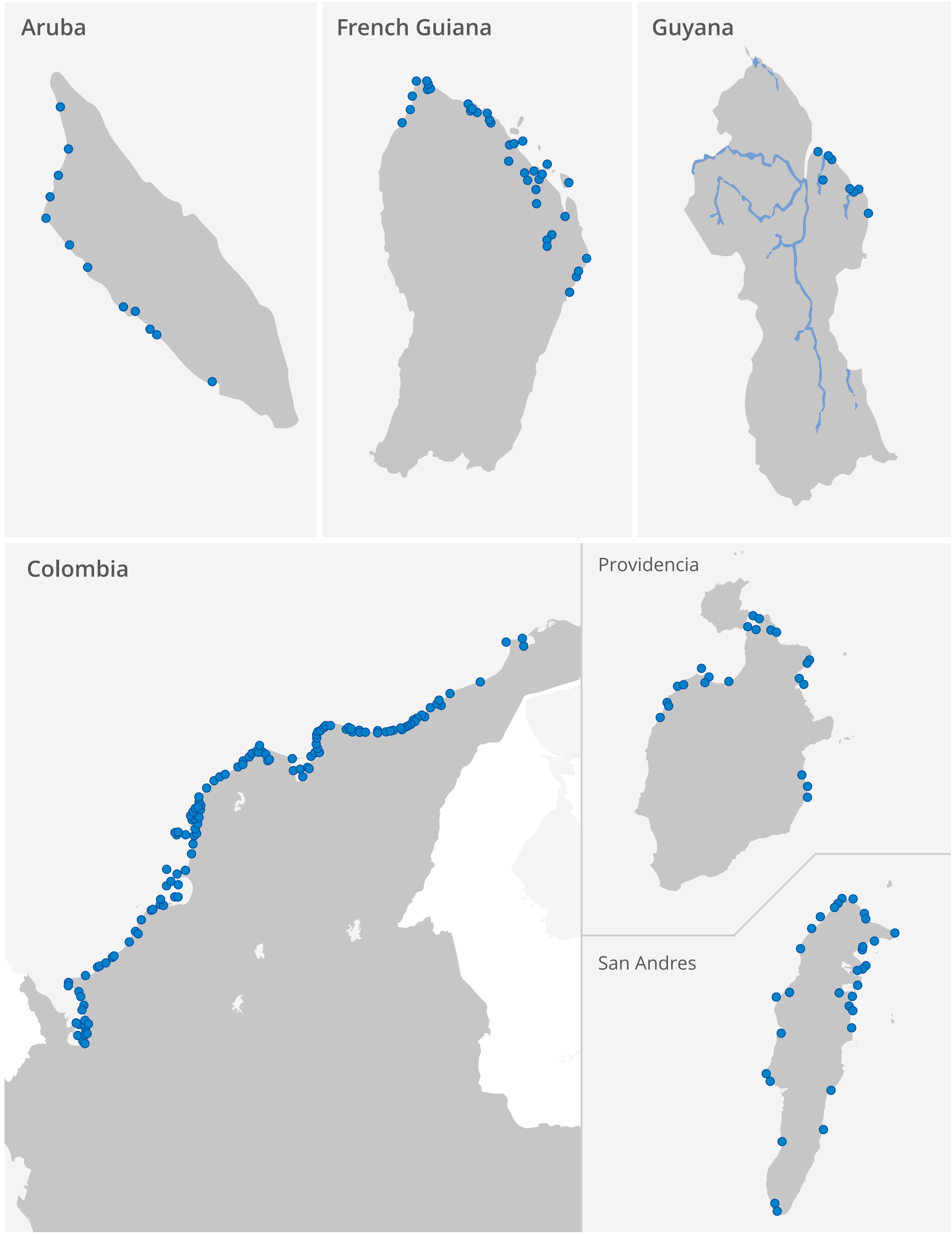
SUB-REGION I: Gulf of Mexico



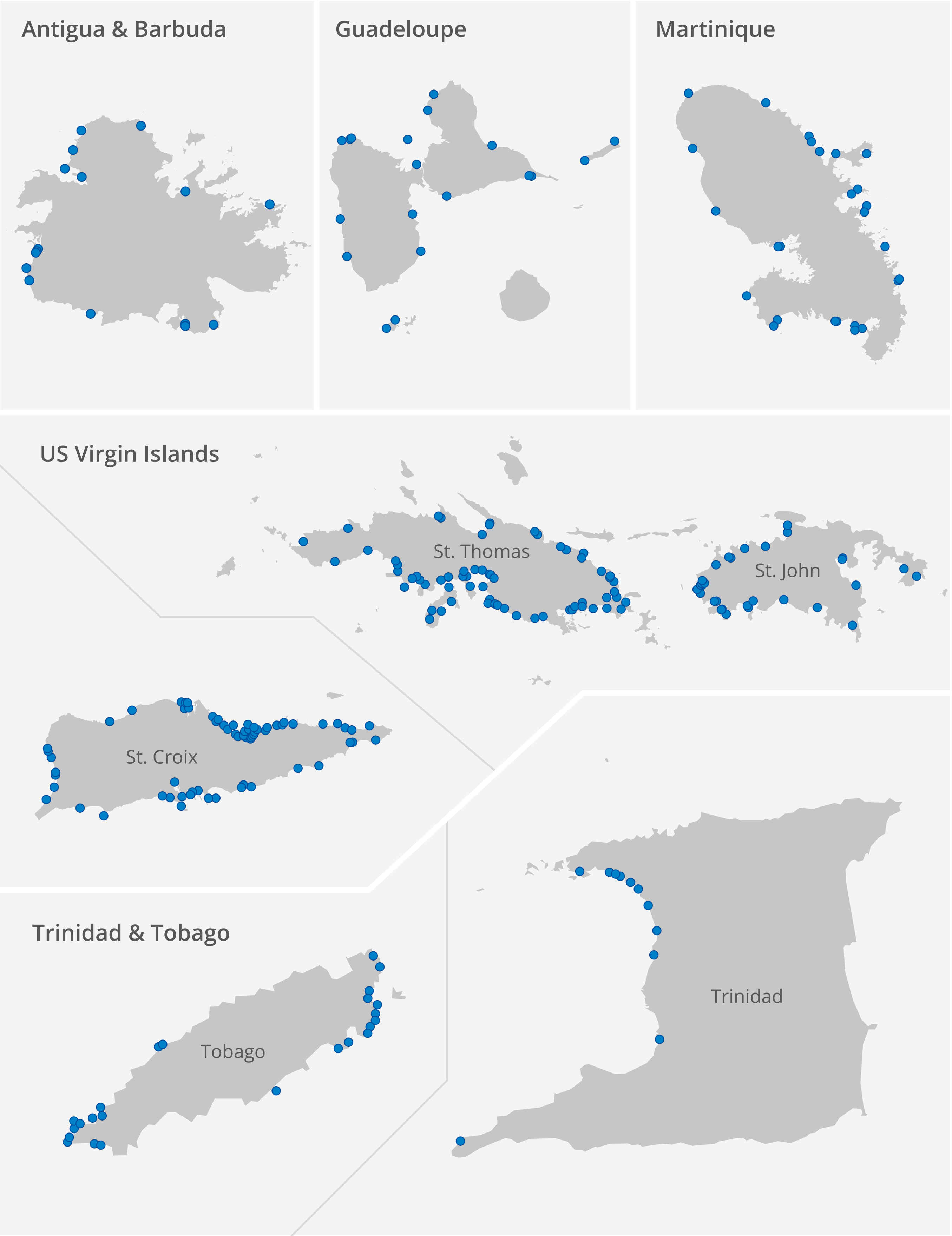
SUB-REGION II: Western Caribbean

No data

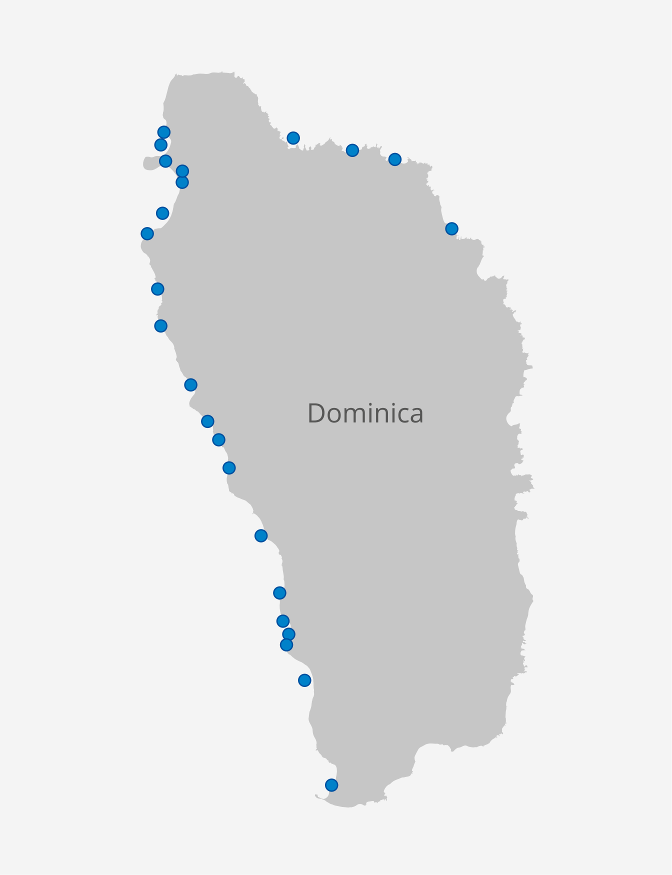
SUB-REGION III: Southern Caribbean

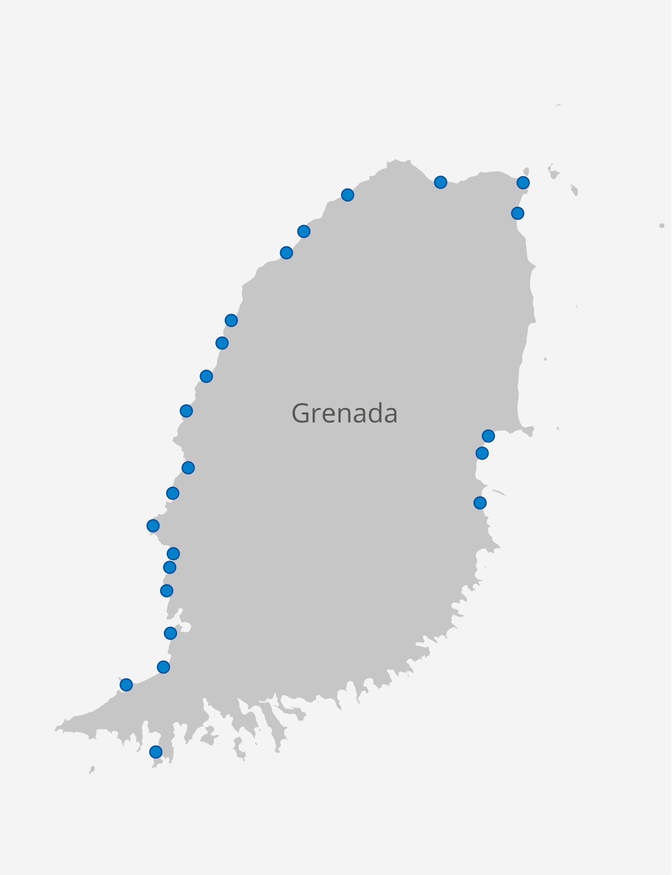


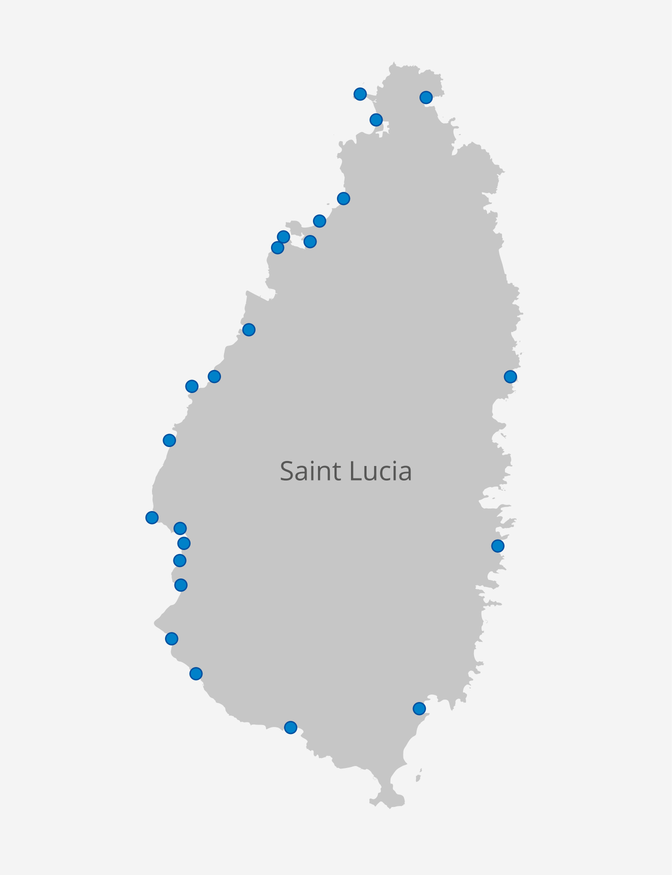
SUB-REGION IV: Eastern Caribbean



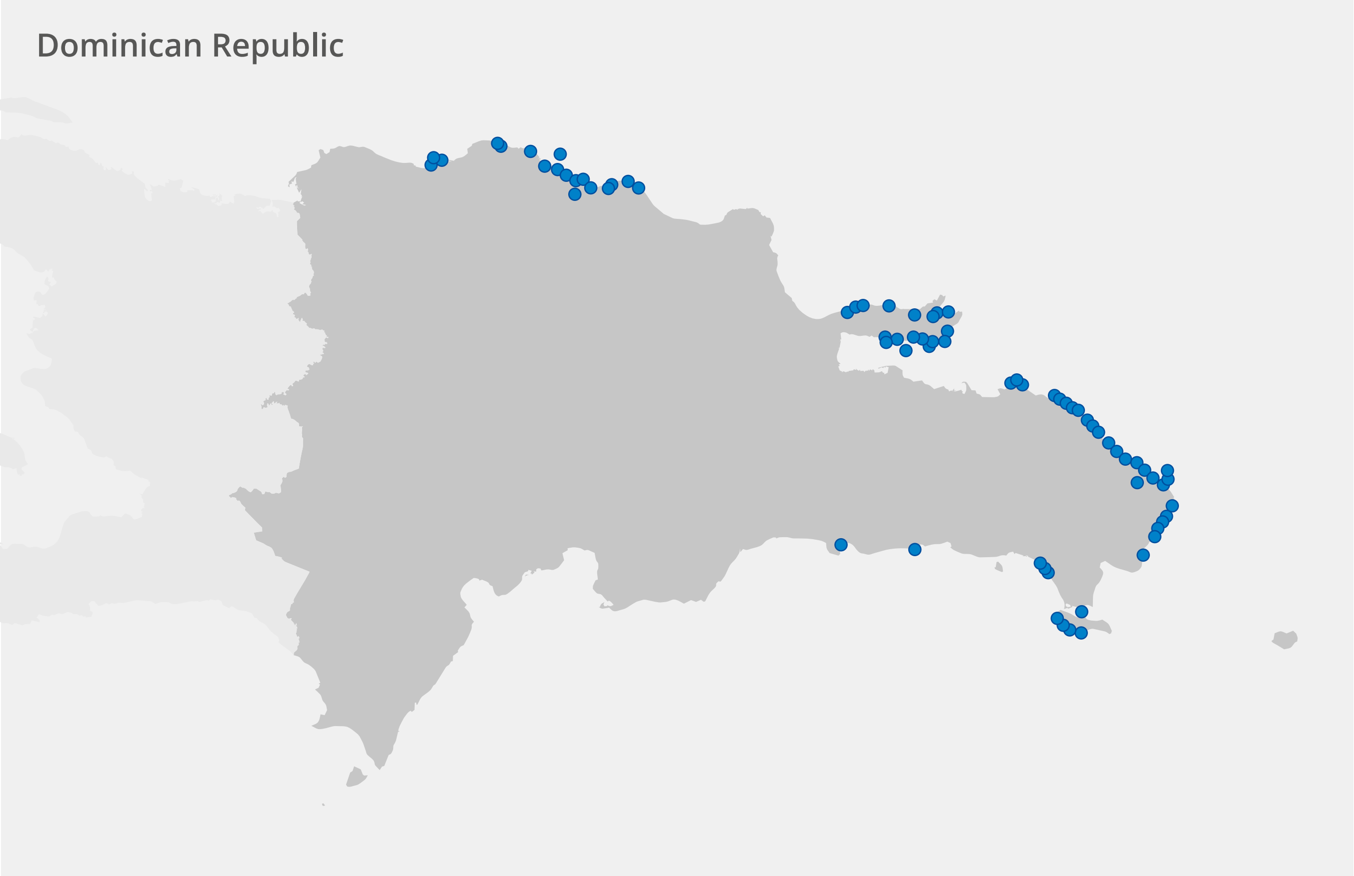
SUB-REGION IV: Eastern Caribbean (De Leon, 2012)

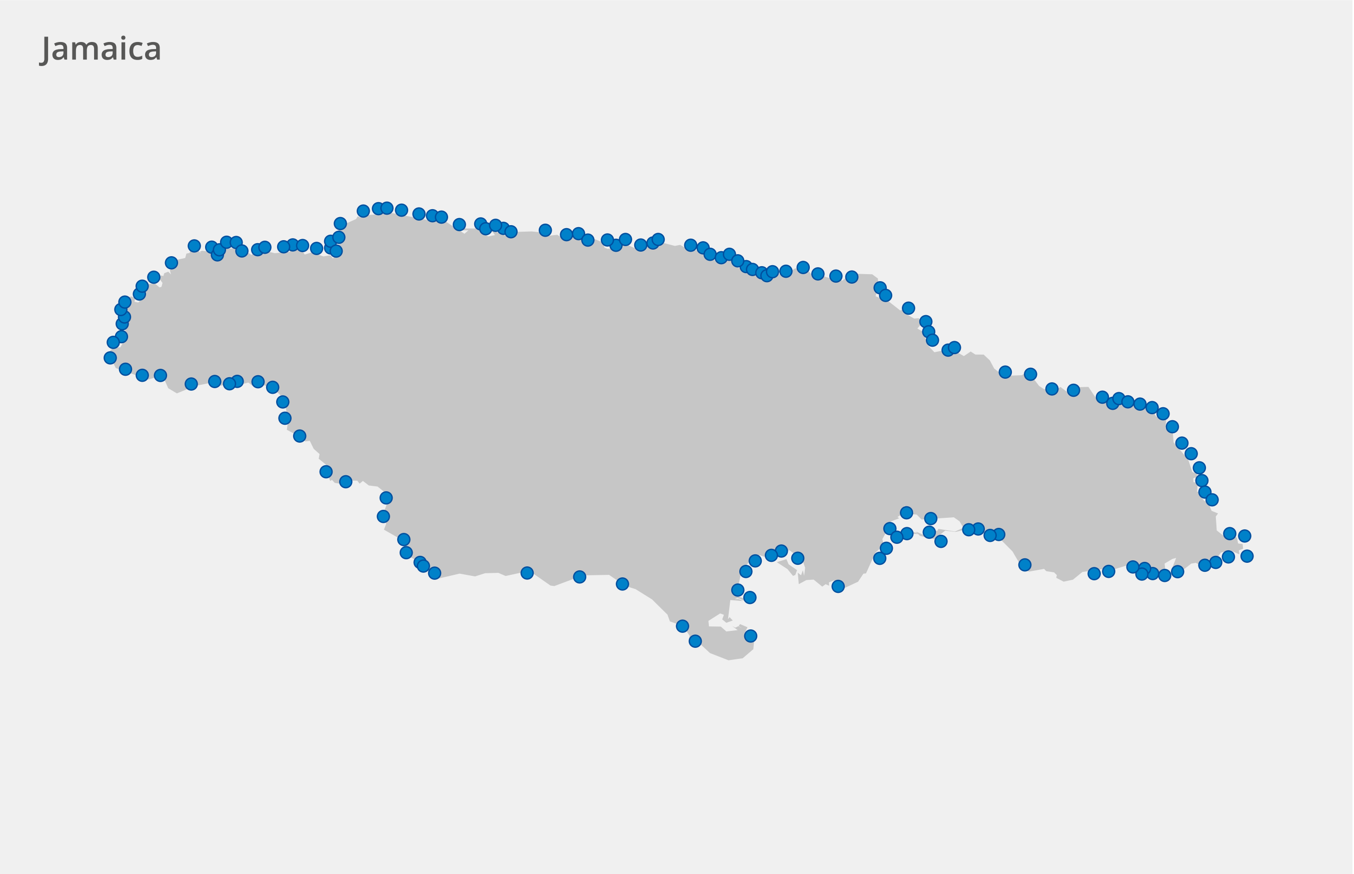






SUB-REGION V: Northeastern & Central Caribbean





Annex 4.1. Technical Notes

For this report, Talaue-McManus quantified a number of socioeconomic and biophysical indicators (see the table below) that are relevant in assessing coastal water quality in the Cartagena Convention Area. A number of these indicators, such as nutrient sources, domestic wastewater generation and discharge, as well as solid waste generation by resident and tourist populations, may be the first such estimates for the Wider Caribbean Region. Annex 4.1 details data sources, assessment methods and calculations, so these can be refined in succeeding Convention Area reporting. Hyperlinks to data sources are included.

List of socioeconomic and biophysical indicators for the SOCAR assessment
1. Population change, 1950–2050
2. Spatial coastal populations, 2010, 2015, 2020
3. Urbanization rate, 1950–2050
4. Populations by size of coastal cities and agglomerations, by WCR Sub-region, 1950–2030
5. Built-up surfaces as % of national areas, 2014
6. Human Development Indices, 2011–2015 averages
7. Tourism contribution to national GDP, national averages over the 2011–2015 period
8. Fisheries: average landed value and catch by fishing sector for the 2010–2014 period
9. Average fishing economic impact as % sub-regional or Group GDP, 2010–2014
10. Fish protein as an average % of national total animal protein supply, averaged from 2004 to 2013
11. Agriculture contribution to national GDP, national averages over the 2011–2015 period
12. Domestic (municipal) wastewater generated and discharged, Chapter 5.3
13. Agricultural Fertilizer use inventory
14. Nutrient sources and loads in the WCR using an Integrated Assessment Model IMAGE-GNM global data set
15. Solid waste generated in the WCR coastal margin, mismanaged marine plastics
16. Tourism-generated solid waste in Eastern Caribbean Currency Union (ECCU) member states

In general, and where data is available, estimates are based on at least five years of data, so that the estimates capture inter-annual variability. To coincide with the biophysical data from country data providers, averages were computed for the period 2011–2015. In the case of fisheries data, the latest 5-year period was from 2010 to 2014. Thus, the reader is cautioned from making comparisons of the 5-year averages with single-year value estimates.

In the case of municipal wastewater and solid waste, estimates were made for single years given the lack of coherent time-series data. Singe-year estimates can be highly variable. As such, these are offered as preliminary estimates with the aim of stimulating further work and refinement of both the input data and assessment methods.

For the fertilizer inventory, estimates of agricultural fertilizer use were based on 2002 data, the earliest data year for this data domain, so that these serve as coarse reference values for estimates of agricultural nutrient sources for model year 2000 generated by Beusen et al., (2016). Nutrient biogeochemical dynamics require accurate determinations of agricultural fertilizer applications. Their influence on soil nutrient budgets and the eventual conveyance of these through surface run-off and groundwater, in the case of nitrogen, may be appropriately modelled and quantified, given that agriculture is the singular major influence of anthropogenic nutrient loads on land and sea in the contemporaneous world.

Supplementary data are provided in Annex tables 4.1 to 4.4, Annex tables 5.1 to 5.3, and Annex tables 8.1 to 8.2, following Annex 4.1.

1. Population change, 1950–2050, Chapter 4.2.1

Population size at country scale for continental and island countries and island territories are tracked every five years over a century using UN population data.

Data source
UN World Urbanization Prospects (2018) at https://population.un.org/wup/

Assessment method
National population data aggregated by sub-regions of the Wider Caribbean following **Table 3.1** and summed for the entire WCR, for each year of the period 1950–2050 (**Figure 4.1**)

2. Contemporary estimates and features of coastal populations for 2010, 2015, and 2020, Chapter 4.2.2

Coastal populations, those living along the 100 km coast of continental countries, and whole populations for island states and territories, are analyzed from spatially explicit data for three time steps: 2010, 2015, and 2020. Spatial data was provided by the SEADAC, Columbia University, and processed and mapped by CATHALAC. The 2015 spatial population data is critical in implementing the domestic waste inventory in item (12).

Data source

- Center for International Earth Science Information Network—CIESIN—Columbia University, 2018. Gridded Population of the World, Version 4 (GPWv4): Population Count Adjusted to Match 2015 Revision of UN WPP Country Totals, Revision 11. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4PN93PB. Accessed 25 Jan 2018.

Assessment method

a. Spatial population data adjusted to match 2015 Revision of the UN World Population Prospects Country totals were downloaded for years 2010, 2015, and 2020 from the link above.

b. The raster files were analyzed by CATHALAC using Geographic Information System (GIS) methods to obtain population counts within 100 km from shore for continental countries. For island territories and island states, total population counts were used.

c. Resident populations residing within 100 km of the coast is considered to impact coastal waters through economic activities and the fluxes of wastewater and solid waste from the watershed to the coast.

d. Data is summarized at national, sub-regional and WCR scales for 2010, 2015, and 2020. Visuals represent sub-regional and WCR values as in **Figure 4.2** and country-scale data is summarized in **Annex 4.2**

3. Urbanization rate, 1950-2050, Chapter 4.3

The growth of the urban population with countries aggregated at sub-regional scale is tracked over a century.

Data sources: https:/population.un.org/wup/Download/

- Percentage of Population at Mid-Year Residing in Urban Areas by region, subregion and country, 1950-2050
- Annual Total Population at Mid-Year by region, subregion and country, 1950–2050 (thousands)

Assessment method

- National data on urban percentages at mid-year for the period 1950–2050, was weighted by the proportion of national total population at mid-year to sub-regional total population at mid-year, to obtain the weighted sub-regional urban percentages for the period 1950 to 2050.
- Trends by sub-region, for WCR, and World are shown in **Figure 4.3.**

4. Populations by size of coastal cities and agglomerations, by WCR Sub-region, 1950–2030, Chapter 4.3

The growth of urban agglomerations and coastal cities is examined by the size of the agglomeration, over an 80-year timespan.

Data source: https://population.un.org/wup/Download/

- WUP2018-F22_Cities_Over_300K_Annual.xls

Assessment method

a. Coastal urban agglomerations within 100 km of the coast, were identified, within countries and territories of the WCR.

b. These coastal urban agglomerations were then classified into five groups following the Urbanization Prospects 2018 Revision using 2017 as the reference year: (1) 300,000 to 500,000; (2) 500,000 to 1,000,000; (3) 1to 5 million; (4) 5 to 10 million; (5) 10 million and greater.

c. Population changes in these agglomerations were plotted from 1950 through 2030 as shown in **Figure 4.4**.

d. Using the classified urban agglomerations, CATHALAC prepared the map shown in **Figure 4.5**.

5. Built-up surfaces as a % of national areas, 2014, Chapter 4.3

Definition

“Built-up” is defined as the presence of buildings (roofed structures). This definition largely excludes other parts of urban environments and the human footprint, such as paved surfaces (roads, parking lots), commercial and industrial sites (ports, landfills, quarries, runways), and urban green spaces (parks, gardens). Consequently, such built-up areas may be quite different from other urban area data that use alternative definitions. (OECD 2018). Increases in the area of Built-up surfaces indicate natural land cover changes which alter rates of water infiltration through the substrate, and accelerate the flow of surface run-off across landscapes to the coast.

Data sources

- Built-up area, in km^2 and per cent of national land areas before 1990, 2000, and 2014 from https://stats.oecd.org/Index.aspx?DataSetCode=BUILT_UP
- National land area from http://sedac.ciesin.columbia.edu/data/set/lecz-urban-rural-population-land-area-estimates-v2/data-download

Assessment method

Data is visualized at national scale, WCR sub-region, total WCR, total continental countries, and total island nations and territories in **Figure 4.6** and **Annex 4.2**

6. Human Development Indices, 2011–2015 averages, Chapter 4.4

The Human Development Index, and the dimensions and indicators that underpin this index, provide core and quantitative basic measures of human health, educational attainment and affluence, to describe resident human populations. In the WCR, the direct influence of coastal water quality on public health and livelihoods justify why water quality assessments must include an HDI evaluation.

Data sources

- http://hdr.undp.org/en/content/human-development-index-hdi
- http://hdr.undp.org/sites/default/files/hdr2018_technical_notes.pdf

Assessment method

a. Human development dimensions, which comprise the country-scale Human Development Index were chosen to match the data coverage of water quality parameters, and to provide a 5-year average (covering the period 2011–2015) for each metric that provides a more robust estimate than indices computed on single-year values. These dimensions include life expectancy at birth in years, mean number of years of schooling, expected number of years of schooling, and gross national income.

b. Following the HDR Technical notes, the raw values for each dimension averaged over 5 years are assessed following minimum and maximum values set for each dimension so these can be transformed into indices with values between 0 and 1. The goalposts for each dimension are as follows:

$$\text{Dimension index} = \frac{\textit{5-year average of actual values -minimum value}}{\textit{maximum value -minimum value}}$$

Dimension	Indicator	Minimum	Maximum
Health	Life expectancy (years)	20	85
Education	Expected years of schooling (years)	0	18
	Mean years of schooling (years)	0	15
Standard of living	Gross national income per capita (2011 PPP $)	100	75.000

c. For the education dimension, the equation above is applied to each of the two indicators (mean years of schooling and expected years of schooling), and then the arithmetic mean of the two resulting indices is taken.

d. For income, the natural logarithm of the actual (average in this case), minimum and maximum values is used.

e. To aggregate the dimensional indices to produce the 5-year average Human Development Index, the geometric mean of the indices is computed as follows:

$$HDI = (I_{Health}\ X\ I_{Education}\ \text{X}\ I_{Income})^{1/3}$$

f. Five-year averages of dimensions, resulting indices, and the 5-year HDI for the period 2011–2015, are shown in **Annex 4.3**

7. Tourism contribution to national GDP, national averages over 2011–2015 period, Chapter 4.5.1

Data sources

https://tool.wttc.org/

Assessment method

a. Contributions of tourism to national GDP (% of GDP) of 33 sovereign states and territories in the WCR were obtained for the years 1995 to projected data up to 2025 with 2015 as base year for GDP values.

b. Data entries for the years 2011 to 2015 were averaged by country or territory and presented in **Figure 4.7**.

c. To compute the average contribution of tourism to national GDP of WCR countries at regional scale, real prices referenced to base year 2015 were averaged for the period 2011-2015 for each country.

d. The national averages for the period were summed across all countries to get the amount that tourism contributed to the region, and which is valued at $1,685 billion in 2015 US prices. Using simple averaging of per cent national contributions, tourism contributed 25% to the region.

e. Note that the individual per cent contribution of tourism to the GDP of each country is reckoned from each national GDP. The average per cent contribution then shows the value that tourism added to the national GDP of a numerically average country in the WCR.

f. Another way of computing regional contribution is by adding the Tourism GDPs across all WCR countries and territories and dividing the SUM by the aggregate of national GDPs. This percentage yields a different value from that obtained in Step (e) above. Since GDP is meaningful at national scale, the preferred computation is as described in Step (e).

g. When simple averaging of per cent contributions was done among islands only, estimate rose to 33% of GDP.

h. With simple averaging of per cent contributions were done for continental countries only, the value added by tourism to this group's aggregate GDP became half that for islands at 12%.

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8. Fisheries: average landed value and catch by fishing sector for the period 2010 to 2014, Chapter 4.5.1

Data sources:

http://www.seaaroundus.org/data/#/lme

Assessment method

a. Fisheries data for a five-year coverage (2010–2014) for four large marine ecosystems (LMEs) that comprise Wider Caribbean Regional waters (Gulf of Mexico LME, Southeast US Shelf LME, Caribbean Sea LME, North Brazil LME) was downloaded from the Sea Around Us website using reconstructed FAO fisheries data.

b. The Pivot table function in Excel was used to summarize fisheries catch data by tonnage and landed value (constant 2010 US$) of catch by fishery sector (artisanal, industrial, recreational, subsistence) in each fishing country, for each of the five years, in each LME.

c. The annual sums by fishery sector are averaged over the 5-year period for each fishing country in each LME.

d. The 5-year averages of catch and landed value by fishery sector are summed across the four LMEs for each fishing country in the WCR.

e. The WCR sub-regional totals for each fishery sector across all countries and territories in each subregion, as average percentages of total landed value across all fishing sectors, are presented in **Figure 4.8A.**

f. 6. A detailed summary of derived fisheries data by country and sub-region is provided in **Annex 4.4.**

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9. Average fishing economic impact as % sub-regional or Group GDP, 2010–2014, Chapter 4.5.1

Data sources

- https://www.researchgate.net/publication/227347673_Economic_Impact_of_Ocean_Fish_Populations_in_the_Global_Fishery

Assessment method

a. Dyck and Sumaila (2010) provide national fishing total economic impact multipliers and fisheries derived household income multipliers obtained from economic input-output modelling.

b. For each country, the total economic impact of fishing is obtained as follows:

Total economic impact of fishing = Total Landed value X economic impact multiplier

c. The economic impact is expressed in constant 2010 US$ and as % of national GDP (constant 2010 US$) obtained from the World Bank, for each country or territory, **Figure 4.8B.**

d. To disaggregate the impact of fishing on household income for each country, the income multipliers are used as follows:

Fishing impact on household income = Total landed value X Income multiplier

e. Economic impact and household income by country are shown in **Annex 4.4**.

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10. Fish protein as average % of national total animal protein supply, averaged from 2004 to 2013, Chapter 4.5.1.

Data sources:

- http://www.fao.org/faostat/en/#data/FBS

Assessment method

a. Food balance-sheet data on protein supply (g/capita/day) derived from animal products and, in particular, from marine fisheries products, was obtained from FAO, for a 10 year period from 2004–2013. The ratio of fish protein supply per capita per year and total animal protein supply is estimated

b. Fish protein dependence is the ratio of fish protein supply to total animal protein supply, both in grams/capita/day, and is averaged over a 10-year period, for each country.

c. **Figure 4.8C** shows the average fish protein dependence among countries with data in each of the five WCR Subregions, as well as the WCR average, and the averages for continental countries, and for island states and territories.

d. Fish protein dependency data is summarized in **Annex 4.4.**

e. Livestock production can become a significant source of liquid and solid waste as well as greenhouse gases. Thus, SOCAR, in future can include the domestic production of livestock, and its contribution to meat consumption in its assessment to establish protein security as well as its contribution to nutrient loading.

11. Agriculture contribution to national GDP, national averages over 2011–2015 period, Chapter 4.5.2

Data sources

- GDP contribution by agriculture in % of GDP https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS
- GDP contribution by agriculture in 2010 constant prices https://data.worldbank.org/indicator/NV.AGR.TOTL.KD
- GDP contribution by tourism in 2015 prices https://tool.wttc.org/

Assessment method

a. Data on value added by agriculture to national GDP was obtained from the World Bank, both as percentages, and in 2010 prices.

b. To rescale to 2015 base year, national GDP values in 2015 prices were computed from 2015 tourism GDP values and the percentages these contributed to the national GDPs, using the World Tourism and Travel Council database.

c. Agriculture GDP in 2015 prices were derived by multiplying the % contribution of agriculture to national GDPs in 2015 prices and the national GDP values in 2015 prices from Step (b) above.

d. A five-year average for the period 2011 to 2015 is computed for each of the WCR countries, as shown in **Figure 4.7**. Simple averages of national per cent contributions are likewise computed and shown for the WCR region, continental countries, and for islands and territories. As noted in the method for Tourism GDPs, the average impact of tourism at national scale is highlighted by the simple averaging of nationally derived per cent contributions.

e. Contributions of agriculture and tourism sectors are shown in **Figure 4.7** for side-by-side comparisons.

12. Domestic (municipal) wastewater generated and discharged, Chapter 5.3

These metrics are assessed to provide preliminary estimates of the quantity and nutrient composition of municipal wastewater that influences the State of the Convention Area. The quality of the data to support these assessments is highly variable. Steps were taken to make the assembled data set amenable to comparisons by scaling all per capita rates to 2015 coastal population sizes. The average ratio of produced municipal wastewater to municipal water withdrawal obtained from countries with existing data, was used to fill the data gaps. The scaling and data filling techniques preserve the underlying numerical relationships among the baseline data. Per capita rates and ratios change as populations increase, and are modified when new treatment technology is acquired or when more rigorous measurements and sewage monitoring are implemented. The assembled data set here is meant to be updated, and the assessment approach to be replaced with better estimation techniques when higher quality data becomes available.

A comparison of the amounts of loaded nutrients from sewage estimated by this author using this data set and that calculated from Beusen et al., 2016, shows a remarkable consistency, considering the 15-year difference in model years, the independent and disparate data sources, and the differences in calculations. These values of loaded nutrients and the corresponding volumes of media (basin discharge and untreated wastewater) through which these were delivered to coastal waters are first estimates for the WCR.

Source data, model year	Data or Model Year	Tg Sewage N	Tg Sewage P	Associated water flux
This study using domestic wastewater inventory for year 2015, with data coverage for 83% of coastal population	2015	0.61	0.10	10 billion m^3 of untreated sewage
This study using Beusen et al., 2016 modelled data for year 2000 from 429 drainage basins	2000	0.51	0.07	3,434 billion m^3 of river basin discharge

Definitions (FAO Aquastat)

- ***Municipal water withdrawal***: Annual quantity of water withdrawn primarily for direct use by the population. It can include water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. It is usually computed as the total water withdrawn by the public distribution network. It can include components of industries and urban agriculture that are connected to the municipal network. The ratio between the net consumption and the water withdrawn can vary from 5 to 15% in urban areas and from 10 to 50% in rural areas.
- ***Produced municipal wastewater:*** Annual volume of domestic, commercial, and industrial effluents, and storm water run-off, generated within urban areas.
- ***Treated municipal wastewater***: Treated wastewater (primary, secondary and tertiary) annually produced by municipal wastewater treatment facilities in the country.
- ***Unit of volume:*** 10^9 m^3 yr^{-1}, equivalent to 1 km^3 yr^{-1}
- ***Primary sewage treatment:*** Also referred to as "Less than secondary treatment," primary treatment removes solids by filtration, sedimentation, and chemical coagulation (US EPA, 2007). Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (TSS), and 65% of the oil and grease are removed during primary treatment (FAO, http://www.fao.org/3/t0551e/t0551e05.htm).
- ***Secondary sewage treatment:*** Removal of up to 90% of the organic matter in wastewater by using biological treatment processes, such microbial films attached to stone or plastic media, or microbial growth suspended in aerated water mixture. (US EPA, 2004). High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85% of the BOD_5 and suspended solids, and some of the heavy metals, originally present in the raw wastewater (FAO, http://www.fao.org/3/t0551e/t0551e05.htm). In the US, "nearly all wastewater treatment plants provide a MINIMUM of secondary treatment. In some receiving waters, the discharge of secondary treatment effluent would still degrade water quality and inhibit aquatic life. Further treatment is needed" (US EPA, 2004).
- ***Tertiary (advanced) treatment:*** Removal of dissolved nutrients, very fine suspended solids, refractory organics, heavy metals and toxins. Nitrifying bacteria can biologically convert ammonia to non-toxic nitrate through nitrification. Because nitrate is a nutrient, and thus needs to be controlled, nitrate can be removed by bacteria through the process of denitrification, which releases nitrogen gas, in an oxygen-free environment. Phosphorus can be removed through chemical addition and a coagulation-sedimentation process, which forms a chemical sludge that is costly to dispose. Carbon adsorption technology can be used to removed organic materials that cannot be degraded through biological treatment (US EPA, 2004).

Data sources

- Municipal water withdrawal, produced municipal wastewater, and treated wastewater
- http://www.fao.org/nr/water/aquastat/data/query/results.html
- national population, UN World Urbanization Prospects (2018) at https://population.un.org/wup/
- coastal population (2015), Item 2, Annex 4.1
- national and CEP reports on population (numbers or per cent) connected to sewage treatment plants, http://www.cep.unep.org/publications-and-resources/technical-reports/technical-reports

Assessment method

a. The latest available data on municipal water withdrawals, produced municipal wastewater and treated wastewater were obtained from FAO Aquastat database. Reference years for each variable were noted. The national population for the latest year of each parameter is obtained.

b. Per capita values for each parameter (municipal water withdrawal, produced wastewater) in indicative year are computed by dividing volume by national population. Results are in m^3 $person^{-1}$ yr^{-1}.

c. Using per capita rates, the volumes at indicative years are rescaled to that of the coastal population for year 2015, by multiplying per capita rates with 2015 coastal population. Continental countries have coastal populations living within a 100 km coastal zone. For islands, the total population is the coastal population. The results are divided by 10^9 so the expression is in 10^9 m^3 for year 2015 applied to the coastal population. Coastal populations in 2015 are in **Column 2, Annex 5.1A.** Using national populations for continental countries will give inflated and wrong estimates, since the non-Caribbean facing coastlines of these countries do not influence waters of the WCR.

d. The rescaled municipal wastewater production and municipal water withdrawal rates to a common year (2015) makes for a more consistent time-based derived dataset, amenable to further analysis. Note that rescaling means the numerical relationship for the indicative year is preserved for year 2015. The rescaling should be updated by the most recent available data on population and municipal water withdrawal rates. Values shown in **Column 3, Annex 5.1** are municipal water withdrawals for year 2015.

e. Produced municipal wastewater is another critical input data needed to estimate the potential volume of municipal wastewater for treatment or potentially discharged to the environment. The ratio of produced municipal wastewater to water withdrawals can be used to fill data gaps on generated wastewater. Available data to compute this ratio came from 12 countries as below. Calculated empirical ratios averaged 69% (**Column 4, Annex 5.1**). Since the 12 countries make up 83% of WCR population, the average ratio is deemed robust for data filling.

Mexico, USA, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, Colombia, Venezuela, Grenada, Cuba, and Dominican Republic

f. The average ratio was multiplied by municipal water withdrawal to estimate the missing data on produced municipal wastewater. Results are shown on **Column 5, Annex 5.1A**. At the scale of the WCR, it is estimated that 15 billion m^3 municipal wastewater was generated.

g. AquaStat has a scanty assembly of data on volumes of treated wastewater, some of which have not been updated since 1994. As such, an alternate method to estimate the volume of treated wastewater, is to multiply the produced municipal wastewater by the proportion of population connected to sewage treatment plants. "Treatment" in this context is all inclusive: from just collection, with no treatment, to primary, secondary, and advanced (tertiary, post-secondary) treatment.

A literature search for this metric was done using a wide range of data sources including scientific journal articles, technical studies, newspaper and web-based materials (**Annex 5.1B reference list**). Values are shown in **Column 6, Annex 5.1A**.

h. Knowing the extent of sewer service coverage serves a second and equally important purpose. When produced wastewater is multiplied by (1-% population sewer network coverage), an estimate of untreated or uncollected sewage is obtained, and constitutes the presumptive discharge volume to waterways and coastal waters. These values are shown in **Column 7, Annex 5.1A**.

i. Columns 8 and 9 show the total nitrogen and total phosphorus content of municipal wastewater, and which were calculated following an estimated nutrient composition of 60 g sewage-sourced TN m-3 wastewater and 10 g sewage-derived TP m-3 wastewater (CEP TR85, 2015).

j. Main results are summarized in **Table 5.1**, and calculations shown in **Annex 5.1A** and associated country references in **Annex 5.1B**.

13. Agricultural Fertilizer use inventory, Chapter 5.4.2

Agriculture is the single most critical source of coastal nutrient loads. The fertilizer input inventory is meant to provide a coarse theoretical upper limit for the contribution of agriculture to nutrient loads discharged at river mouths, and which are also estimated for this report using Beusen et al. 2016 global data set (see Item 14 of this annex). Country-scale fertilizer inputs expressed as Total Nitrogen and Total Phosphorus are available at FAOSTAT Fertilizers by Nutrient domain. The critical determinant in using this data set to relate nutrient fluxes to the coast by using a hydrology-relevant scaling factor, which is the **proportion of arable land within Caribbean Sea-draining watersheds to the national cropland area.** Future reporting should include this analysis to constrain estimates by using more appropriate scaling factors.

Assessment	Results
Item 13. Agricultural fertilizer (this study)	● **6.4 Tg total nitrogen** for year 2002 ● **2.3 Tg total phosphorus** for year 2002 ● Scaling factors for continental countries related to agricultural land area (arable land) within WCR-draining watersheds, are most appropriate to use, and will modify these highly preliminary values.
Item 14. Agricultural sources of coastal nutrient loads () using global data set generated by the Integrated Assessment Model results of Beusen et al. (2016)	● **3.278 Tg TN = 60% of total N load to the coast for model year 2000** = 2.195 Tg TN (agriculture-impacted groundwater) + 1.083 Tg agricultural surface run-off ● **0.34 Tg TP = 56% of Total TP load to the coast for model year 2000** = from agricultural surface run-off

Data sources

- area of watersheds draining to the WCR coastal water from Burke and Maidens (2004) at https://databasin.org/maps/new - datasets=b4467d4d168b4876bb2eee4ee6061a80
- Fertilizer use by Nutrient at FAOSTAT at http://www.fao.org/faostat/en/ - data/RFN/metadata
- Country and island areas from https://www.citypopulation.de/America.html

Assessment method

a. The watersheds shapefile was analyzed and watershed areas draining to the WCR coastal waters were summed by country or island territory.

b. The proportion of drainage areas (i.e. draining to the Caribbean Sea/ Gulf of Mexico) to national areas were computed to scale national fertilizer use data in the absence of data on proportion of cropland area within WCR-draining watersheds, and which is the correct scaling factor to use. In the case of island countries, the current scaling factor suffices in that the assumption that all cropland falls within watershed areas, with an 11% potential error, given that island watershed area, on average, is 89% of island area.

c. The fertilizer use in croplands in WCR-draining watersheds is:

$$Fertilizer\ use_{WCR\ draining\ cropland\ area} = Fertilizer\ use_{national\ cropland\ area\ area}\ X\ \frac{cropland\ area_{WCR\ draining\ watershed}}{cropland\ area_{national}}$$

d. In the absence of data on cropland area within watersheds, the scaling factor using proportion of Caribbean Sea-draining watershed area to island area is a good approximation. For continental countries, the scaling factor is not ideal because it does not contain any information on arable land within watershed area. Thus, these estimates may change dramatically when the proportion of arable area with watersheds is determined for each continental country.

e. Future analysis should include analysis of land use data within hydrological units that are hydrologically connected with the WCR receiving basins, using GIS, to resolve the most appropriate scaling factors for analysis of country-scale data accessible from globally curated datasets such as those in FAOSTAT. Data on agricultural land for USA watersheds including those hydrologically connected to the Gulf of Mexico is available at: https://www.nass.usda.gov/Publications/AgCensus/2007/Online_Highlights/Watersheds/wtrsheds.pdf

f. Results are visualized in **Figures 5.1, A to C.**

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14. Nutrient sources and loads in the WCR using a Global Integrated Assessment Model IMAGE-GNM, Section 5.4.3

Key Results (this study from global data of Beusen et al. 2016)

Results	Total Nitrogen (model year 2000)	Total Phosphorus (model year 2000)
All Nutrient Sources in WCR basins (Total)	5.47 Tg	0.61 Tg
Nutrients from agricultural groundwater in WCR basins (Total)	2.19 Tg	P is adsorbed
Nutrients from agricultural surface run-off in WCR basins (Total)	1.08 Tg	0.34 Tg
Nutrients from wastewater (sewage) in WCR basins (Total)	0.51 Tg	0.07 Tg
Nutrient loads at river basin mouth to WCR coastal waters (Total)	2.48 Tg	0.24 Tg

The analysis of the global data sets on nutrient sources and nutrient loads provided the WCR region much needed estimates that were generated using an integrated assessment model. The results provide robust estimates at drainage basin scale, on which nutrient management policies at regional and national scales can be anchored.

Model description

- Beusen et al. 2015. Coupling global models for hydrology and nutrient loading to simulate nitrogen and phosphorus retention in surface water – description of IMAGE-GNM and analysis of performance. Geoscientific Model Development, Geosci.Model Dev., 8, 4045-4067 https://www.geosci-model-dev.net/8/4045/2015/
- Beusen et al. 2016. Global riverine N and P transport to ocean increased during the 20th century despite increased retention along the aquatic continuum. Biogeosciences, 13, 2441-2451 at https://www.biogeosciences.net/13/2441/2016/bg-13-2441-2016.pdf

Data sources

- Supplement to the journal article by Beusen et al. (2016) https://www.biogeosciences.net/13/2441/2016/bg-13-2441-2016-discussion.html
- Data files (data structure explained in associated Read_me files):
  - N and P sources, model year 2000 only (data available for every 5th year for the period 1900-2000)
  - Discharge, 1900-2000
  - Nutrient Loads, 1900-2000

Assessment method

a. Global data files as listed above were read by creating a Python script (courtesy of L.C. McManus, Rutgers University) to generate output csv tables. Using the basin long-lat IDs to tag each individual basin by country, data on 429 watersheds of the WCR were extracted from the global data sets. Extracted data tables included the following:

Global Data files	Extracted WCR data: Nitrogen	Extracted WCR data: Phosphorus
Files by nutrient source (data analyzed for this report was model year 2000; available data every 5th year for period 1900-2000)	Sources of Nitrogen (kg^3 N yr^{-1}): ● Surface run-off (agricultural) ● Surface run-off (natural) ● Groundwater (agricultural) ● Groundwater (natural) ● Allochthonous organic matter input from wetlands and floodplains to rivers ● Aquaculture ● Direct deposition on surface water ● Wastewater discharge	Sources of Phosphorus (kg^3 P yr^{-1}): ● Surface run-off (agricultural) ● Surface run-off (natural) ● Weathering ● Allochthonous organic matter input to rivers ● Aquaculture ● Wastewater discharge ***Subsurface transport of P is neglected because of P adsorption by soil minerals (Beusen et al. 2015). As such transport via agricultural and natural groundwater is not parameterized by the model.
Annual river discharge, 1900-2000	One data file on annual river discharge at mouth,	
Annual Loads at river mouth by nutrient, 1900-2000	Annual Net Nitrogen loads at river mouth in WCR, 1900 – 2000 (i.e. exclusive of retained fraction)	Annual Net Phosphorus loads at river mouth in WCR, 1900-2000 (i.e. exclusive of retained fraction)
Annual Fraction retained at river mouth, 1900-2000	Annual fraction of Nitrogen load retained at river mouth in WCR, 1900-2000	Annual fraction of Phosphorus load retained at river mouth in WCR, 1900-2000

b. Seventeen (17) data files were analyzed for this dataset. For each time step, each parameter value is summed by country, and by WCR Sub-region, as well as by totals for the WCR region, for continental countries combined, and for islands combined.

c. Sources of Nitrogen are shown in **Table 5.2, Figure 5.2, and Figure 5.3.**
d. Sources of Phosphorus are shown in **Table 5.3, Figure 5.4, and Figure 5.5.**
e. Data on Basin coverage, basin discharge, total N and P load for model year 2000, were compared between those derived from Beusen et al. (2016) (this study) and from Mayorga (this study), **Table 5.4**.
f. Annual N and P loads from 1900 to 2000, are shown in **Figure 5.6.**
g. Sub-regional totals of N and P sources are provided in **Annexes 5.2 and 5.3.**

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15. Solid waste in the WCR, Section 8.2

Solid waste has become a major sustainability issue specially in space-limited islands of the WCR, and among coastal areas where mismanaged waste become marine debris. The assessment method used published data on municipal per capita solid waste generation rates (Kawai and Tasaki, 2016; Jambeck et al., 2015), and calibrated by spatial population data for 2015, disaggregating rural and urban populations.

About **79 million tonnes of solid waste** were generated in 2015 in the WCR, of which 10 million tonnes were plastics. Anywhere from 2 to 50% of solid waste was mismanaged, causing around **1.3 million tonnes** of plastics to be littered in coastal waters (Figure 8.2, Annex 8.1).

Definitions

- Municipal or urban solid waste: Solid or semi-solid waste produced through the general activities of a population centre and includes waste from households, commercial businesses, services and institutions as well as common (non-hazardous) hospital waste, waste from industrial offices, waste collected through street sweeping, and the trimmings of plants and trees along streets and in plazas and public green spaces (Espinoza et al. 2011)
- Household solid waste: Solid or semi-solid waste originating exclusively from residences and generated by household human activity (Espinoza et al. 2011)
- Rural solid waste: Solid waste generated by the rural population, assuming that rural waste per capita generation is 75% that of municipal rates (this study)

Data sources

- WCR coastal population, 2015 (this study, Annex 4.1 [Item 2], Annex 4.2)
- Urban and rural populations (UN Urbanization Prospects, 2018), https://population.un.org/wup/Download/
- Per capita waste generation used for urban waste estimates, Kawai and Tasaki (2016) at https://core.ac.uk/download/pdf/81531242.pdf;
- https://publications.iadb.org/en/regional-evaluation-urban-solid-waste-management-latin-america-and-caribbean-2010-report; references for PRI, USVI, Cayman, Bonaire, Anguilla, St. Martin (to be added)
- % Plastic in generated waste, Jambeck et al. (2015) https://jambeck.engr.uga.edu/landplasticinput
- % Mismanaged waste, Jambeck et al. (2015) https://jambeck.engr.uga.edu/landplasticinput

Assessment method

a. To estimate urban waste in tonnes yr^{-1}, 2015

$$\text{Urban waste} = \text{Coastal Population X \% Urban X daily urban resident waste generation}$$

To estimate rural waste in tonnes yr^{-1}, 2015, 75% municipal waste generation was based on a range of 0.63 kg p^{-1} d^{-1} to 1.05 kg p^{-1} d^{-1} for rural Mexico (or a midpoint of 0.8 kg p^{-1} d^{-1}) (Taboada-Gonzalez, 2010) and scaled to the average municipal rate in Latin America and Caribbean of 0.93 kg p^{-1} d^{-1} (2010 Regional Evaluation Report).

$$\text{Rural waste} = \text{Coastal Population X} \\ \text{(1-\% Urban)X 0.75 X (daily urban resident waste generation)}$$

b. To estimate total coastal country waste in tonnes yr^{-1}, 2015

$$\text{Total coastal country waste}=\text{Urban waste}+\text{Rural waste}$$

c. To estimate Plastics waste generated in tonnes, 2015

$$\text{Plastics waste}=\text{\% plastic in waste stream X Total coastal country waste}$$

d. To estimate Plastics waste disposed in ocean in tonnes, 2015

$$\text{Marine Plastics}=\text{\% Mismanaged plastics waste X Plastics waste}$$

e. Results at sub-regional and WCR scales are shown in **Figure 8.2** and country-scale data are provided in **Annex 8.1**.

16. Tourism-generated solid waste in Eastern Caribbean Currency Union (ECCU) member states

The issue of solid waste mismanagement is growing increasingly acute among small islands of the WCR. The idea of using solid waste indicators as basis for planning tourism expansion is not new. Georges (2004) showed two unsustainable trends for British Virgin Islands (BVI) using solid waste indicators - increasing waste per unit of economic output via tourism; and tourist transient population exceeding the capacity of the island to manage solid waste.

The simple assessment methods discussed here show that tourists in the ECCU countries contributed almost 50,000 tonnes of waste to 663,000 tonnes generated by ECCU residents, or 7%. It is highly recommended that waste flows be integrated in planning the growth of the tourism sector, to ensure that environmental impacts are minimized and public health within the islands are protected for residents and visitors alike.

Data sources

- Tourism statistics from Eastern Caribbean Currency Union (ECCU) Statistics Office at https://www.eccb-centralbank.org/p/tourism-statistics). Member countries of the ECCU include Anguilla, Antigua and Barbuda, Dominica, Grenada, Monserrat, Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines. Data year: 2015
- Municipal solid waste per capita generation rates for ECCU residents and tourist originating countries from Jambeck et al. (2015) at https://jambeck.engr.uga.edu/landplasticinput
- Assumptions (references in **Annex 8.2**):
    - Average length of stay for stay-over visitors = 8 days
    - Cruise ship passengers = 0.5 days
    - Chartered boats = 90 days
    - Excursionists = 1 day

Assessment method

a. Solid waste generated by stay-over tourists, staying 8 days per visit, in tonnes yr^{-1}, 2015:

$$\text{Solid waste generated by stayover tourists by originating country} \\ = \text{Annual no stayover tourists X per capita generation rate X 8 days}$$

Sum across all originating countries to get total solid waste generated by stayover tourists.

b. Solid waste generated by excursionists, staying for 1 day, generating 1.75 kg solid waste p-1 d-1, 2015

$$\text{Solid waste}_{\text{excursionists}}=\text{Annual no excursionists X 1.75}$$

c. Solid waste generated by cruise ship passengers, stay 0.5 day, generating 3.5 kg solid waste p-1 d-1, 2015

$$\text{Solid waste}_{\text{cruise ship}} = \text{Annual no cruise ship passengers X 0.5 day X 3.5}$$

d. Solid waste generated by charter boat passengers, stay for 90 days onboard, 1.75 kg solid waste p^{-1} d^{-1}, 2015

$$\text{Solid waste}_{\text{charter boat}} = \text{Annual no yachters X 90 X 1.75}$$

e. Sum solid waste generated across all tourist types to get Total solid waste from tourists, 2015.

f. Total solid waste from ECCU residents, 2015, from **Annex 8.1**.

g. Results are shown in **Annex 8.2**.

Annex 4.2. Demographic features of continental countries, island states, and territories of the Wider Caribbean Region, and their built-up areas. Coastal populations are residents within the 100-km coast of continental countries (this study; see Annex 4.1 for data sources and technical notes).

Country/Territory	Coastal population			% Urbanization			Density per km²		Caribbean Coastal Area, krn²	National Area, km²	Bult up area, % national land area		
	2010	2015	2020	2010	2015	2020	2015	2020			1990	2000	2014
Mexico	16,632,867	17,486,689	17,903,536	52%	53%	53%	70	71	251,423	1,933,842	0.46%	0.56%	0.67%
United States	31,655,204	33,713,411	36,092,066	82%	82%	82%	79	85	425,512	9,351,599	1.22%	1.41%	1.63%
Sub-region 1 Gulf of Mexico	48,288,071	51,200,100	53,995,602	72%	72%	72%	76	80	676,935	11,285,441	1.09%	1.27%	1.47%
Belize	312,928	355,922	392,985	45%	45%	46%	16	18	21,804	21,804	0.06%	0.10%	0.11%
Costa Rica	3,136,334	3,255,766	3,379,746	72%	77%	81%	132	137	24,692	50,532	0.92%	1.04%	1.19%
Guatemala	436,449	479,819	527,499	48%	50%	52%	28	31	16,941	107,701	0.74%	0.85%	0.99%
Honduras	3,502,178	3,749,099	4,085,328	52%	55%	58%	65	71	57,733	108,151	0.29%	0.42%	0.52%
Nicaragua	472,193	624,350	741,529	57%	58%	59%	13	16	47,032	118,577	0.15%	0.19%	0.25%
Panama	3,207,133	3,675,524	3,971,857	65%	67%	68%	60	65	61,009	74,606	0.23%	0.32%	0.39%
Sub-region II Western Caribbean	11,067,214	12,140,480	13,098,944	61%	64%	67%	53	57	229,210	481,370	0.40%	0.49%	0.59%
Aruba	101,485	103,889	105,397	43%	43%	44%	550	558	189	189	19.65%	21.09%	21.68%
Bonaire	15,518	18,398	19,501	75%	75%	75%	64	68	288	288	0.00%	0.00%	0.00%
Curacao	143,784	157,203	163,757	90%	89%	89%	354	369	444	444	0.00%	0.00%	0.00%
Colombia	8>329,481	9,338,870	9,850,385	72%	74%	74%	98	103	95,242	1,126,730	0.16%	0.19%	0.23%
French Guyana	214,788	223,018	246,304	83%	84%	86%	7	7	33,544	82,947	0.04%	0.04%	0.04%
Guiana	622,835	710,323	724,490	27%	26%	27%	15	15	48,016	207,970	0.07%	0.09%	0.09%
Suriname	497,062	504,179	526,408	66%	66%	66%	14	15	36,114	140,669	0.07%	0.08%	0.09%
Venezuela, BR	21,118,308	23,043,369	26,910,855	93%	93%	93%	116	136	198,420	902,627	0.26%	0.30%	0.33%
Sub-region III Southern Caribbean	31,043,260	34,099,249	38,547,097	85%	86%	86%	83	94	412,256	2,461,864	0.18%	0.21%	0.24%
Anguilla	13,769	14,611	15,283	100%	100%	100%	176	184	83	83	1.52%	1.62%	1.72%
Antigua and Barbuda	94,661	99,923	96,413	26%	25%	24%	230	222	434	434	2.13%	2.33%	2.59%
Barbados	279,569	284,217	287,646	32%	31%	31%	653	661	435	435	11.43%	13.62%	16.79%
British Virgin Islands	27,224	30,113	32,634	45%	47%	49%	191	207	158	158	4.53%	6.66%	9.65%
Dominica	71,440	73,162	75,052	68%	70%	71%	97	99	755	755	0.54%	0.64%	0.69%
Grenada	104,677	106,823	109,387	36%	36%	37%	331	339	323	323	3.72%	4.10%	4.27%
Guadeloupe	450,718	450,418	448,427	98%	98%	99%	261	260	1,723	1,723	3.54%	4.19%	4.57%
Martinique	394,910	385,842	385,457	89%	89%	89%	344	344	1,121	1,121	3.02%	3.67%	3.89%
Montserrat	4,944	5,124	5,373	9%	9%	9%	51	53	101	101	0.86%	1.64%	1.87%
Sint Maarten {Dutch part)	34,056	38,824	41,364	100%	100%	100%	1049	1118	37	37	0.00%	0.00%	0.00%
Saint Kitts and Nevis	51,445	54,288	56,813	31%	31%	31%	203	213	267	267	2.73%	3.44%	4.36%
Saint Lucia	172,580	177,206	191,765	18%	19%	19%	288	312	615	615	1.67%	2.12%	2.26%
Saint Martin {French part)	30,235	31,754	32,556				365	374	87	87	0.00%	0.00%	0.00%
Saint Vincent and the Grenadines	109,315	109,455	110,741	49%	51%	53%	252	255	434	434	3.77%	4.67%	5.29%
Trinidad and Tobago	1,328,100	1,360,092	1,377,746	54%	53%	53%	263	267	5,166	5,166	3.43%	3.71%	3.93%
Virgin Islands (U.S.)	108,358	107,710	100,156	95%	95%	96%	295	274	365	365	9.20%	11.59%	13.80%
Sub-region IV Eastern Caribbean	3,276,001	3,329,562	3,366,813	61%	60%	60%	275	278	12,104	12,104	3.50%	4.06%	4.51%
The Bahamas	360,832	386,838	409,628	82%	83%	83%	31	32	12,671	12,671	0.69%	0.77%	0.83%
Cayman Islands	55,507	59,963	63,890	100%	100%	100%	265	283	226	226	3.26%	3.95%	4.36%
Cuba	11,204,351	11,282,863	11,171,362	77%	77%	77%	103	102	110,013	110,013	0.66%	0.72%	0.78%
Dominican Republic	10,225,482	10,507,413	10,863,392	74%	79%	83%	219	227	47,874	47,874	1.17%	1.46%	1.70%
Haiti	10,188,175	10,584,527	11,241,738	48%	52%	57%	405	430	26,163	26,163	1.32%	1.60%	2.03%
Jamaica	2,817,210	2,871,934	2,840,110	54%	55%	56%	261	258	11,016	11,016	3.03%	3.78%	4.80%
Puerto Rico	3,721,525	3,473,177	3,650,608	94%	94%	94%	387	407	8,971	8,971	9.11%	10.75%	12.29%
Turks and Caicos Islands	30,994	34,339	55,926	90%	92%	94%	35	57	983	983	0.45%	0.70%	0.76%
Sub-region V Northern and Central Caribbean	38,604,076	39,201,054	40,296,654	68%	71%	73%	180	185	217,917	217,917	1.32%	1.56%	1.82%
Wider Caribbean Region	132,278,623	139,970,445	149,305,110	73%	74%	75%	90	96	1,548,423	14,458,696	0.92%	1.07%	1.24%
Continental countries	90,137,759	97,160,339	105,352,988	75%	76%	77%	74	80	1,317,481	14,227,754	0.91%	1.06%	1.23%
Island nations and territories	42,140,864	42,810,106	43,952,122	68%	70%	72%	185	190	230,942	230,942	1.45%	1.70%	1.97%

Annex 4.3. Human Development Index and associated metrics for countries in the Wider Caribbean Region, averaged over the period 2011–2015 (this study; see Annex 4.1 for input data sources and technical notes).

HDI Rank (2015)	Country	Sub-region	Average longevity at birth 2011-2015	Average expected years at school 2011-2015	Average of mean years at school 2011-2015	Gross National Income per capita 2011-2015 (2011 PPP$)	Average Health Index, 2011-2015	Average Education Index, 2011-2015	Average Income Index, 2011-2015	Average HDI, 2011-2015	Classification
77	Mexico	I	76.60	13.06	8.44	16,074	0.8708	0.6441	0.7673	0.755	High HD
10	United States	I	78.94	16.56	13.14	51,926	0.9068	0.8980	0.9445	0.916	Very High HD
103	Belize	II	69.9	12.76	10.5	7,359	0.7677	0.7044	0.6493	0.706	High HD
66	Costa Rica	II	79.24	13.92	8.52	13,521	0.9114	0.6707	0.7412	0.768	High HD
125	Guatemala	II	71.60	10.68	5.48	6,806	0.7938	0.4793	0.6375	0.624	Med HD
130	Honduras	II	72.94	11.40	5.84	4,317	0.8145	0.5113	0.5687	0.619	Med HD
124	Nicaragua	II	74.60	11.60	6.36	4,426	0.8400	0.5342	0.5725	0.636	Med HD
60	Panama	II	77.40	12.94	9.66	17,822	0.8831	0.6814	0.7829	0.778	High HD
95	Colombia	III	73.86	13.46	7.42	11,851	0.8286	0.6212	0.7213	0.719	High HD
127	Guyana	III	66.30	10.36	8.42	6,509	0.7123	0.5684	0.6308	0.634	Med HD
97	Suriname	III	70.96	12.70	8.18	15,263	0.7840	0.6254	0.7595	0.719	High HD
71	Venezuela, BR	III	74.04	14.22	9.40	16,477	0.8314	0.7083	0.7711	0.769	High HD
62	Antigua and Barbuda	IV	75.90	13.88	9.26	20,019	0.8600	0.6942	0.8005	0.782	High HD
54	Barbados	IV	75.46	15.30	10.38	14,922	0.8532	0.7710	0.7561	0.792	High HD
96	Dominica	IV	77.70	12.72	7.88	9,923	0.8877	0.6160	0.6945	0.724	High HD
79	Grenada	IV	73.20	15.80	8.54	10,969	0.8185	0.7236	0.7096	0.749	High HD
74	Saint Kitts and Nevis	IV	73.56	13.52	8.24	20,804	0.8240	0.6502	0.8063	0.756	High HD
92	Saint Lucia	IV	74.92	13.08	9.12	9,878	0.8449	0.6673	0.6938	0.731	High HD
99	Saint Vincent and the Grenadines	IV	72.78	13.30	8.54	10,084	0.8120	0.6541	0.6969	0.718	High HD
65	Trinidad and Tobago	IV	70.24	12.68	10.86	27,063	0.7729	0.7142	0.8460	0.776	High HD
58	The Bahamas	V	75.24	12.62	10.90	21,787	0.8498	0.7139	0.8133	0.790	High HD
68	Cuba	V	79.32	14.44	11.64	7,153	0.9126	0.7891	0.6450	0.774	High HD
99	Dominican Republic	V	73.30	13.18	7.56	11,629	0.8200	0.6181	0.7184	0.714	High HD
163	Haiti	V	62.42	9.06	5.00	1,622	0.6526	0.4183	0.4209	0.486	Low HD
94	Jamaica	V	75.48	12.80	9.58	8,291	0.8535	0.6749	0.6673	0.727	High HD

Annex 4.4. Characteristics of marine fisheries in the WCR and its total economic impact and income effect for the period 2010–2014 (this study; see Annex 4.1 for input data sources and technical notes).

Country/ Territory	Artisanal	Industrial	Recreational	Subsistence	Average Landed value 2010-2014,2010 constant USD, Millions	Ave Fishing Income Effect 2010-2014,2010 constant USD, Millions	Ave Fishing Economic Impact 2010-2014, 2010 constant USD, Millions	Average GDP 2010-2014, constant2010 USD, millions	Ave Fishing Economic Impact as % Ave GDP	Fish protein as% animal protein supply
Mexico	89.54%	10.43%	0.03%	0.00%	857	101	523	1,125,474	0.05%	8.40%
USA	31.23%	62.96%	5.81%	0.00%	3,395	4,395	10,523	15,544,454	0.07%	7.21%
Sub-region I (Gulf of Mexico)	**42.99%**	**52.37%**	**4.64%**	**0.00%**	**4,252**	**4,496**	**11,046**	**16,669,928**	**0.07%**	
Belize	77.03%	5.40%	0.00%	17.57%	15	12	52	1,469	3.53%	13.52%
Costa Rica	91.04%	0.01%	0.00%	8.95%	1	1	3	40,334	0.01%	8.14%
Guatemala	61.56%	35.37%	0.00%	3.08%	3	2	6	44,522	0.01%	3.09%
Honduras	67.77%	28.12%	0.00%	4.11%	44	34	153	17,032	0.90%	4.37%
Nicaragua	41.93%	46.29%	0.00%	11.78%	69	28	103	9,859	1.04%	7.10%
Panama	52.67%	15.29%	0.00%	32.04%	4	4	10	35,411	0.03%	12.47%
Sub-region II (Western Caribbean)	55.44%	34.29%	0.00%	10.27%	136	80	326	148,627	0.22%	
Aruba (Netherlands)	28.69%	0.00%	63.91%	7.40%	2	1	3	2,483	0.11%	11.68%
Bonaire (Netherlands)	35.89%	0.00%	24.39%	39.72%	1	0	2	351	0.48%	11.68%
Colombia	44.17%	37.60%	0.00%	22.79%	22	32	70	318,711	0.02%	5.36%
Curacao	62.97%	32.98%	0.41%	10.23%	5	1	6	3,085	0.20%	11.68%
French Guiana	85.40%	0.00%	0.00%	14.60%	11	5	22	4,383	0.51%	no data
Guyana	55.02%	41.64%	0.00%	3.34%	88	39	186	2,514	7.39%	23.97%
Saba and Saint Eustatius (Netherlands)	58.61%	0.00%	1.30%	40.09%	2	1	3	126	2.39%	11.68%
Suriname	66.64%	23.97%	0.00%	9.39%	96	43	203	4,706	4.30%	17.56%
Venezuela	77.69%	20.57%	0.00%	1.75%	393	175	417	419,066	0.10%	10.40%
Sub-region III (Southern Caribbean)	71.25%	24.23%	0.28%	4.45%	621	296	911	755,424	0.12%	
Anguilla (UK)	48.85%	0.00%	0.23%	50.92%	0	0	0	268	0.08%	no data
Antigua & Barbuda	73.24%	0.00%	2.76%	23.99%	1	0	1	1,168	0.06%	24.35%
Barbados	47.79%	25.20%	0.04%	26.97%	3	1	3	4,495	0.07%	23.91%
British Virgin Isl. (UK)	79.90%	0.08%	0.68%	19.36%	4	1	5	867	0.62%	no data
Dominica	47.67%	8.45%	0.00%	43.88%	5	1	6	493	1.13%	16.32%
Grenada	56.49%	27.43%	0.04%	16.04%	7	2	8	789	1.05%	23.61%
Guadeloupe (France)	84.14%	0.00%	2.77%	13.10%	16	5	19	9,946	0.20%	no data
Martinique (France)	68.01%	0.00%	3.76%	28.22%	20	6	24	9,855	0.24%	no data
Montserrat (UK)	84.94%	0.00%	0.00%	15.06%	0	0	0	67	0.30%	no data
Saint Kitts & Nevis	73.95%	0.00%	0.05%	26.00%	6	2	8	743	1.01%	20.55%
Saint Lucia	45.09%	43.71%	0.42%	10.87%	5	1	6	1,409	0.43%	15.77%
Saint Vincent & the Grenadines	78.97%	3.39%	0.06%	17.58%	6	2	8	691	1.12%	11.26%
Sint Maarten	8.34%	67.92%	15.85%	7.89%	1	0	1	886	0.11%	no data
St Barthelemy (France)	53.97%	0.00%	1.60%	44.43%	1	0	1	436	0.19%	no data
St Martin	53.41%	0.00%	2.65%	43.94%	0	0	0	552	0.01%	no data
Trinidad & Tobago	41.62%	34.51%	5.95%	17.93%	42	12	51	22,354	0.23%	16.27%
US Virgin Isl.	75.77%	0.00%	6.97%	17.26%	3	1	3	3,612	0.09%	no data
Sub-region IV (Eastern Caribbean)	59.11%	17.07%	3.43%	20.40%	118	34	144	58,632	0.25%	
Bahamas	13.13%	70.92%	12.27%	3.67%	120	34	147	10,313	1.42%	13.72%
Cayman Isl. (UK)	1.13%	89.70%	8.03%	1.13%	1	0	1	3,050	0.02%	no data
Cuba	83.41%	6.47%	4.72%	5.40%	67	19	82	67,862	0.12%	7.35%
Dominican Republic	48.22%	6.14%	0.24%	45.41%	100	28	121	58,275	0.21%	10.31%
Haiti	64.89%	0.00%	0.00%	35.10%	40	11	49	7,200	0.68%	13.64%
Jamaica	59.17%	0.00%	0.02%	40.81%	54	15	66	13,369	0.49%	18.91%
Puerto Rico (USA)	83.50%	0.00%	13.51%	2.98%	5	1	6	97,763	0.01%	no data
Turks & Caicos Isl. (UK)	85.50%	0.02%	0.87%	13.62%	31	9	38	662	5.74%	no data
Sub-region V (Northern and Central Caribbean)	49.97%	22.97%	4.57%	22.49%	419	119	510	258,495	0.20%	
Wider Caribbean Region	**47%**	**46%**	**4%**	**3%**	**5546**	**5025**	**12938**	**17,891,105**	**0.07%**	
Continental countries	47%	48%	4%	1%	4998	4870	12170	17,567,934	0.07%	
Islands	52%	22%	5%	22%	548	156	667	323,171	0.21%	

Annex 5.1A. Municipal wastewater calculations (this study). Refer to Annex 4.1 for the data sources and computations for each column parameter. Sources for sewer service coverages at country scale are listed in the Annex Table 5.1B.

Country/ Island territory	**Coastal population 2015**	**Municipal water withdrawal (2015) 10^9 m3 yr-1**	**Empirical ratios of produced wastewater: water withdrawal**	**Produced municipal waste water (2015) 10^9 m3 yr-1**	**% Population connected to wastewater treatment plant**	**Municipal waste water not captured by collection systems 10^9 m3 yr-1**	**Tg N in untreated wastewater (2015) (N = 60 g m-3)**	**Tg P in untreated wastewater (2015) (P = 10 g m-3)**
Mexico	16,632,867	1.73	62%	1.08	0.36	0.69	0.04	0.01
US (Gulf States only)	31,655,204	6.78	97%	6.60	0.61	2.57	0.15	0.03
Sub-region I	**48,288,071**	**8.52**		**7.68**		**3.26**	**0.20**	**0.03**
Belize	312,928	0.02	69%	0.01	0.00	0.01	0.00	0.00
Costa Rica	3,136,334	0.44	54%	0.24	0.04	0.23	0.01	0.00
Guatemala	436,449	0.03	80%	0.02	0.05	0.02	0.00	0.00
Honduras	3,502,178	0.17	100%	0.17	0.10	0.15	0.01	0.00
Nicaragua	472,193	0.03	100%	0.03	0.10	0.03	0.00	0.00
Panama	3,207,133	0.59	85%	0.50	0.15	0.42	0.03	0.00
Sub-region II	**11,067,214**	**1.27**		**0.97**		**0.87**	**0.05**	**0.01**
Colombia	8,329,481	0.65	75%	0.49	0.01	0.48	0.03	0.00
French Guiana	214,788	No data						
Guyana	622,835	0.06	69%	0.04	0.05	0.04	0.00	0.00
Suriname	497,062	0.05	69%	0.03	0.00	0.03	0.00	0.00
Venezuela, BR	21,118,308	5.13	67%	3.44	0.00	3.44	0.21	0.03
Aruba	101,485	No data						
Bonaire	15,518							
Curacao	143,784							
Sub-region III	**31,043,260**	**5.88**		**4.00**		**3.99**	**0.24**	**0.04**
Anguilla	13,769	No data						
Antigua and Barbuda	94,661	0.01	69%	0.01	0.00	0.01	0.00	0.00
Barbados	279,569	0.02	69%	0.01	0.04	0.01	0.00	0.00
British Virgin Islands	27,224							
Dominica	71,440	0.02	69%	0.01	0.00	0.01	0.00	0.00
Grenada	104,677	0.02	92%	0.02	0.00	0.02	0.00	0.00
Guadeloupe	450718	No data						
Martinique	394910							
Montserrat	4944							
Sint Maarten (Dutch part)	34,056							
Saint Kitts and Nevis	51,445	0.02	69%	0.01	0.00	0.01	0.00	0.00
Saint Lucia	172,580	0.01	69%	0.01	0.00	0.01	0.00	0.00
Saint Martin (French part)	30,235							
Saint Vincent and the Grenadines	109,315	0.01	69%	0.01	0.00	0.01	0.00	0.00
Trinidad and Tobago	1,328,100	0.24	69%	0.17	0.05	0.16	0.01	0.00
Virgin Islands (U.S.)	108,358							
Sub-region IV	**3,276,001**	**0.35**		**0.25**		**0.24**	**0.01**	**0.00**
The Bahamas	360,832	0.03	69%	0.02	0.07	0.02	0.00	0.00
Cayman Islands	55,507							No data
Cuba	11,204,351	1.71	49%	0.84	0.04	0.81	0.05	0.01
Dominican Republic	10,225,482	0.91	50%	0.45	0.12	0.40	0.02	0.00
Haiti	10,188,175	0.21	69%	0.14	0.00	0.14	0.01	0.00
Jamaica	2,817,210	0.30	69%	0.21	0.08	0.19	0.01	0.00
Puerto Rico	3,721,525	0.93	69%	0.64	0.64	0.23	0.01	0.00
Turks and Caicos Islands	30,994	No data						
Sub-region V	**38,604,076**	**4.09**		**2.31**		**1.79**	**0.11**	**0.02**
WCR	**132,278,623**	**20.11**		**15.20**		**10.15**	**0.61**	**0.10**
Continental countries	90,137,759	15.67		12.64		8.12	0.49	0.08
Island states and territories	42,140,864	4.44		2.55		2.03	0.12	0.02

Annex 5.1B. References used in determining proportion of population connected to a wastewater treatment plant, values for which are also shown in Column 6 of Annex 5.1A (see technical notes in Annex 4.1).

Country/ Island territory	% Population connected to wastewater treatment plant	Reference
Mexico	0.36	Zurita, F., E.D. Roy, J.R. White. 2012. Municipal wastewater treatment in Mexico: current status and opportunities for employing ecological treatment systems, Environmental Technology 33:10,1151 -1158
US (Gulf States only)	0.61	US EPA. 2012. Clean Watersheds Needs Survey (CWNS) - 2012 Report and Data. https://www.epa.gov/cwns/clean-watersheds-needs-survey-cwns-2012-report-and-data
Belize	0.00	Grau, J., M. del Rosario Navia, A. Rihm, J. Ducci, D. Martin, T. Kuratomi. 2013. Water and Sanitation in Belize, Inter-American Development Bank, 37 p.
Costa Rica	0.04	Guzman-Arias, I., J.C. Calvo-Alvarado. 2013. Planning and development of Costa Rica water resource: current status and perspectives. Tecnologia en Marcha. 26(4):52-63.
Guatemala	0.05	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Honduras	0.10	Aquastat. Honduras, 2007. http://www.fao.org/nr/water/aquastat/data/query/results.html
Nicaragua	0.10	Nicaragua National Institute of Development Information. 2008.2008 Anuario Estadistico. INIDE, 414 p.
Panama	0.15	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Colombia	0.01	Campuzano Ochoa et al 2015
French Guiana		
Guyana	0.05	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Suriname	0.00	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Venezuela, BR	0.00	Campuzano Ochoa et al. 2015
Aruba	No Data	
Bonaire		
Curacao		
Anguilla		
Antigua and Barbuda	0.00	ECLAC. 2007. Overview of the water profile and the capacity of national institutions to implement integrated water resources management (Antigua and Barbuda, Dominica, Grenada). ECLAC, 80 p. US Army Corps of Engineers. 2004. Water Resources Assessment of Dominica, Antigua, Barbuda, St. Kitts and Nevis. USACE Mobile District & Topographic Engineering Center, 140 p.
Barbados	0.04	Construction Caribbean, 2018
British Virgin Islands	No Data	
Dominica	0.00	ECLAC. 2007. Overview of the water profile and the capacity of national institutions to implement integrated water resources management (Antigua and Barbuda, Dominica, Grenada). ECLAC, 80 p. US Army Corps of Engineers. 2004. Water Resources Assessment of Dominica, Antigua, Barbuda, St. Kitts and Nevis. USACE Mobile District & Topographic Engineering Center, 140 p.
Grenada	0.00	ECLAC. 2007. Overview of the water profile and the capacity of national institutions to implement integrated water resources management (Antigua and Barbuda, Dominica, Grenada). ECLAC, 80 p.
Guadeloupe	No Data	
Martinique		
Montserrat		
Sint Maarten (Dutch part)		
Saint Kitts and Nevis	0.00	US Army Corps of Engineers. 2004. Water Resources Assessment of Dominica, Antigua, Barbuda, St. Kitts and Nevis. USACE Mobile District & Topographic Engineering Center, 140 p.
Saint Lucia	0.00	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Saint Martin (French part)	No Data	
Saint Vincent and the Grenadines	0.00	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Trinidad and Tobago	0.05	UNEP CEP. 2015. Valuing the costs and benefits of improved wastewater treatment. CEP Technical Report 92,35 p.
Virgin Islands (U.S.)	No Data	
Bahamas, The	0.07	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Cayman Islands	No Data	
Cuba	0.04	Westbrook, A and N. S. De Freitas Alves. 2016. Havana's wastewater treatment plants: Changes over time and estimate of replacement cost. https://www.ascecuba.org/asce_proceedings/havanas-wastewater-treatment-plants-changes-over-time-and-estimate-of-replacement-cost/
Dominican Republic	0.12	Grullon, F. A. 2013. Wastewater treatment update. Dominican Republic. PowerPoint presentation at GMI Municipal Wastewater Subcommittee Meeting, Vancouver, Canada, 13 March 2013. https://www.globalmethane.org/expo-docs/canada13/mww_01_Dominican_Republic.pdf
Haiti	0.00	Herscher, R. 2017. You probably don't want to know about Haiti's sewage problems. https://www.npr.org/templates/transcript/transcript.php?storyId=537945957
Jamaica	0.08	UNEP CEP. 2010. Situational Analysis. Regional Sectoral Overview of Wastewater Management in the Wider Caribbean Region. CEP Technical Report 66,184 p.
Puerto Rico	0.64	US EPA. 2012. Clean Watersheds Needs Survey (CWNS) - 2012 Report and Data. https://www.epa.gov/cwns/clean-watersheds-needs-survey-cwns-2012-report-and-data
Turks and Caicos Islands	No Data	

Annex 5.2. Modelled values of nitrogen by source for each sub-region and the WCR as a whole for year 2000 (this study; input data from Beusen, et al., 2016).

Sub-region	Atmospheric deposition	Vegetation in floodplains	Surface run-off (agriculture)	Surface run-off (natural)	Groundwater (agriculture)	Groundwater (natural)	Sewage	Aquaculture	All N inputs
I	45.14	255.38	755.24	21.77	1,800.24	231.79	294.32	3.13	**3,407.01**
	1.3%	7.5%	22.2%	0.6%	52.8%	6.8%	8.6%	0.1%	**100.0%**
II	4.12	27.51	65.48	6.05	53.39	57.79	15.06	0.27	**229.65**
	1.8%	12.0%	28.5%	2.6%	23.2%	25.2%	6.6%	0.1%	**100.0%**
III	8.87	435.82	219.80	34.37	267.35	490.58	150.48	4.05	**1,611.31**
	0.6%	27.0%	13.6%	2.1%	16.6%	30.4%	9.3%	0.3%	**100.0%**
IV	0.00	15.87	1.36	0.11	7.40	2.03	3.71	0.00	**30.48**
	0.0%	52.1%	4.5%	0.3%	24.3%	6.7%	12.2%	0.0%	**100.0%**
V	0.36	14.75	41.28	1.31	66.85	16.78	45.84	2.13	**189.30**
	0.2%	7.8%	21.8%	0.7%	35.3%	8.9%	24.2%	1.1%	**100.0%**
WCR (10^3 t N)	58.49	749.31	1,083.15	63.60	2,195.23	798.97	509.42	9.59	**5,467.76**
WCR (Tg N)	0.058	0.749	1.083	0.064	2.195	0.799	0.509	0.010	**5.468**
WCR (%)	1.1%	13.7%	19.8%	1.2%	40.1%	14.6%	9.3%	0.2%	**100.0%**

Annex 5.3. Modelled values of phosphorus by source for each sub-region and the WCR as a whole for year 2000 (this study; input data from Beusen, et al., 2016).

Sub-region	Weathering	Vegetation in floodplains	Surface run-off agriculture	Surface run-off natural	Sewage	Aquaculture	All P inputs
I	26.65	21.28	215.38	8.06	34.49	0.27	306.13
	8.7%	7.0%	70.4%	2.6%	11.3%	0.1%	100.0%
II	17.67	2.29	27.49	2.48	2.28	0.03	52.23
	33.8%	4.4%	52.6%	4.7%	4.4%	0.1%	100.0%
III	70.32	36.32	71.33	8.83	21.69	0.53	209.01
	33.6%	17.4%	34.1%	4.2%	10.4%	0.3%	100.0%
IV	1.10	1.32	0.36	0.02	0.65	0.00	3.45
	32.0%	38.4%	10.3%	0.5%	18.8%	0.0%	100.0%
V	3.93	1.23	23.99	0.35	7.29	0.25	37.04
	10.6%	3.3%	64.8%	1.0%	19.7%	0.7%	100.0%
WCR (103 t P)	119.66	62.44	338.55	19.74	66.39	1.07	607.86
WCR (Tg P)	0.120	0.062	0.339	0.020	0.066	0.001	0.608
WCR (%)	19.7%	10.3%	55.7%	3.2%	10.9%	0.2%	100.0%

Annex 8.1. Calculations in estimating total solid waste at country and WCR scales (this study).

COUNTRY/ Sub-region	**Coastal Population 2015**	**% Urban (2015)**	**Urban Residents (2015, kg/per/day)**	**Urban Waste (tonnes/yr)**	**Rural Waste at 75% of Urban Rate (tonnes/year)**	**Total Waste (2015, tonnes/yr)**	**% Plastic in Waste Stream**	**Plastic Waste Generated (2015, tonnes)**	**% Mismanaged Plastic Waste**	**Plastic Waste to Ocean (2015, tonnes)**
Mexico, I	17,486,689	0.53	1.24	4,172,511	2,806,473	6,978,984	7	488,529	14	68,394
United States, I	33,713,411	0.82	2.58	26,087,265	4,245,490	30,332,756	13	3,943,258	2	78,865
Belize, II	355,922	0.45	2.87	169,309	152,653	321,962	6	19,318	31	5,988
Guatemala, II	479,819	0.50	2.00	175,029	131,429	306,458	14	42,904	38	16,304
Nicaragua, II	624,350	0.58	1.10	145,117	79,170	224,287	13	29,157	47	13,704
Honduras, II	3,749,099	0.55	1.45	1,094,689	667,141	1,761,830	13	229,038	42	96,196
Costa Rica, II	3,255,766	0.77	1.36	1,242,182	280,485	1,522,667	19	289,307	18	52,075
Panama, II	3,675,524	0.67	1.21	1,082,738	405,418	1,488,156	12	178,579	20	35,716
Guiana, III	710,323	0.26	5.33	365,374	762,393	1,127,767	12	135,332	17	23,006
Suriname, III	504,179	0.66	1.36	165,331	63,707	229,039	12	27,485	17	4,672
French Guyana, III	223,018	0.84	1.20	82,522	11,370	93,892	12	11,267	27	3,042
Colombia, III	9,338,870	0.74	1.20	3,046,549	782,907	3,829,456	12	459,535	23	105,693
Venezuela, BR, III	23,043,369	0.93	0.86	6,698,048	401,449	7,099,497	12	851,940	7	59,636
Aruba, III	103,889	0.43	2.10	34,329	33,977	68,305	12	8,197	3	246
Bonaire, III	18,398	0.75	2.76	13,837	3,504	17,341	12	2,081	2	42
Curacao, III	157,203	0.89	2.10	107,663	9,625	117,288	12	14,075	2	281
British Virgin Islands, IV	30,113	0.47	2.59	13,260	11,405	24,666	12	2,960	2	59
Virgin Islands (US), IV	107,710	0.95	3.74	140,165	5,127	145,291	12	17,435	2	349
Anguilla, IV	14,611	1.00	1.20	6,400	0	6,400	12	768	4	31
Saint Martin, IV	31,754	1.00	2.10	24,339	0	24,339	12	2,921	2	58
Sint Maarten, IV	38,824	1.00	2.10	29,759	0	29,759	12	3,571	2	71
Saint Kitts and Nevis, IV	54,288	0.31	5.45	33,294	56,024	89,318	12	10,718	8	857
Antigua and Barbuda, IV	99,923	0.25	5.50	50,149	112,835	162,984	12	19,558	8	1,565
Montserrat, IV	5124	0.09	1.20	203	1,531	1,734	12	208	14	29
Guadeloupe, IV	450418	0.98	1.20	194,205	2,308	196,514	12	23,582	27	6,367
Dominica, IV	73,162	0.70	1.24	23,040	7,555	30,595	12	3,671	21	771
Martinique, IV	385842	0.89	2.10	263,156	24,444	287,600	12	34,512	2	690
Saint Lucia, IV	177,206	0.19	4.35	52,080	171,959	224,039	12	26,885	22	5,915
Saint Vincent and the Grenadines, IV	109,455	0.51	1.70	34,610	24,980	59,590	13	7,747	23	1,782
Barbados, IV	284,217	0.31	4.75	153,988	254,080	408,068	12	48,968	6	2,938
Grenada, IV	106,823	0.36	2.71	38,039	50,719	88,758	12	10,651	20	2,130
Trinidad and Tobago, IV	1,360,092	0.53	14.40	3,811,657	2,502,740	6,314,397	25	1,578,599	5	78,930
Cuba, V	11,282,863	0.77	0.81	2,565,214	577,924	3,143,137	11	345,745	25	86,436
Haiti, V	10,584,527	0.52	1.00	2,025,556	1,378,348	3,403,903	9	306,351	49	150,112
Dominican Republic, V	10,507,413	0.79	1.10	3,314,653	678,055	3,992,708	12	479,125	27	129,364
Jamaica, V	2,871,934	0.55	1.50	862,138	532,684	1,394,822	19	265,016	29	76,855
Puerto Rico, V	3,473,177	0.94	2.35	2,789,050	142,551	2,931,601	12	351,792	49	172,378
Bahamas, The, V	386,838	0.83	3.25	379,729	59,368	439,097	12	52,692	3	1,581
Turks and Caicos Islands, V	34,339	0.92	2.10	24,268	1,540	25,808	12	3,097	2	62
Cayman Islands, V	59,963	1.00	3.11	68,000	0	68,000	12	8,160	2	163
Total						**79,012,812**		**10,334,732**		**1,283,354**

Annex 8.2. Preliminary estimates of tourism-generated solid waste among Eastern Caribbean Currency Union (ECCU) countries (Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines) (this study; input data from Eastern Caribbean Currency Union Statistics Office at https://www.eccb-centralbank.org/p/tourism-statistics).

Tourist Type	Average Length of Stay Onshore (day)	Solid Waste Generated (kg person^{-1} day^{-1})	2015 Visitors	Solid Waste Generated (2015, (tonnes)
Stay-over visitors by Air	8[a]			
USA		2.58	444,065	9,166
Canada		2.33	93,619	1,745
UK		1.79	208,046	2,979
Caribbean		1.55	213,126	2,643
Other countries		1.42	114,373	1,299
Subtotal				17,832
Excursionists	1[b]	1.75	132,310	232
Cruise ship passengers	0.5[c]	3.5	2,860,932	5,007
Yacht passengers	90[d]	1.75	163,913	25,816
Total waste from tourists				48,886
Total waste from ECCU resident populations				663,418
Tourism contribution to solid waste in ECCU				7%

[a] Caribbean Tourism Review, Industry Update, End of Year 2014

[b] By definition, excursionists spend 1 day at destination.

[c] https://www.cruisecritic.com/articles.cfm?ID=1161

[d] The Sailing Company. 2014. The Sailing Market 2014. State of the Industry, February 2014.