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STATE OF THE CARTAGENA CONVENTION AREA REPORT

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

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May 2019

UNEDITED

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Contents

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
N	Nitrogen
NEWS	Nutrient Export from Watersheds Model
NWC	National Water Commission (Jamaica)
P	Phosphorus
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
RAC	Regional Activity Centres
RAN	Regional Activity Network
RAPMaLi	Regional Action Plan for Marine Litter
REPCar	Reducing Pesticide Runoff 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 Report
SOMEE	State of the Marine Environment and Associated Economies
STAC	Scientific and Technical Advisory Committee
TSS	Total Suspended Solids
UNDP	United Nations Development 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 socio-economic prosperity and human wellbeing. 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 Island 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.

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

[i] Patil et al. 2016

[ii] 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 and to which countries across the globe have committed to 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.

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

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, Oils Spills, and Specially Protected Areas and Wildlife).

Figure ES 1. **The Cartagena Convention Area**

State of the Convention Area Report (SOCAR)

In 2010, the Contracting Parties to the Land-based Sources (LBS) Protocol took a decision to produce the first State of the Convention Area Report (SOCAR) 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 is the first of its kind for this region, where empirical water quality data sets from several WCR countries and territories are combined 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 (9 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 runoff 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[1] 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.

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 tons of nitrogen and 100,000 tons 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).

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[1] "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)

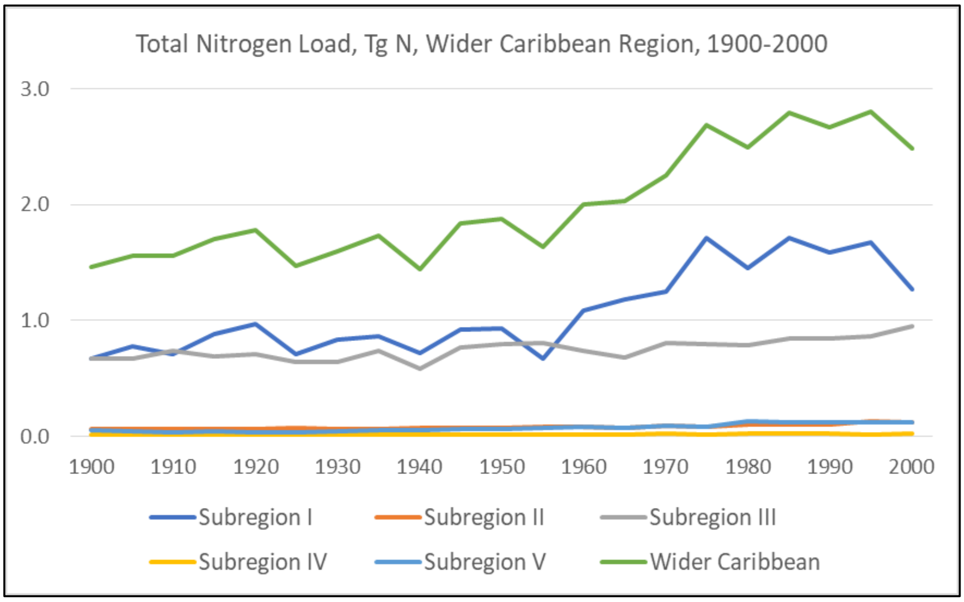


Figure ES 3. Simulated annual nitrogen load in each sub-region and the WCR for the 20th century

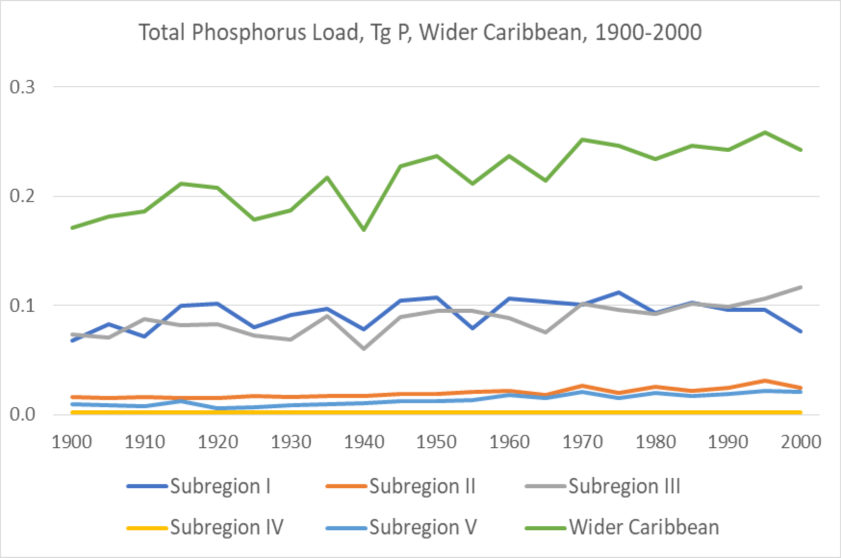


Figure ES 4. Simulated annual phosphorus loads in each sub-region and the WCR for the 20th century

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 runoff greatly exceeding that from sewage. Moreover, groundwater impacted by agricultural fertilizers, rather than surface agricultural runoff 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.

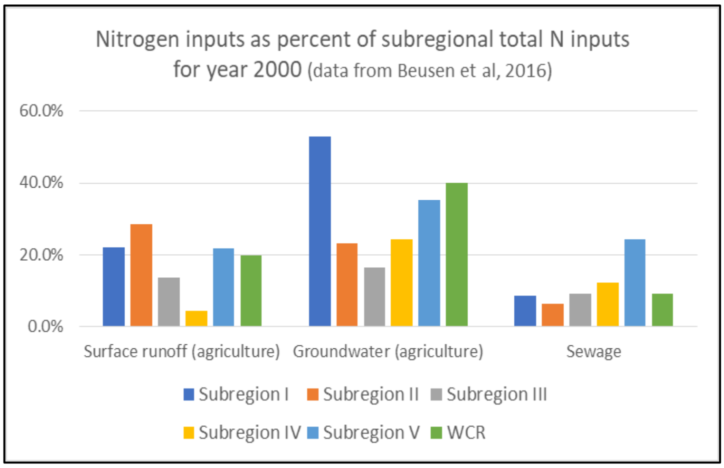
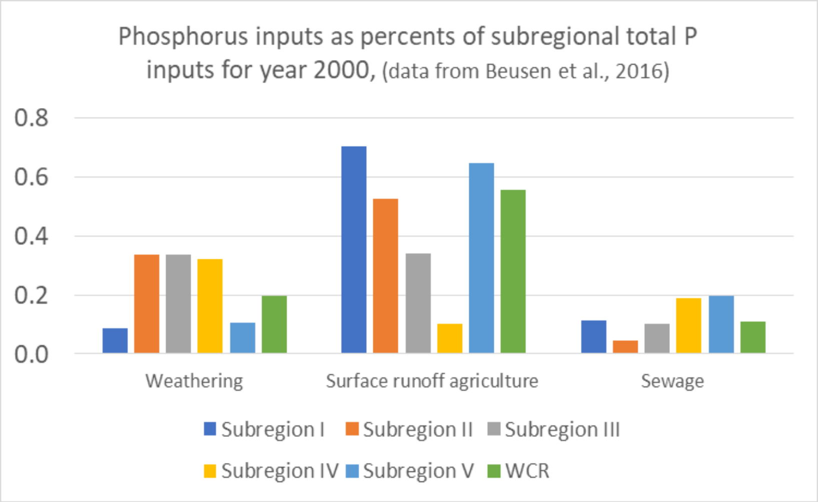


Figure ES 5. Nitrogen (N) contribution by major anthropogenic sources for each sub-region as a proportion of the sub-regional total N source loads

Surface agricultural runoff 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.



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

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 (Gulf of Mexico), III (Southwestern Caribbean), and sub-region 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.

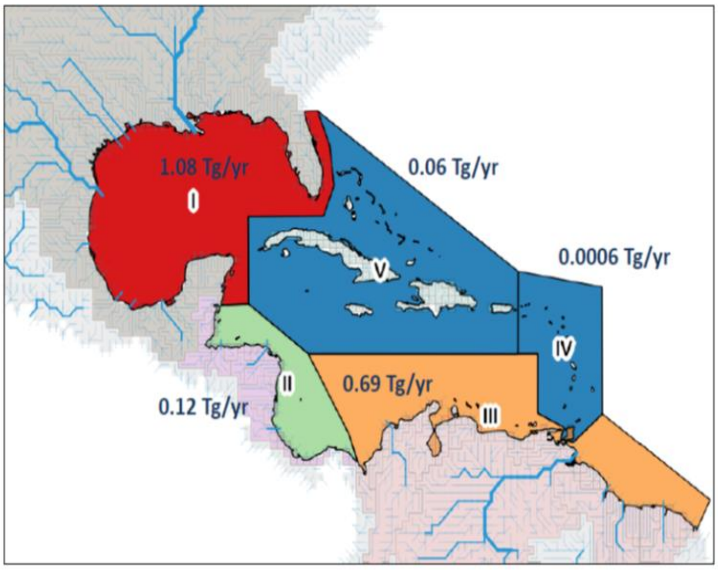


Figure ES 7. Dissolved Inorganic Nitrogen (DIN) inputs (Tg) from watersheds to coastal areas in the five sub-regions, in model year 2000. Colours represent the range of values (red=highest; orange=high; green=medium; blue=lowest).

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.

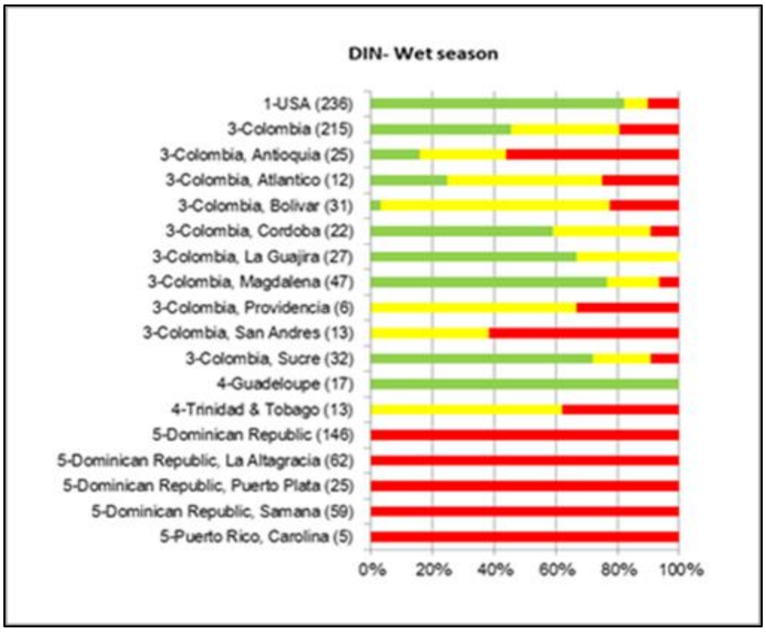


Figure ES 8. Proportion of sampling sites showing good, fair, and poor status in the wet season for dissolved inorganic nitrogen (DIN)

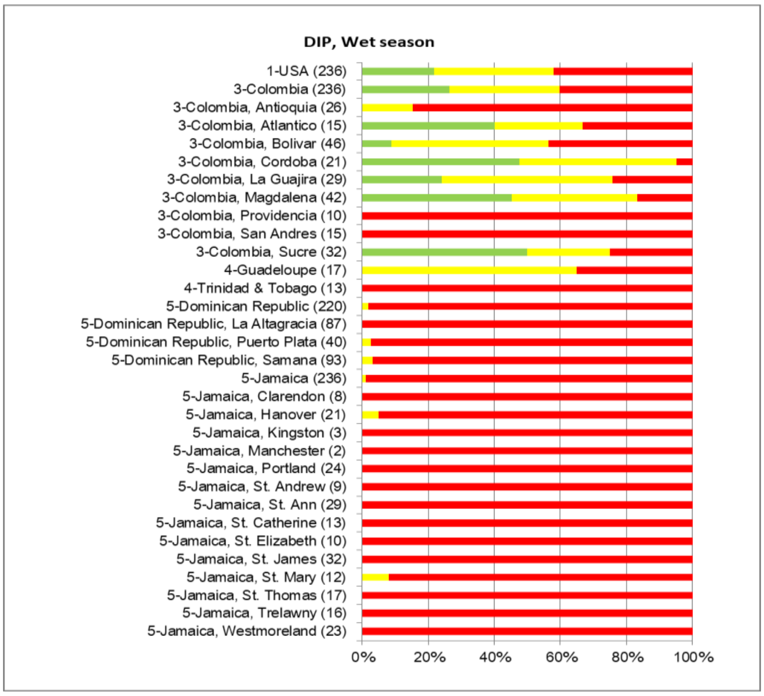


Figure ES 9. Proportion of sampling sites showing good, fair, and poor status in the wet season for dissolved inorganic phosphorus (DIP)

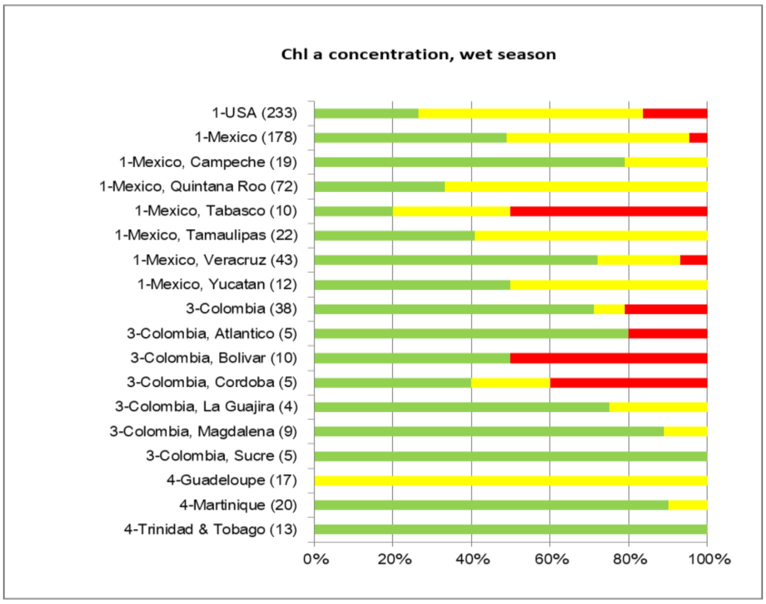


Figure ES 10. Proportion of sampling sites showing good, fair, and poor status in the wet season for chlorophyll a (Chl a)

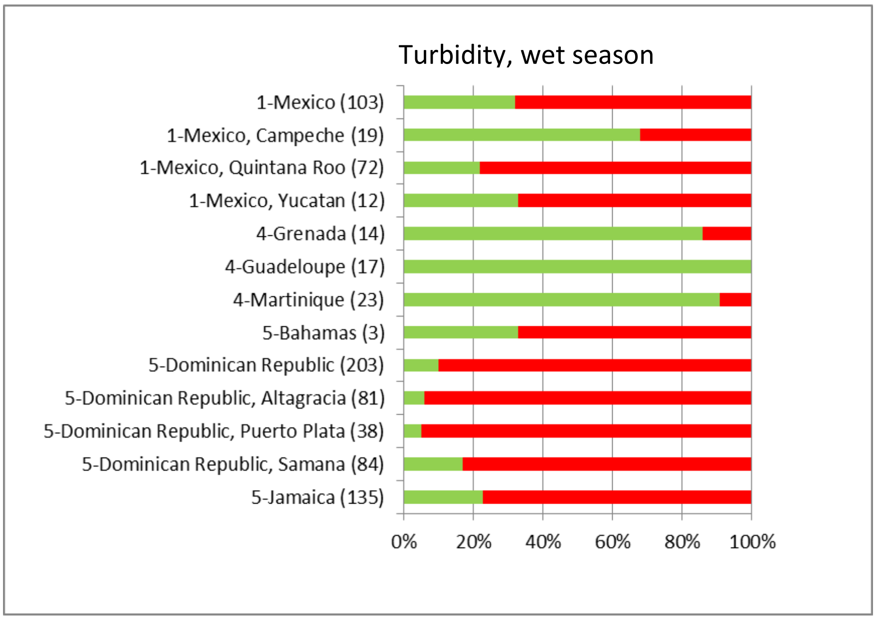


Figure ES 11. Proportion of sampling sites within (green) and outside (red) the acceptable range in the wet season for turbidity

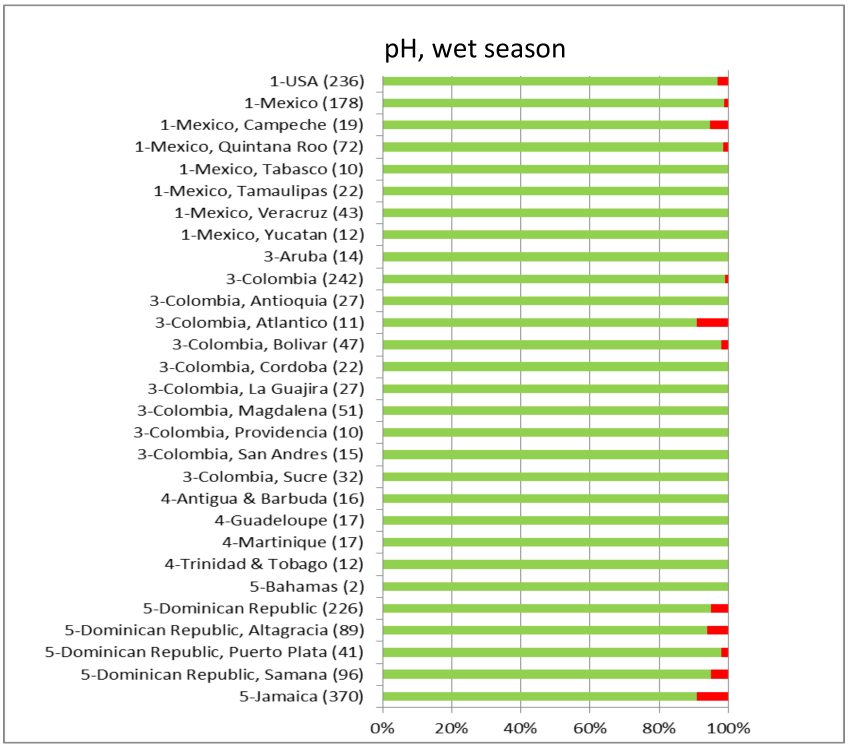


Figure ES 12. Proportion of sampling sites within (green) and outside (red) the acceptable range in the wet season for pH

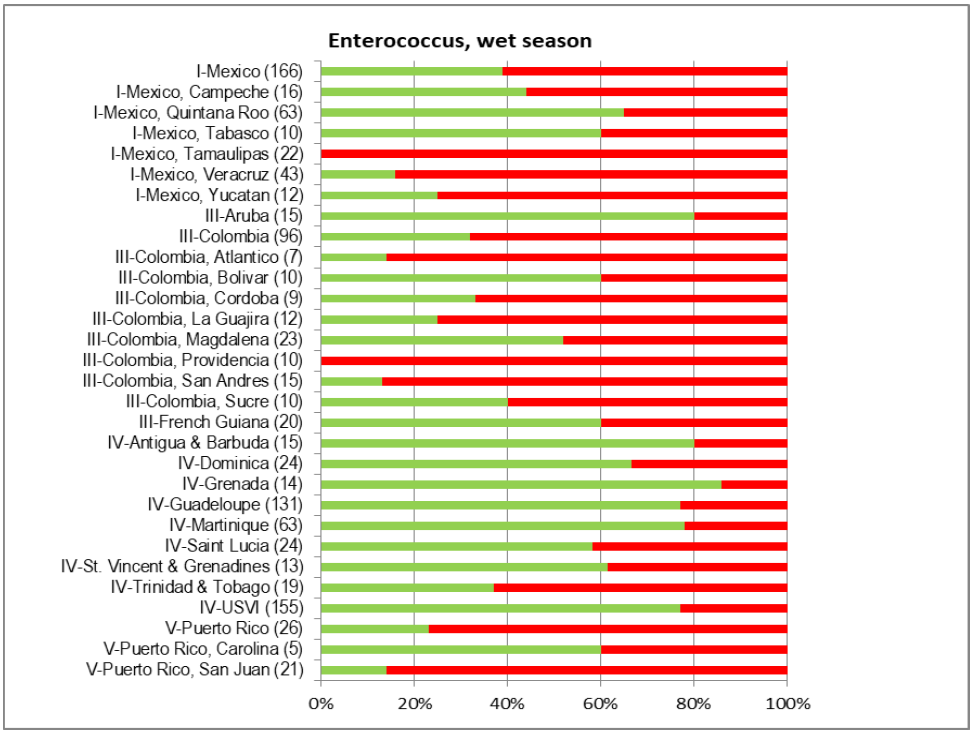


Figure ES 13. Percentage of sampling sites within (green) and outside (red) the acceptable range in the wet season for *Enterococcus*

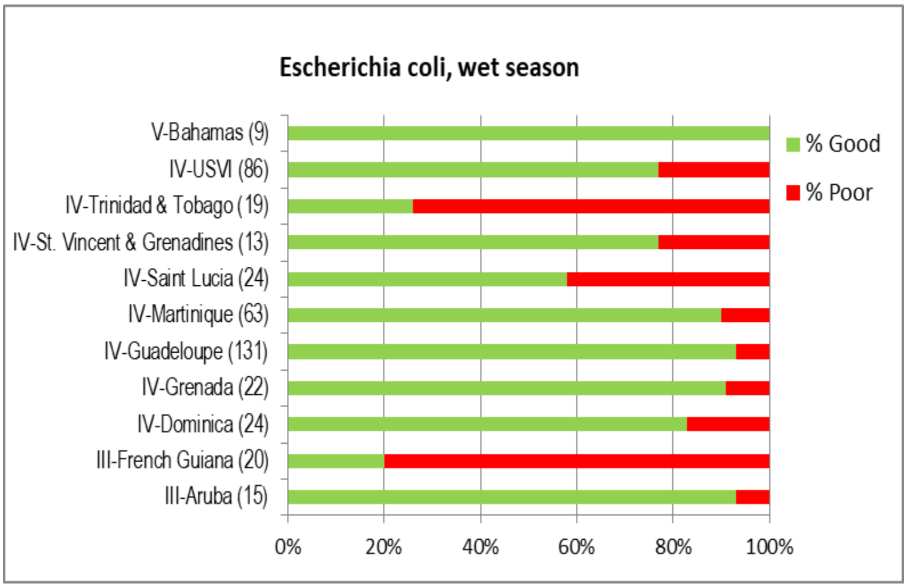


Figure ES 14. Percentage of sampling sites within (green) and outside (red) the acceptable range in the wet season for *E. coli*

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 runoff.
- The proportion of sites with poor status or outside of the acceptable range increased in the wet season as a result of intensification of runoff from land during this period.
- In general, areas with an elevated proportion of sites in these categories were associated with river runoff. 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 human intoxications, including 119 human fatalities, were mainly associated with paralytic shellfish poisoning (linked to HABs) in the Pacific and Atlantic coasts, and ciguatera fish poisoning (CFP) in the Caribbean. PSP are linked to the incidence of HABs. During 2011, 248 cases of clinically diagnosed CFP were reported from six 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, wellbeing, 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 abate 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 tons of solid waste, which is projected to increase to 84 million in 2020. From this, 1.3 million tons 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 tons and 49,000 tons, 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 analysed.

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 tons 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

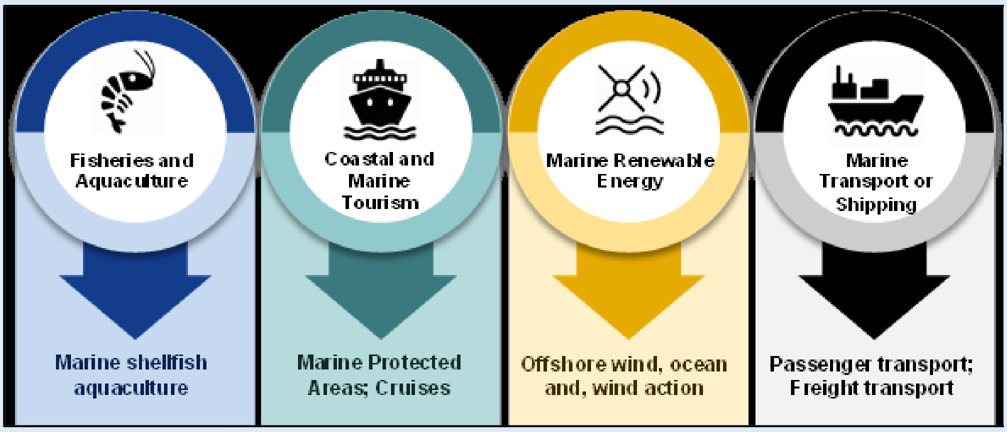
1.1. Land-based pollution: what's at stake

Our coastal and marine ecosystems are not the receptacle for our wastes, as they are often viewed by some. On the contrary, these fragile but immensely productive ecosystems are the source of an enormous array of vital goods and services that we humans enjoy for their aesthetic value (e.g., tranquil beaches and fascinating coral reefs), depend on for socio-economic 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 for protection from extreme weather events. Furthermore, many of these 'eco-services' are of fundamental importance to the functioning of the Earth's life-support system and for human survival (such as production of oxygen 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, of which about 56% 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 wellbeing. 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, 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 paradigm.

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)



Yet, 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 from land-based sources, is a serious and pervasive threat to the marine environment and human health. So great and widespread is the concern over pollution that this issue is reflected in every international framework related to the environment and sustainable development 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 Report (SOCAR) on land-based pollution.

1.2. The Cartagena Convention Area

The WCR comprises 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).[2] The Cartagena Convention area encompasses four large marine ecosystems[3] (LMEs): Gulf of Mexico, Caribbean Sea, North Brazil Shelf, and Southeast US Continental Shelf LMEs. A description of the main physical and socio-economic features of the Wider Caribbean Sea pertinent to land-based pollution is given in Chapters 2 and 4, respectively, of this report.

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

1.3. The Caribbean Environment Programme and Cartagena Convention

In 1976, UN Environment launched the Caribbean Environment Programme (CEP)[4], 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 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;
- 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 – the Convention for the Protection and Development of the Marine Environment

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

[3] Coastal regions of 200,000 km² 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.

[4] http://www.cep.unep.org/

of the Wider Caribbean Region or **Cartagena Convention**[5] (Figure 1.2). The Convention, which remains to date the only regional legally binding agreement for the protection, sustainable development, and use of the region's coastal and marine resources, is supported by three technical agreements or Protocols:

1. The Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region;
2. The Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region;
3. The Protocol Concerning Pollution from Land-Based Sources and Activities (LBS Protocol).

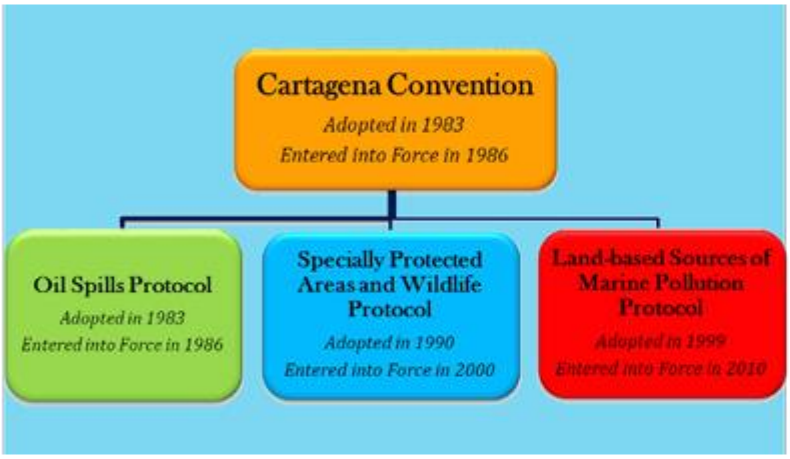

Figure 1.2. The Cartagena Convention and its three Protocols

The LBS Protocol requires the development by Contracting Parties of plans, programmes, and measures to prevent, reduce and control pollution of the Caribbean Sea from land-based sources and activities. To date, the LBS Protocol has been ratified by 14 States (Figure 1.3 and http://www.cep.unep.org/cartagena-convention). The Convention also works in support of other global environmental conventions, agreements, and commitments.

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[5] A description of the obligations under the Convention and Protocols are available at http://www.cep.unep.org/cartagena-convention

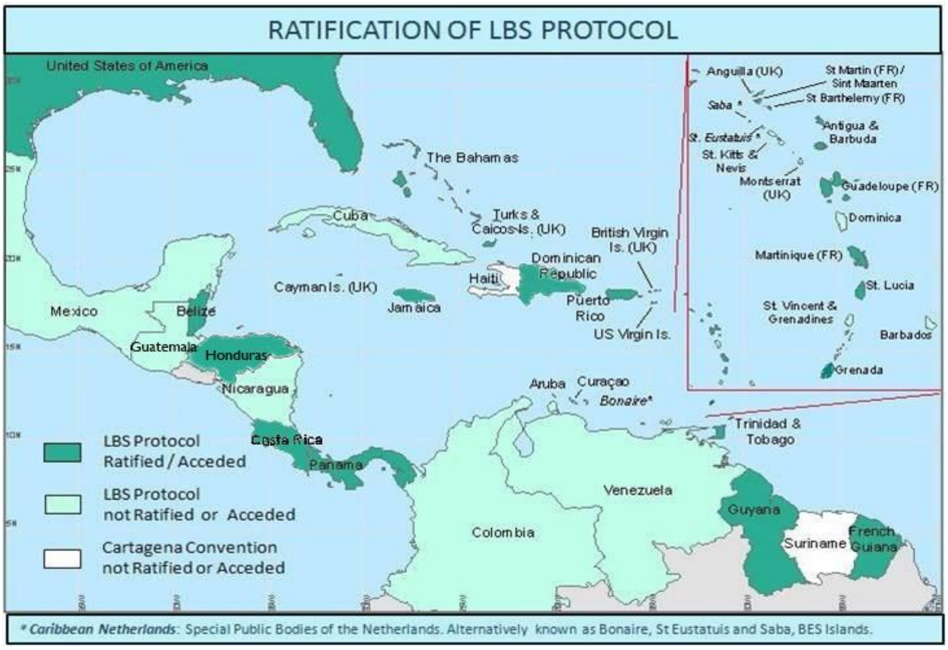

Figure 1.3. Status of ratification of the Cartagena Convention and LBS Protocol (April 2019)

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 is the culmination of a series of events and activities that date back to 1987. This first SOCAR report is preceded by two landmark technical reports that were produced by the Cartagena Convention Secretariat in 1994 and 2010: UNEP CEP Technical Report 33[6] and UNEP CEP Technical Report 52[7].

Several other reports that cover marine pollution in the region have been produced by various organizations. A recent report is the World Bank ‘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

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

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

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 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.

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 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.

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 assessment of 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 of environmental status with respect to key international agreements including Multilateral Environment Agreements; and facilitate monitoring and evaluation of the Strategic Action Programme (SAP) for the Caribbean and North Brazil Shelf LMEs[1];
- ✓ Support Governments in reporting on progress towards the achievement of 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.

The SOCAR will be complemented by a report on the State of Marine Habitats 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 two reports.

1.4.2. Target audience

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

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

This diversity reflects the need for collective action at all levels, since we all benefit from marine ecosystem goods and services but at the same time contribute to pollution of the marine environment at all spatial scales. Thus, we all have a role and responsibility to reverse the current worrying trends.

1.4.3. SOCAR development process

The proposed outline for the SOCAR was approved at the 2nd LBS COP (Decision 5), following which 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 including defining the conceptual framework, core LBS parameters, data sources, and workplan. The Secretariat contracted two consultants for the development of the report. They were supported by other experts and the LBS Working Group as well as by the Data Sub-Group that was established following the inception workshop. One-day technical workshops were held in 2017 (Cayenne) prior to the 17th IGM/ 3rd LBS COP and in July 2018 (Panama) prior to the 4th LBS STAC meeting.

The LBS Protocol STAC and 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 development of this SOCAR was supported by a series of Global Environment Facility (GEF) funded projects including GEF/UN Environment 'Reducing Pesticide Runoff to the Caribbean Sea' REPCar;GEF/UN Environment 'Integrating Watershed and Coastal Area Management in the Small Island Development States of the Caribbean' (IWCAM); GEF/UN Environment 'Caribbean Regional Fund for Wastewater Management' (CReW); GEF/UN Environment '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+) projects.

2. 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 LMEs. 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 the effective management of 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 and the presence of river systems that are among the world’s largest. The proportion of drainage basin area relative to the total national area in the WCR is 57% (see Chapter 5 of this report). 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 the marine areas. The Amazon Basin is not included, but this system also exerts a strong influence in this region’s marine area (see below).

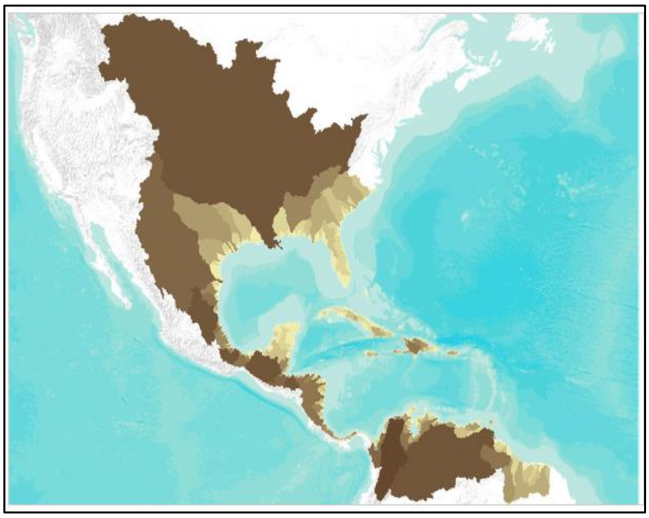

Figure 2.1. Extent of watersheds draining into the Caribbean Sea and Gulf of Mexico (Burke and Maidens 2004; https://databasin.org/datasets/b4467d4d168b4876bb2eee4ee6061a80)

Notable among the river basins are:

- *Orinoco, Venezuela*: A watershed area of about 990,000 km^2 (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 kilometers to the northwest (Müller-Karger et al. 1988).

- *Magdalena, Colombia*: This is Colombia's largest river river basin, which covers a surface of 273,000 km^2 (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)*: This is the largest drainage basin in North America, at 3.2 million km^2 in area, 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, among others, 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. (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)

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)	

2.3. Ocean circulation

The following description is based on Gyory et al (2013).

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 flows 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 off-shore of 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.

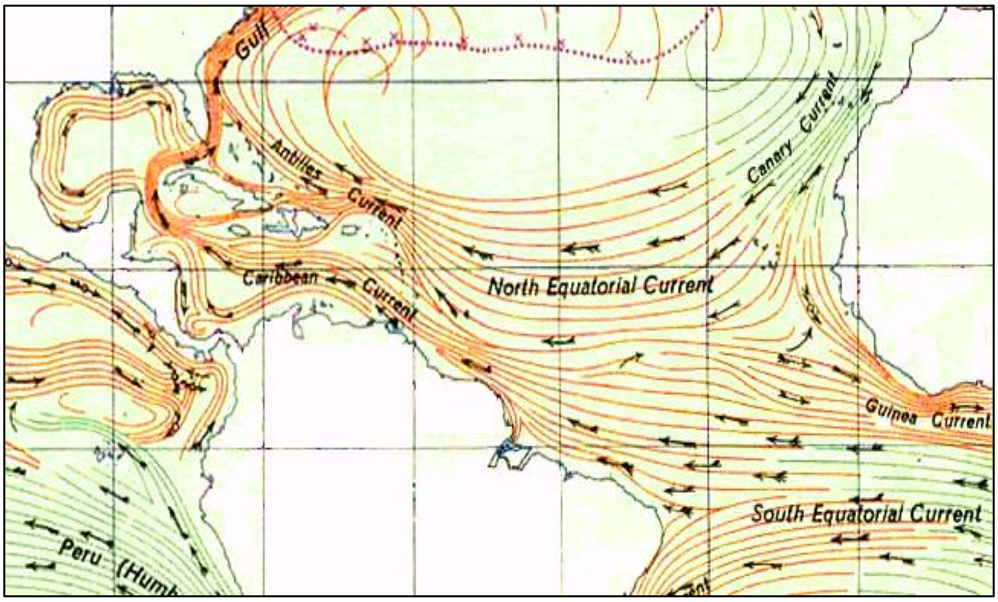

Figure 2.2. Major ocean currents influencing the Wider Caribbean Sea. (https://en.wikipedia.org/wiki/Caribbean_Current)

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. Further, mesoscale eddies and meanders in the Caribbean Sea may retain contaminants for extended periods. For example, a 10-month journey from the Lesser Antilles to the Yucatan Channel is typical for most eddies (Murphy et al. 1999).

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 of Mexico, 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, and wide expanses of muddy continental shelf and pelagic system and associated biodiversity. 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 Marine Habitats Report. As mentioned in the preceding chapter, the goods and services provided by marine ecosystems underpin important economic sectors (e.g., fisheries and tourism) in the WCR.

3. 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. It describes the interactions between human society and the environment, and was developed by the European Environmental Agency (EEA 2007).

Driver (or driving forces): The socio-economic and socio-cultural 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 runoff).

State: The state or condition of the environment and /or a socio-economic 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 socio-economic state and desired state that society aspires to[8]. These Impacts trigger Responses.

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

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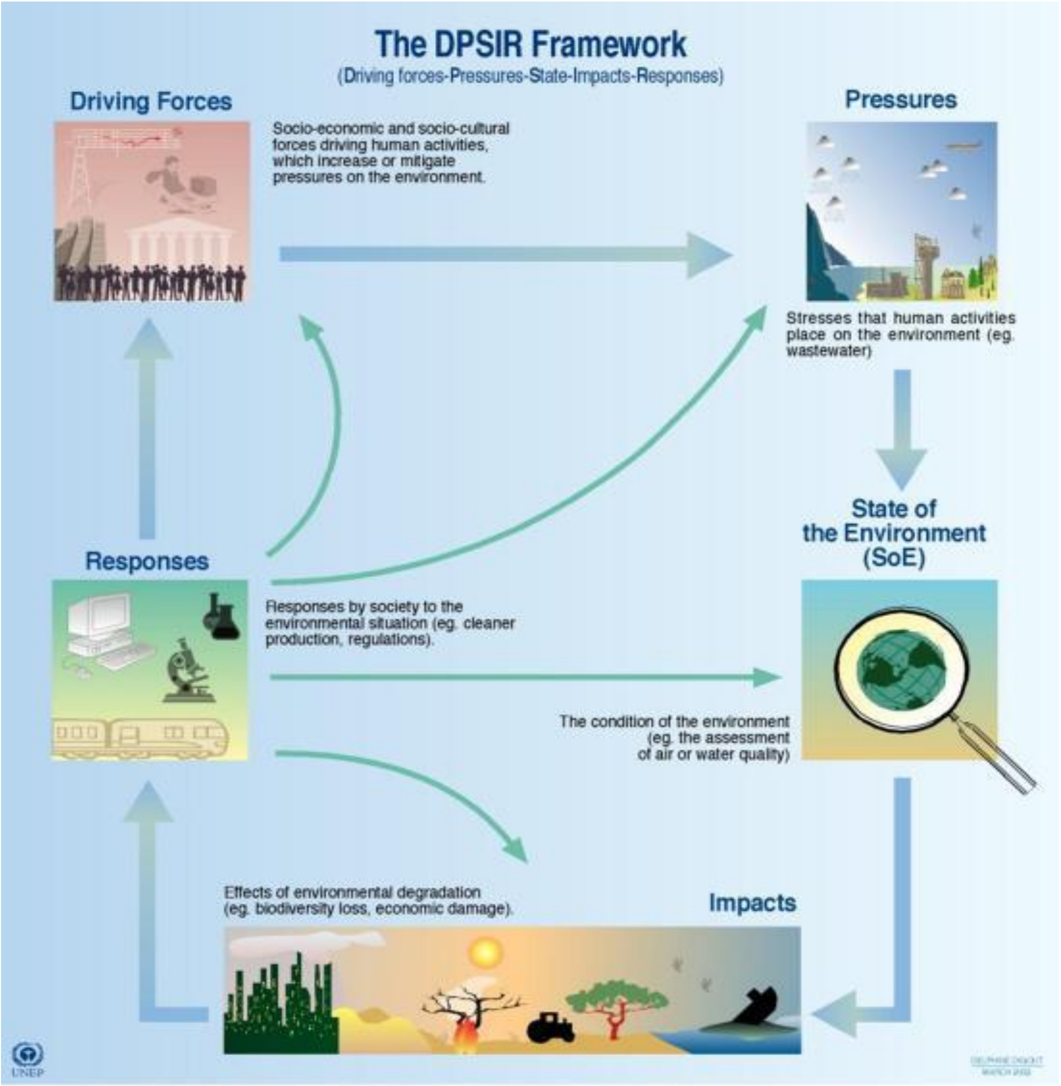
[8] CLME+ Project



Source : Global International Water Assessment (GIWA), 2001; European Environment Agency (EEA), Copenhagen.

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

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?

3.2. Geographic scale

The broad geographic scale of the assessment is the Cartagena Convention area (Figure 1.1). This encompasses the entire Gulf of Mexico and Caribbean Sea LMEs and part of the North Brazil Shelf LME and of 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 5 sub-regions (Figure 3.2 and Table 3.1) designated in the UNEP CEP Technical Report 52 (UNEP CEP 2010a).

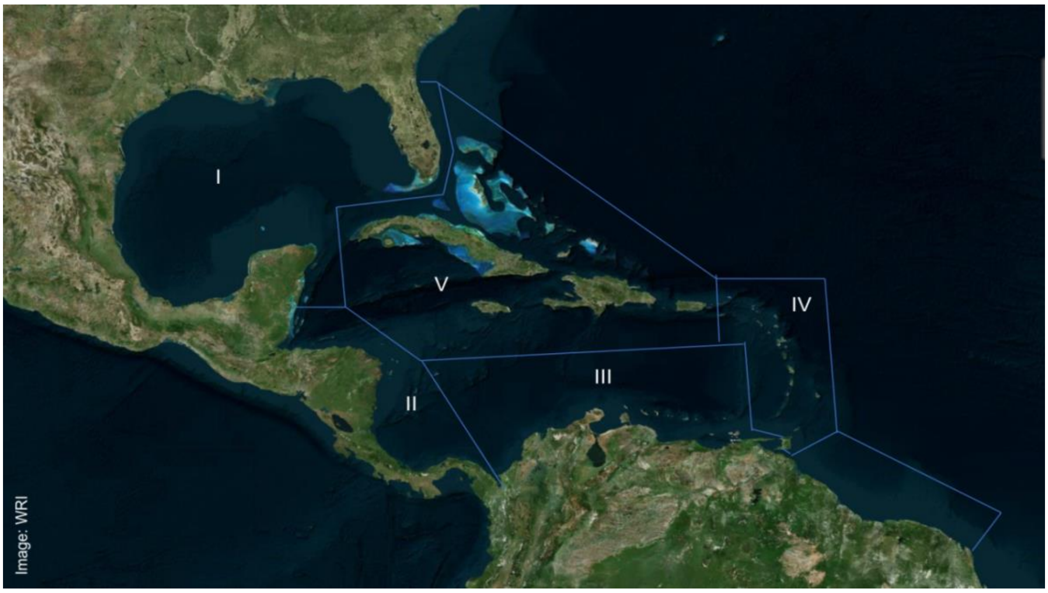


Figure 3.2. The Wider Caribbean Region and the five SOCAR sub-regions (see Table 3.1 for associated countries and territories)

Table 3.1. 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, in February 2018 the LBS Data Sub-group agreed 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 but for the SOCAR 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 of high levels in humans in several Caribbean SIDS who were thought to be exposed to mercury through consumption of certain species of marine fish.

3.3.2. Socio-economic parameters

A description of the region's key socio-economic features is necessary to understand the linkage between the human system and the marine environment, and to assess the potential socio-economic impacts of degradation of the marine environment 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[9] and Class II Waters[10] (as defined in Annex III of the LBS Protocol), but this was not feasible since most of the 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 and distributed by the Secretariat to the 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 were for sugar factory effluent and were 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[11], Dominica, Saint Lucia, and St. Vincent and the Grenadines) were available in a Master's thesis[12] from the University of the West Indies and provided by the Caribbean Public Health Agency (CARPHA). Countries and territories that submitted data, and the main parameters covered are given in Annex 3.1.

Because of sensitivity by the 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.

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[9] 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

[10] 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

[11] Not used in this assessment

[12] 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

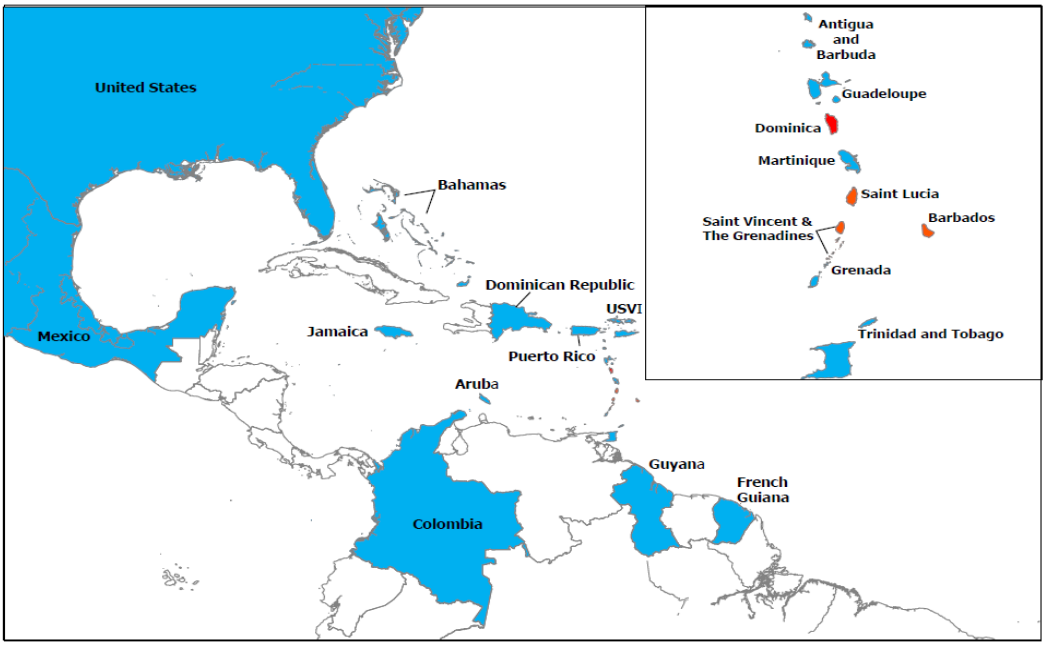

Figure 3.3. Submission of water quality data by countries
(blue: data submitted by countries; red: data from CARPHA)

3.4.2. Regional and global data sets

Modelled results for dissolved nutrient loads (DIN, DIP) 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 implemented in 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. Computational steps

For each country and territory, separate analyses were conducted for the dry and wet seasons[13] for each of the core parameters, where data availability allowed. 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[14]. The assessment ranges are based on the United States National Coastal Condition Report III (2008, http://water.epa.gov/type/oceb/assessmonitor/nccr/index.cfm), 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 (colour-coded: green [good], yellow [fair], and red [poor]; or within [green] or outside [red] of the acceptable range) was generated by season. Maps were also prepared

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[13] 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/)

[14] 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

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.

4. 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 and inadequate wastewater treatment facilities and 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 socio-economic linkages and dependencies is also critical to support WCR countries as they explore blue economy approaches.

This chapter provides the socio-economic context for the assessment of land-based pollution in the Cartagena Convention area. Socio-economic data from existing global and regional data sets, and indicators estimated by Talaue-McManus (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), the population show a decelerating increase over a 100-year period from 1950 to 2050, and 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, countries of the Western Caribbean (sub-region II) and Southern Caribbean (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).

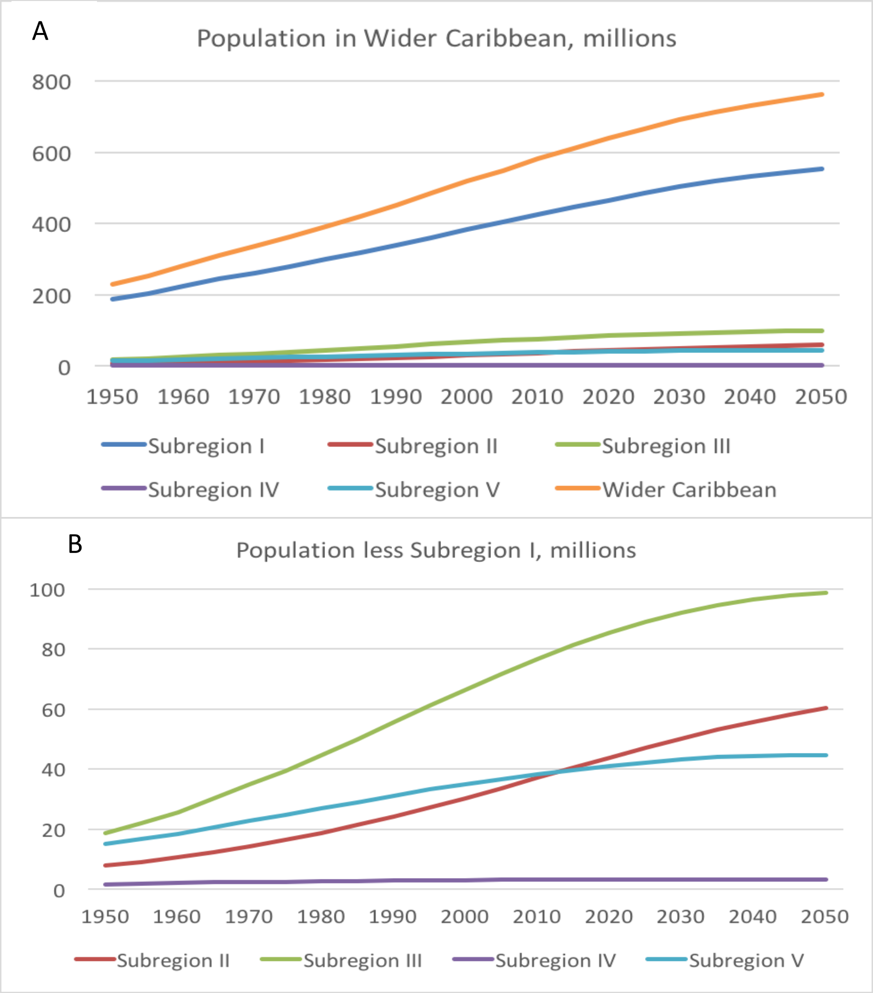


Figure 4.1. Demographic patterns in the Wider Caribbean using national population estimates for the period 1950-2050. 4.1A: Population change by sub-region. 4.1B: Population change, less sub-region 1 (Gulf of Mexico) (Data source: UN World Urbanization Prospects 2018)

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 favored 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 & 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 1049/ 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.

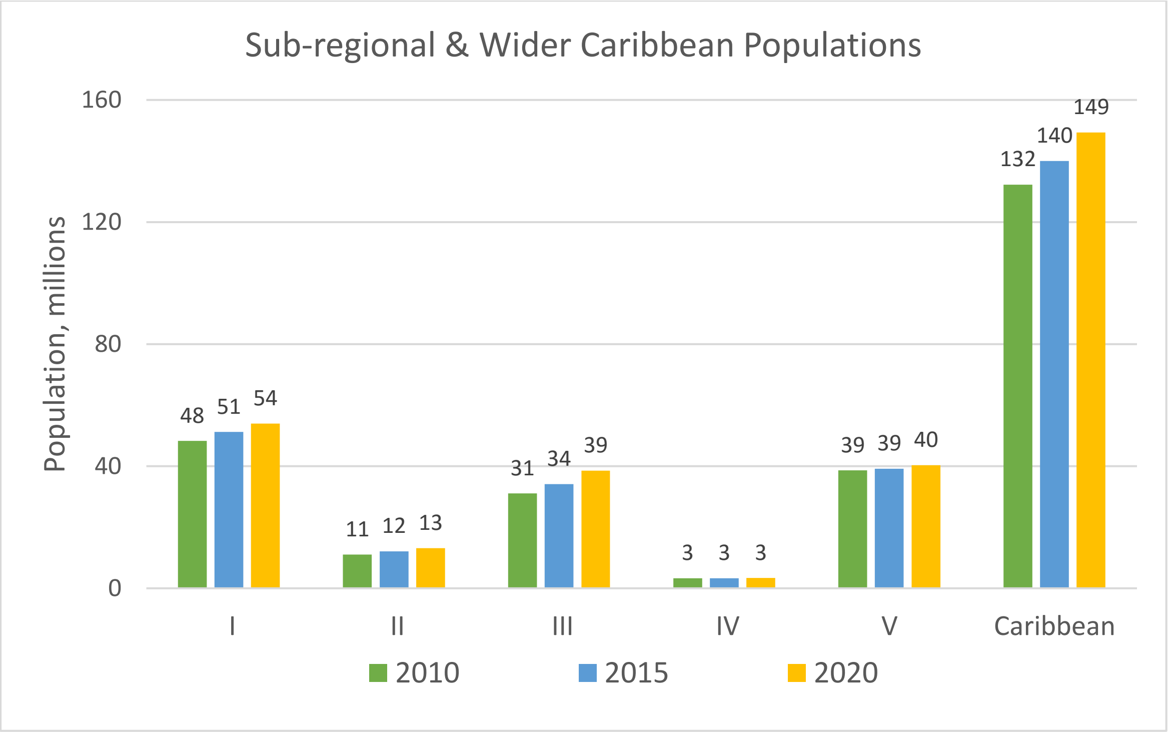


Figure 4.2. Population distribution in the Wider Caribbean Region for contemporary years 2010, 2015, and 2020 within 100 km of the coast and at the sub-regional and WCR scales. Over the 10-year period, the resident population averaged 140 million inhabitants (input data source: Spatial population data from Columbia University CIESIN 2017, and processed by CATHALAC)

4.3. Urbanization, 1950-2050

Urbanization has profound impacts on land cover and use, water cycles, and biogeochemical cycling at local and regional scales (Talaue-McManus 2010, Seto et al. 2010). Urban growth in the region has not been accompanied by adequate urban planning, especially in the small and medium sized cities (UNEP 2016). 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 Andres 2015).

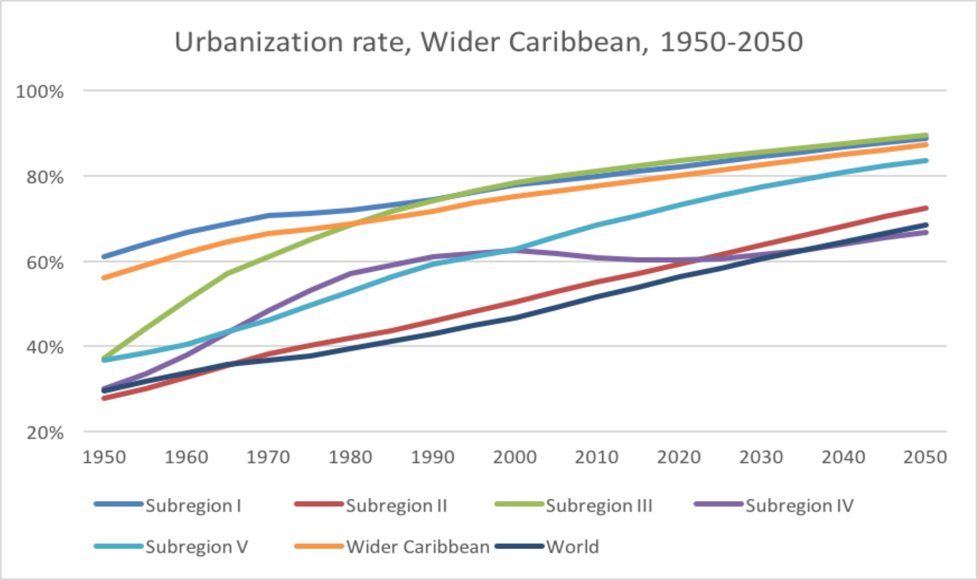


Figure 4.3. Urbanization rate in the WCR for the period 1950-2050 (Input data source: UN Population Division Urbanization Prospects 2018).

To identify centers of coastal population growth for the period 1950-2030, the coastal cities and agglomerations of 300,000 and above in population size 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).

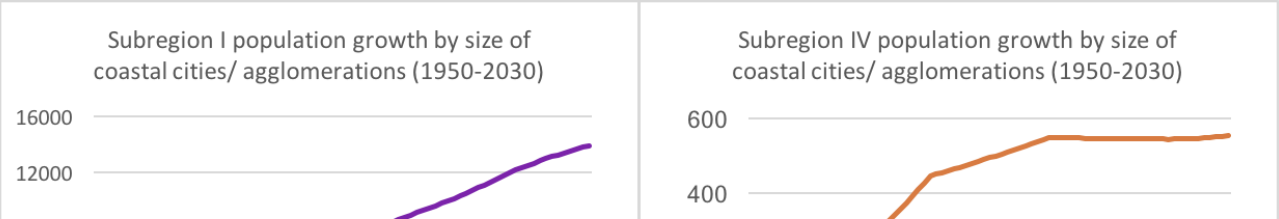


Figure 4.4. Sub-regional population growth (in thousands) by size of coastal cities agglomerations for the period 1950 to 2030. (Input data source: UN Population Division Urbanization Prospects 2018).

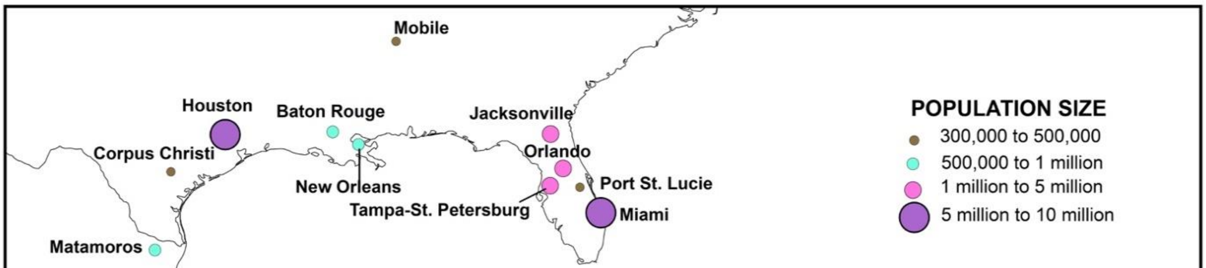


Figure 4.5. Main coastal urban centers in the WCR based on population sizes in 2017 (data from UN Population Division Urbanization Prospects 2018; map prepared by CATHALAC)

Pressures on coastal areas from urban centers are exacerbated by increased urban runoff due to replacement of vegetation (such as forests and agricultural lands), including on hillsides and steep slopes, with paved surfaces and built up areas that are impervious to water infiltration. 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 runoff. Impermeable surfaces also prevent water infiltration that helps replenish groundwater.

Since the late 1970s, studies began to chronicle the visible degradation of aquatic ecosystems as 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 runoff 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 initially, 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).

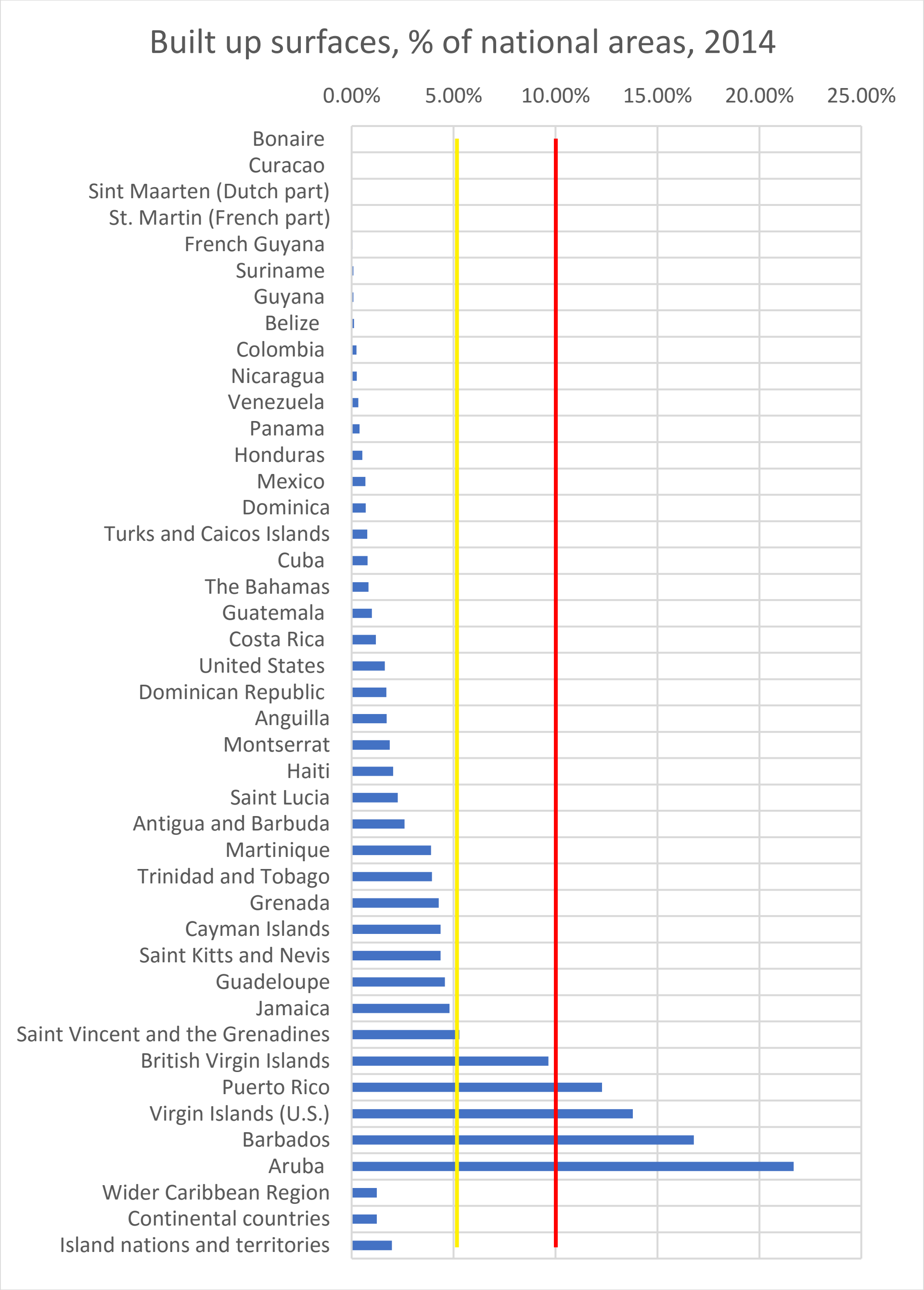


Figure 4.6. Built-up areas by country or territory as a percentage of national territory area in 2014 (data from OECD.Stat) including the 5% threshold yellow line and 10% threshold red line.

Demographic and development changes in the Wider Caribbean have long crossed the threshold of irrevocable land use change caused by increasing built-up surfaces decades before the world at large did, and may be reaping both 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 in assessing the Human Development Indices (HDI) for each of the 25 sovereign countries in the WCR, for which data is available are given in Annex 4.3 (with technical notes in Annex 4.1). Based on the average 5-year HDI for the period 2011-2015, 19 states have high HDI, 4 have medium HDI, 1 has very high HDI, and 1 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 USA. Per capita Gross National Incomes exceed US$20,000 for a number of countries including the USA, Antigua and Barbuda, Saint Kitts and Nevis, The Bahamas, and Trinidad and Tobago.

With the majority of the sovereign states belonging to the high HDI category, the WCR in general enjoys a level of affluence that whets appetites for lifestyles requiring greater consumption of energy and higher extraction rates of ecosystem goods and services, than 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 capacity to recover, reuse, or treat waste, a variety of consumer products and substances of industrial origin end up in coastal and marine waters.

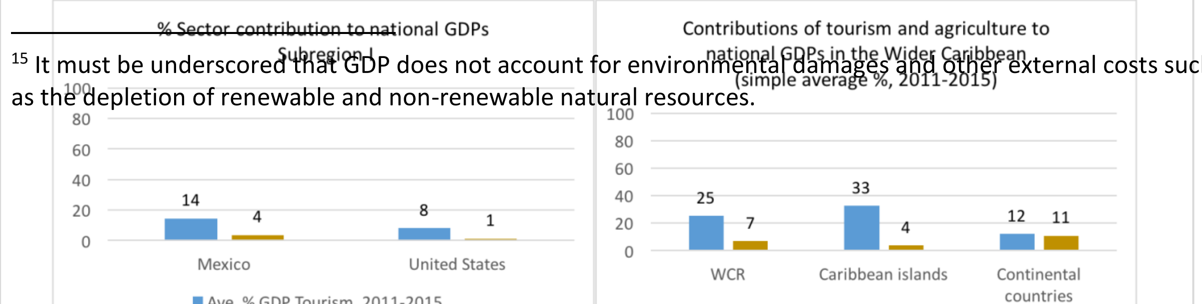
4.5. Major economic sectors related to the marine environment

Tourism and capture fisheries, in addition to agriculture, shipping, manufacturing, and petroleum industries are among the major contributors to the Gross Domestic Product[15] (GDP) in specific WCR countries. On the other hand, these sectors also represent major sources of pressures, including land-based pollution, on the environment and natural living resources. 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 the relevant 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.

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 (Talaue-McManus, 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, and accounts for over 50% of GDP for 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, obtaining only 12% of their GDP from tourism on average. At the regional scale and 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.



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[15] 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.

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).

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 is its coral reefs. A recent study estimated the total value for all reef-associated tourism (on-reef and reef-adjacent[16]) in the Caribbean at over US$7.9 billion of expenditure and 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 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 at 34% as the main target destination in 2013 (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 destinations, and economic incentives to develop high value tourism packages remain.

But tourism, particularly mass tourism, can be a threat to itself, which may be more pronounced around coral reefs that 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, and other recreational vessels, produce vast quantities of waste. For example, on a one-week voyage a moderate-size 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 tons of garbage (WWF 2015). An important component of the tourism services complex in the region is the yachting and marina sub-sector (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.

Fisheries

In the WCR, for the latest available 5-year dataset from 2010-2014, the average annual landed fisheries catch of 2.2 million tons was priced at 2010 constant 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 (Talaue-McManus, this study); 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). Yet, 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 sub-sector, the majority of fishers

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[16] 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. It includes values derived from views, calm waters, coastal protection, beach generation, and high-quality seafood.

in countries and territories of the WCR are artisanal, made up of small-scale commercial fishers, who fish mostly in domestic waters with passive (stationary) gear (Pauly and Zeller 2018).

Some of the countries and territories show a high dependence on fish as a protein source, particularly the islands, 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, including women, in the region. Moreover, the sector (including fish farming) represents a vital social safety net, especially for rural communities.

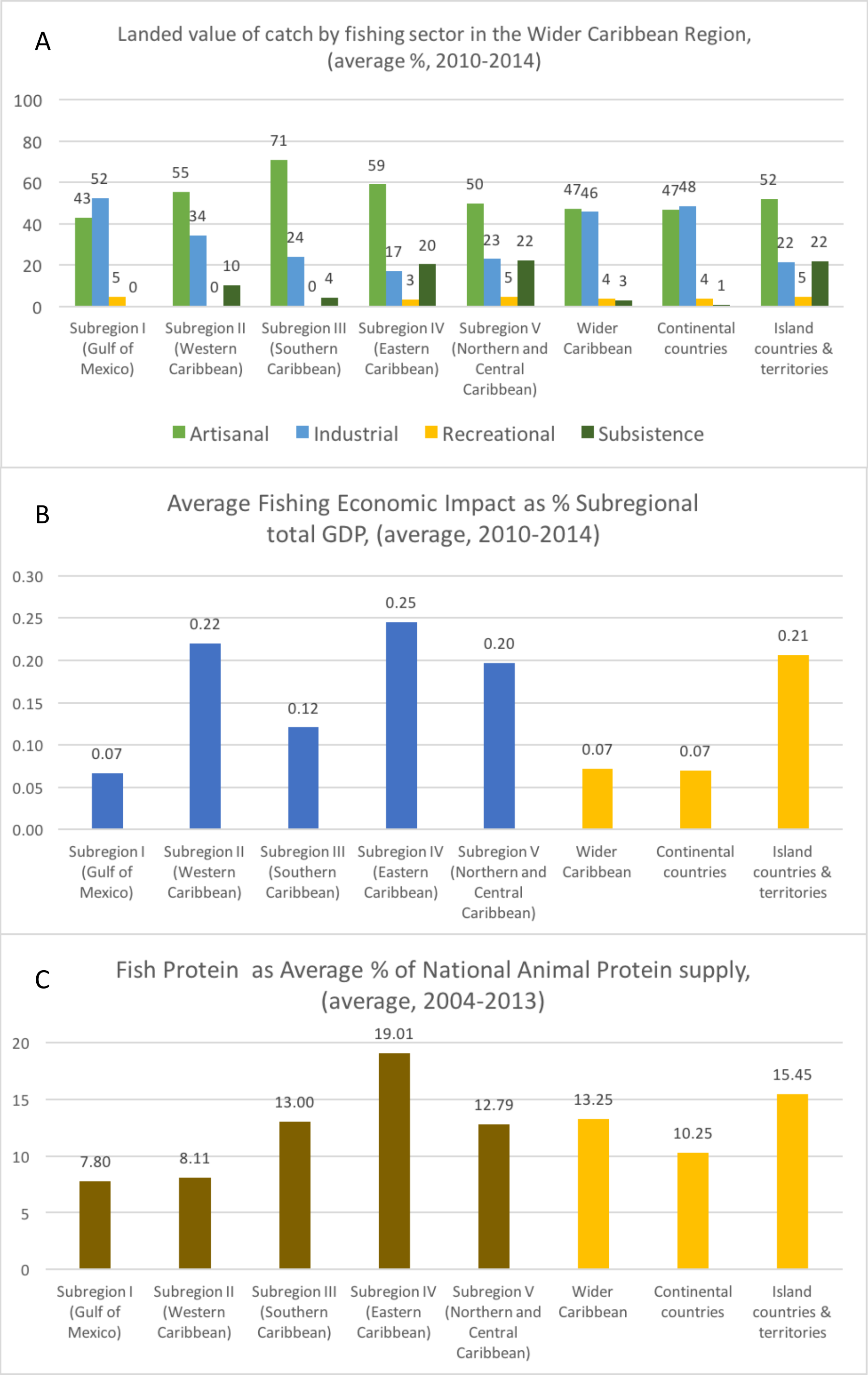

Figure 4.8. Characteristics of marine fisheries in the WCR and its total economic value for 2010-2014. A. Landed value as average percentages from artisanal, industrial, recreational and subsistence fishing sectors for 2010-2014; B. Fishing economic value as percentage of sub-regional GDP or Group total GDP for 2010-2014; and C. Fish protein as average % 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 years 2000 to 2010, overexploited and collapsed fish stocks increased to 24% and 25%, respectively, or almost half of the total number of fish stocks in the four LMEs that make up the Wider

Caribbean fishing grounds. 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), and 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 pollution of the marine environment 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, ensuring minimal seafood contamination by pollutants, and pathogen- or toxin- bearing organisms amidst increasing demand by residents and tourists for seafood, are some of the tough challenges the fishing sector currently faces.

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 production of about 40 million tons of fish in less than 1.5 % the countries' Exclusive Economic Zones (EEZ). Production in Latin America and the Caribbean (LAC) by countries producing 100 tons per year or more for the period 2012-2014 is presented in Table 4.2. In 2015, Mexican farmed shrimp production amounted to 90,600 tons, 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 nearest whole number) in LAC by countries producing 100 tons per year or more, 2012-2014 (FAO 2017, based on data in FAO FishStat 2016)

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

Aquaculture requires good water quality but at the same time, this activity can have significant adverse environmental impacts on surrounding areas. Increased production has combined with greater use of antibiotics, fungicides and anti-fouling agents, which in turn contribute to pollution of downstream 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). To this must be added the contribution of contaminants from other sectors that together can result in poor water quality, jeopardizing the development and sustainability of aquaculture and mariculture in the region. This is particularly concerning considering the increasing demand for seafood, overfishing and collapse of some fisheries, and the large imports of seafood by many of the countries.

4.5.2. Agriculture

In the WCR, 22 countries generate considerable wealth through agriculture (crop and livestock farming), with 12 reporting at least 5% contribution to GDP per year, on average, for the period 2011-2015 (Figure 4.7, Talaue-McManus, this study). Among Caribbean islands, agriculture posts a modest average contribution of 4%, given real constraints in the size 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, agriculture and fishing, which deal with food commodities, appear to generate low contributions to GDP compared to service sectors such as tourism, at the macro-scale.

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 and, in intensive systems, heavy metals, drug residues, hormones, and antibiotics (FAO 2018), which can pollute surface and groundwater.

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 take into account 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 few among a list of many, which should reshape farming in the region. How such shifts alter fertilizer use and nutrient loading are 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 can be hope to achieve nutrient reduction in the WCR.

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.

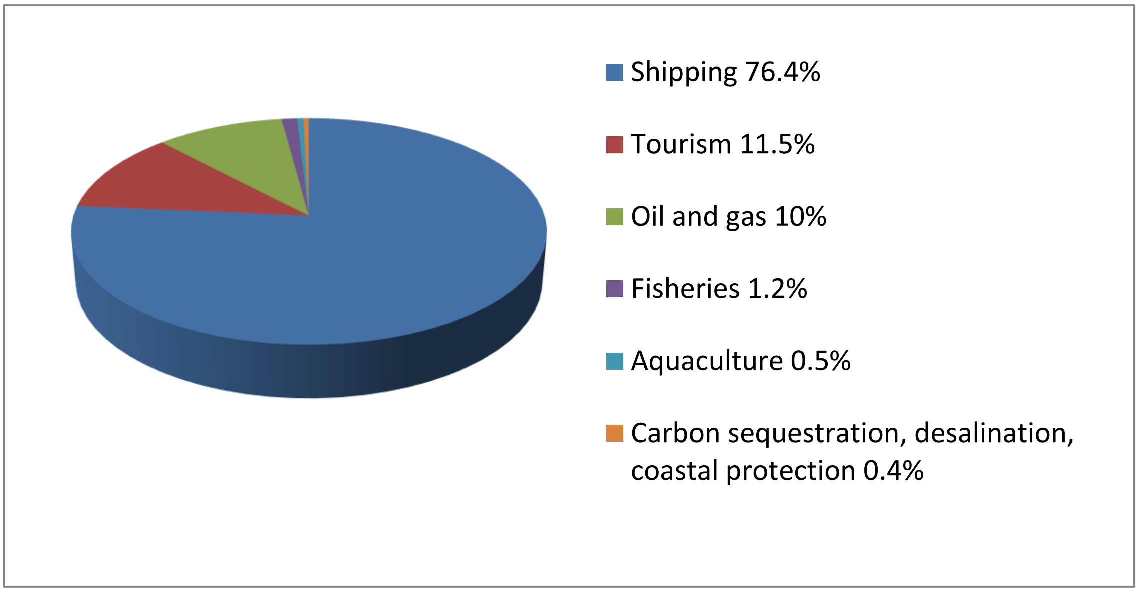

Figure 4.9. The measurable ocean economy in the Caribbean in 2012 (Data from Patil et al. 2016).

Some of the region's container ports (Colon and Balboa in Panama; and Georgia and Houston in the USA) are among the world's largest ports[17]. 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 OECS ports (CBD 2016). With the opening of the expanded Panama Canal in 2016, maritime transport in the Caribbean basin is expected to witness 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

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

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.

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 activities conducted within the 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 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 Dominican Republic (UNEP CEP 2010).

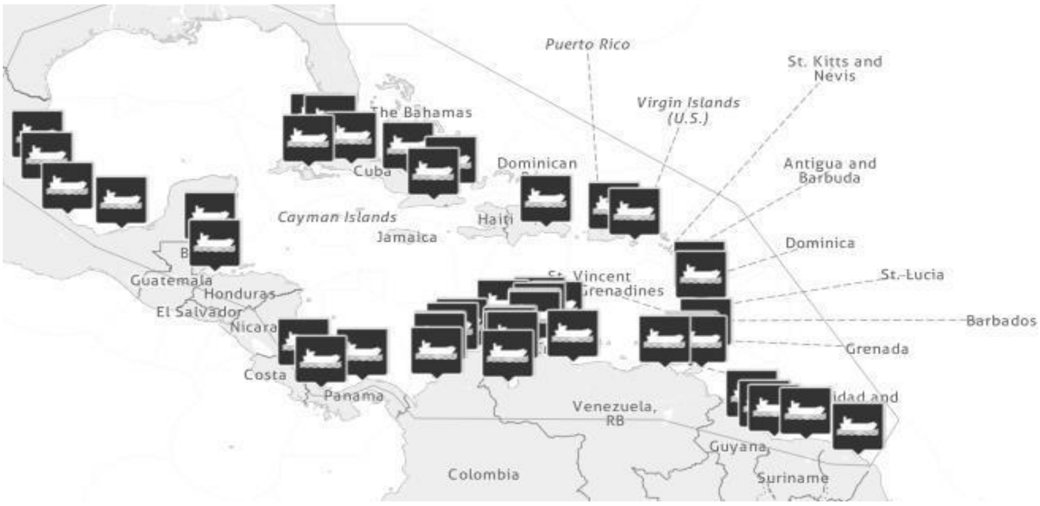

Figure 4.11. Oil terminals in the WCR (Source: http://cep.unep.org/racrempeitc/maritime-traffic).

Increased industrial diversification is taking place in many countries of the region. However, while the industrial sector brings significant socio-economic benefits to the countries, 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.

The pressures or stressors on the marine environment that are associated with human activities and economic sectors are discussed in the following chapter.

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 of the 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 tons of total nitrogen and 190,000 tons of total phosphorus are estimated to have been released to coastal waters of the WCR 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 runoff, 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 centers 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, and 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 owing to 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 the assessment of 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 (rivers and outfalls) and non-point sources (runoff and leaching) as well as atmospheric deposition. While polluted rivers are generally considered as 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). Groundwater is highly susceptible to pollution due to the ease of percolation of water, which can be laden with contaminants that are eventually discharged into the coastal environment with little assimilation. Direct emission of domestic wastewater and sewage through submarine outfalls is another common practice in the region.

Box 5.1. Polluted waterways

- Rivers: Nearly all the transboundary rivers in this region have been found to be at very high risk from wastewater pollution, and several of them at high risk of nutrient pollution (UNEP-DHI and UNEP 2016). In addition, there is evidence of widespread pollution of national rivers in the region.
- Groundwater aquifers: A recent assessment of groundwater aquifers in Caribbean SIDS showed that among 17 SIDS, nine are at very high risk and seven at moderate risk from anthropogenic pollution, with only one (Aruba) at low risk (UNESCO-IHP and UNEP 2016).
- In Cuba, five main sources of pollution to karst aquifers have been identified: sea water intrusion, agricultural practices, waste disposal, industrial activity, and mining and oil production (León and Parise 2009).
- Hernández-Terrones et al. (2015) found high nitrate levels and high coliform bacteria densities in coastal aquifers at some sites in the eastern Yucatan Peninsula of Mexico.
- The karst aquifer system along the Caribbean coast of the Yucatan Peninsula in Mexico was found to be contaminated with pharmaceuticals and personal care products originating from domestic sewage; PAHs from runoff from highways and other impermeable surfaces; and herbicides applied to golf course turf (Metcalfe et al. 2011).

5.3. Domestic (municipal) wastewater loads

5.3.1. Overview

Untreated municipal wastewater is of particular concern in the WCR, because of its direct threat to public health arising from its 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, faecal bacteria, chemicals, suspended solids, and contaminants of emerging concern such as endocrine disruptors[18] and hormones, among others. Nutrients and faecal bacteria (as indicators of faecal contamination) are of particular focus for this assessment.

Population growth including rapidly expanding urban populations without 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 (UNEP CEP 2010Most of the 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).

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[18] 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.

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 the 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 degradation in 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. Quantifying the amount of municipal wastewater generated and that which is potentially discharged to coastal waters, given available data on treatment levels, are first attempted in this report.

5.3.2. Volume of municipal wastewater potentially discharged in coastal waters

In this report, an analysis of untreated and discharged wastewater for the WCR is attempted for the first time (Talaue-McManus, this study). 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 cubic meters of municipal water was withdrawn in the region, from which 15 x 10^9 cubic meters of wastewater were generated in 2015, 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 to coastal waters in 2015 (Table 5.1; see data sources, technical notes and input data in Annex 4.1 and additional results in Annex 5.1). 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 post-secondary treatment methods can rid wastewater of nutrients, pathogens, heavy metals, and toxins. Data on the level of sewage treatment (primary, secondary, tertiary), the percentage of population connected to each treatment level, and the amount of wastewater discharged or reused 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 analysis of domestic liquid waste, noting that tourism will remain a major economic driver in the region for the long-term.

Table 5.1. Municipal wastewater discharged in the WCR in 2015, expressed as annual volume and its 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 coastal water quality impairment. Eutrophication promotes increased growth and biomass of phytoplankton (expressed by 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 termed 'dead zones' due to the absence of macrofauna) and 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. The 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 to coastal waters from diffuse (non-point) and point sources in increasing quantities. Among the major anthropogenic sources of nutrient loading to coastal areas are untreated sewage, runoff 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 faecal wastes (FAO 2017). Fertilizer use in tourism especially for golf courses in coastal areas may be another substantial source of nutrients via runoff 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 to coastal waters is expected to continue to increase in the coming decades.

5.4.2. Assessing nutrient inputs to 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; Talaue-McManus, this study). About 610,000 tons (0.61 Tg) of nitrogen and 100,000 tons (0.1 Tg) of phosphorus were contained in the 15 x 10^9 cubic meters of domestic wastewater generated in 2015. These values are slightly higher than the model year 2000 values of nitrogen (0.51 Tg) and of phosphorus (0.07 Tg) calculated from the Beusen et al. 2016 global data set, noting a 15-year difference in model years.

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 the WCR countries was implemented by Talaue-McManus (this study) using FAOSTAT data on fertilizer usage expressed in total nutrient (nitrogen and phosphorus) weights for the year 2002. The values obtained, which were at national scale, were scaled to the total drainage basin area draining to WCR coastal waters relative to 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, modeled estimate of agricultural sources of total nitrogen for model year 2000 was 3.3 Tg; and of total phosphorus to be 0.34 Tg (Talaue-McManus, this study 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 arable land in total nutrient weights to further constrain estimates. (See Annex 4.1 for data sources and methods).

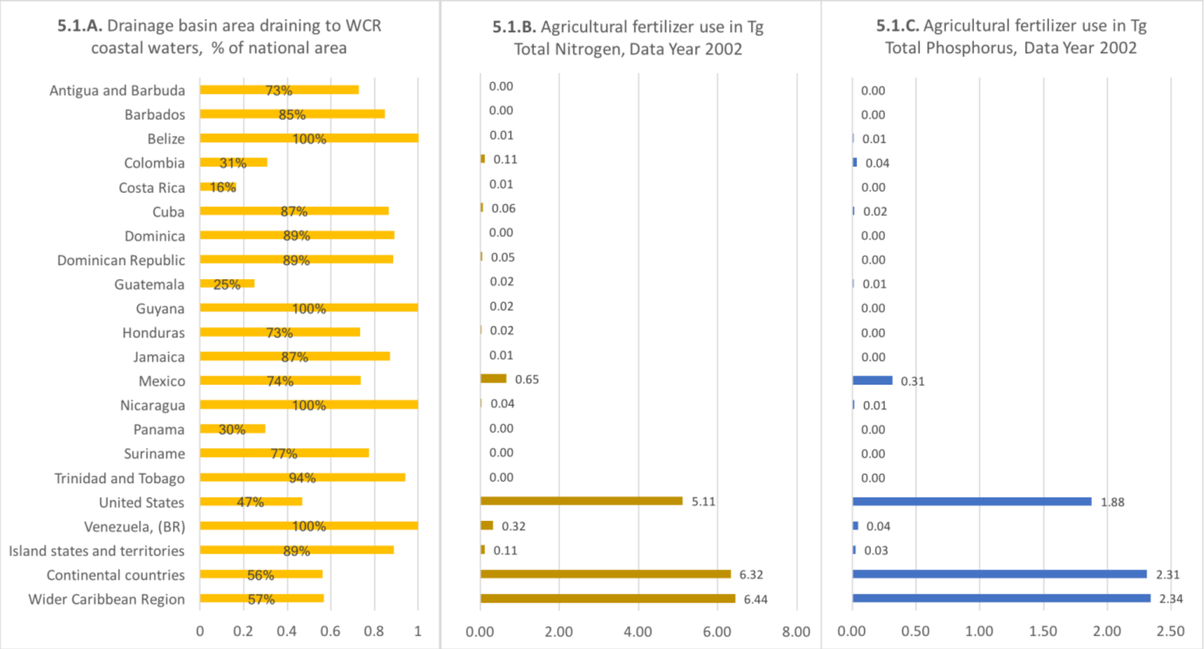

Figure 5.1A. Proportion of drainage basin area draining to WCR coastal waters relative to national area; Figure 5.1B. Agricultural fertilizer use in Tg total nitrogen (data year 2002); and Figure 5.1C. Agricultural fertilizer use in Tg Total Phosphorus (data year 2002). See Annex 4.1 for data sources and methods.

Model-based assessment of nutrient sources and loads

A fundamental limitation of nutrient source inventories is the absence of monitoring programmes that regularly track nutrient sources, both diffuse and point sources, at watershed scale. Integrated models offer a mechanistic approach to help understand how socio-economics, biogeochemistry, hydrology, and climate, among others, 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 UN Environment-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 simulated results of an integrated global nutrient model for year 2000 by Beusen et al. (2015, 2016)[19]. Modeled values of nitrogen by source, extracted from the global modeled dataset, are presented for the WCR in Table 5.2, Figures 5.2, and 5.3 (detailed results by sub-region are given in Annex 5.2). Agriculture surface runoff 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 modeling results indicate that this can and should be empirically validated.

Sewage contributes 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 runoff and groundwater), compared to sewage, and further, the dominance of groundwater (non-point sources) at the regional scale have come as surprises, considering that the focus has conventionally 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.

Table 5.2. Modeled 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 runoff (agric)**	**Surface runoff (natural)**	**Groundwater (agricultural)**	**Groundwater (natural)**	**Sewage**	**Aquaculture**	**All N inputs**
WCR (10^3 tons)	58.49	749.31	1083.15	63.60	2195.23	798.97	509.42	9.59	5467.76
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**

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

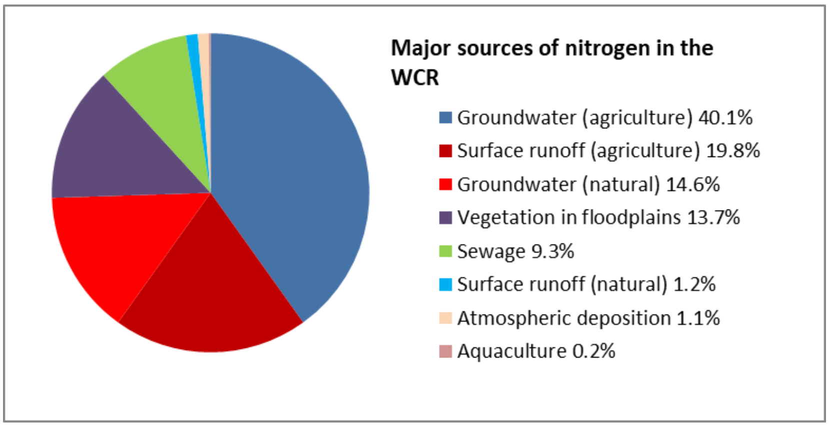

Figure 5.2. Proportion of nitrogen by source for the WCR for year 2000 (see Annex 4.1; based on data from Beusen et al. 2016)

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 runoff followed by agricultural groundwater
- Sub-region III: agricultural groundwater followed by surface runoff
- 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 runoff 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.

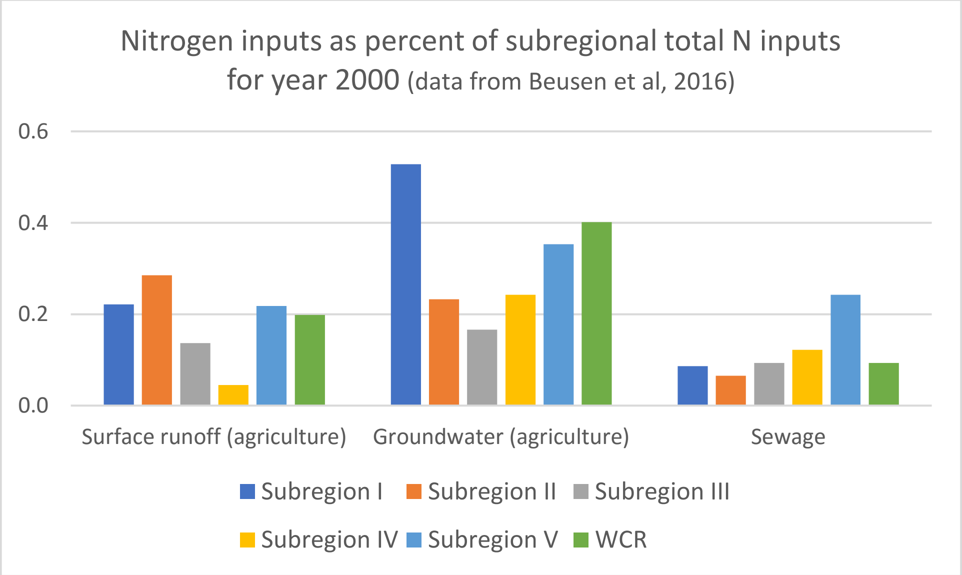

Figure 5.3. Nitrogen contribution by major anthropogenic source as proportions of sub-regional totals for each source (see Annex 4.1; data from Beusen et al. 2016)

Modeled values of phosphorus by source and by sub-region of the WCR were computed from Beusen et al. (2016) (see Annex 4.1 for technical notes) for year 2000 (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, agricultural runoff accounts for about 56% and sewage 11%, of phosphorus discharges (Figure 5.4). The inventory for domestic wastewater phosphorus at 0.0.10 Tg in 2015 in this assessment is higher than modeled sewage phosphorus at 0.07 Tg for model year 2000, noting the 15-year difference between model years (Annex 5.2). High amounts of sewage phosphorus are observed in sub-regions IV and V at 19% and 20%, respectively, as is also observed for sewage nitrogen 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.

Table 5.3. Modeled 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 runoff agriculture**	**Surface runoff natural**	**Sewage**	**Aquaculture**	**All P inputs**
WCR (10^3 tons 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**

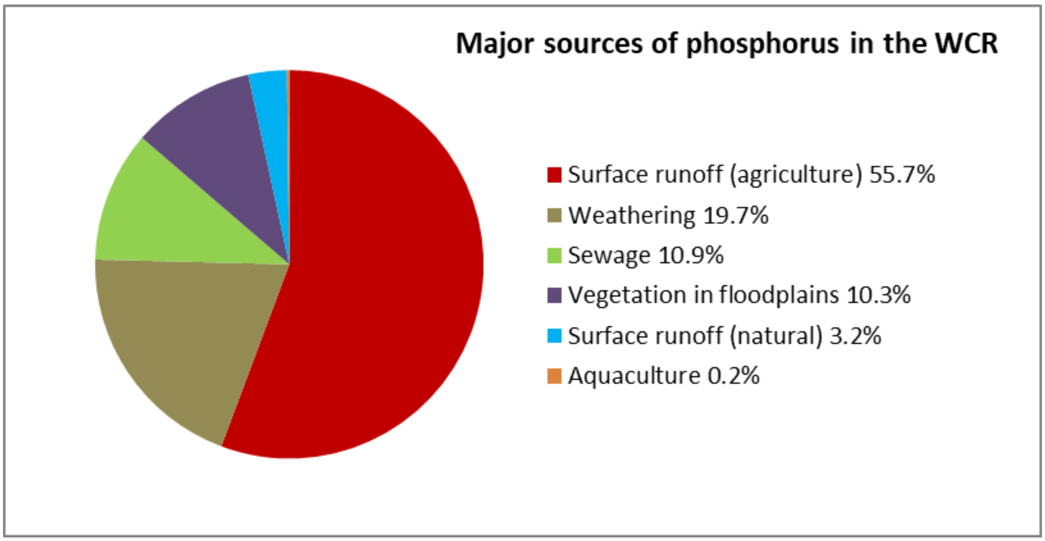

Figure 5.4. Proportion of phosphorus by source for the WCR for year 2000 (based on data from Beusen et al. 2016)

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

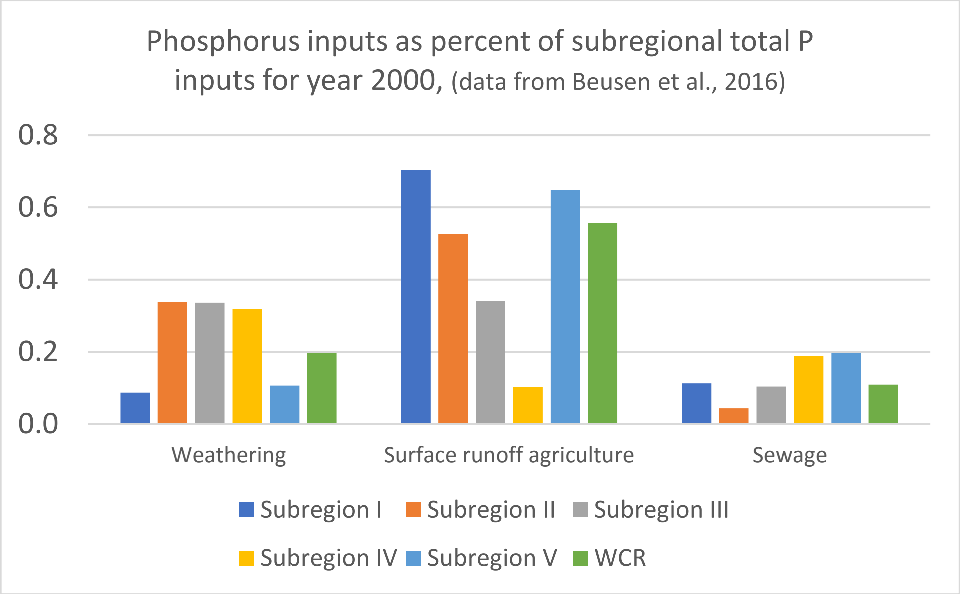

Figure 5.5. Phosphorus contribution by major anthropogenic source (and weathering) for each sub-region, as a proportion of sub-regional totals for each source. See Annex 5.3 for detailed phosphorus sources by sub-region (based on Beusen et al. 2016).

Table 5.4 compares two sets of modeled data (Mayorga, this study based on Seitzinger and Mayorga 2016; Talaue-McManus 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 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.

Table 5.4. Comparison of modeled 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 Subregion	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 modeled coastal nutrient loading, 1900-2000

Over the 20th century, simulated nutrient loads in the region (Talaue-McManus, this study, using input data from Beusen et al. 2016) show a jump in nitrogen loading beginning in the 1960s when total loading crossed the 2 Tg (2 million tons) mark (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 loaded to coastal waters. In the case of phosphorus loads, the 100-year simulation 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[20] are conveyed to coastal waters is of particular importance as 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 simulations 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 favored 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 currently 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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[20] Including nitrogen, phosphorus, silica and other macro- (e.g., potassium, calcium, magnesium) and micronutrients (e.g., iron, zinc, molybdenum)

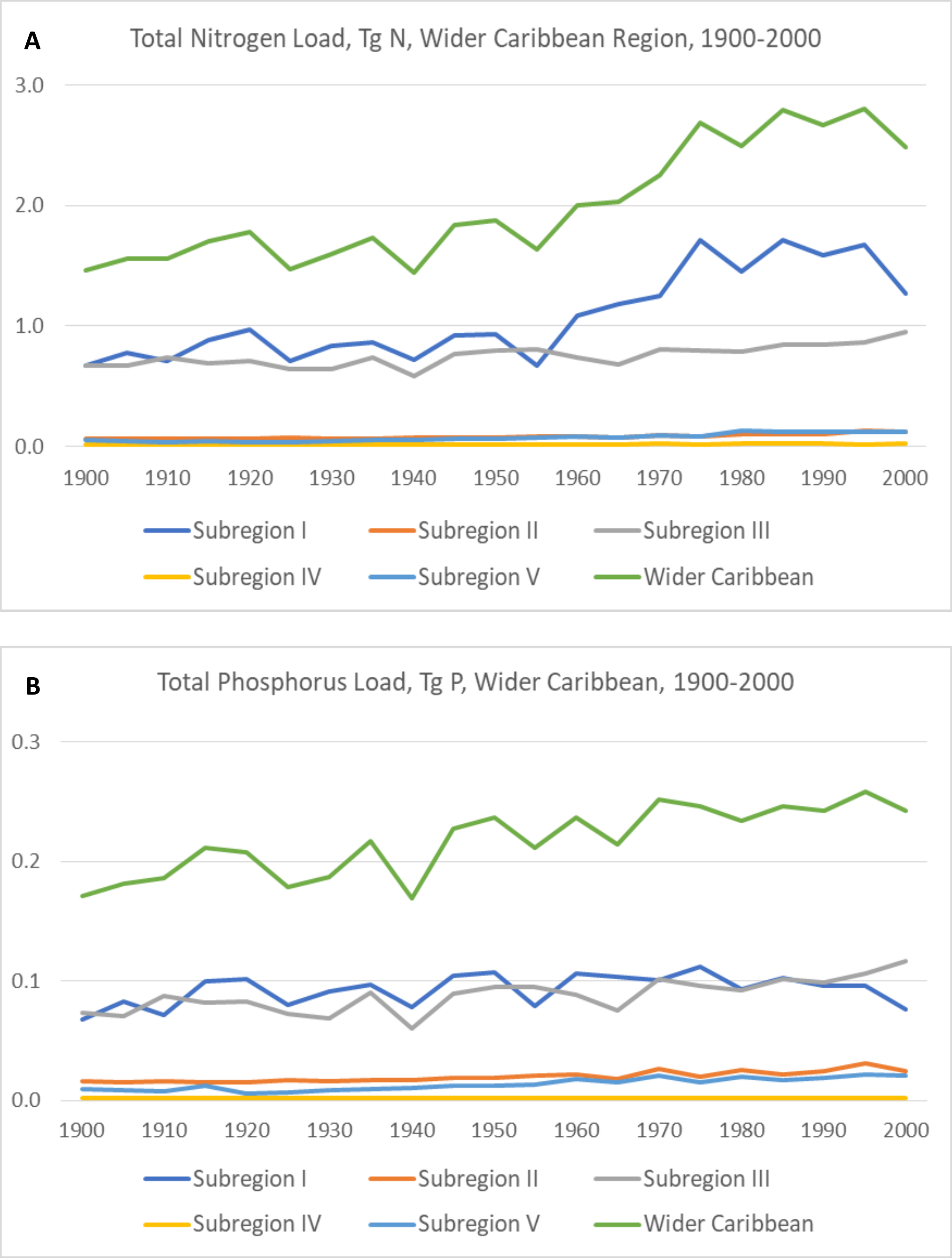

Figure 5.6. Simulated nitrogen (A) and phosphorus (B) loads in each sub-region and the WCR for the 20th century (input data from Beusen et al. 2016).

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) are directly utilizable 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). Nutrient indicators assessed for SOCAR 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)- see Box 5.2.

Box 5.2. Global Nutrient Export from Watersheds (NEWS) model

The Global NEWS model simulates the river export of nutrients from land to coastal seas, and quantifies the annual river export of nitrogen, phosphorus, carbon, and silica in dissolved inorganic, organic, and particulate forms. Model outputs are quantified at the basin scale as a function of human activities on land (e.g., agriculture and urbanization) and basin characteristics (e.g., hydrology).

NEWS model outputs were developed at a grid cell resolution of 0.5 degrees (basins made up of 0.5 degree x 0.5 degree grid cells), or about 50 km x 50 km. Given this resolution, many small coastal watersheds were effectively aggregated into a single cell, and larger watersheds that may be equivalent to only a few cells are likely misrepresented. Therefore, results should not be used directly for basins made up of less than 10 cells; such results should only be used via further aggregation into larger spatial units. Since the NEWS is a global model, its resolution is fairly coarse for the SOCAR sub-region IV, in which there are many small islands. In this sub-region, the only island that is actually modeled is Trinidad (Trinidad and Tobago); no other island in this sub-region is included since they are too small for the Global NEWS resolution. For smaller regions applied at a sub-global scale, the model's utility should be critically evaluated.

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 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-regions II, associated with river basins such as the Motaqua and Chamelecon. An assessment of nutrient pollution in transboundary river basins conducted under the TWAP River Basin component (UNEP-DHI and UNEP 2016) revealed that several rivers in the region had a high (Catatumbo, Massacre, Artibonite, and Motaqua) and moderate (Chamelecon and Rio Grande) risk of nutrient pollution. As expected, in general, the larger the watershed the greater the 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 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 (tons 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**	

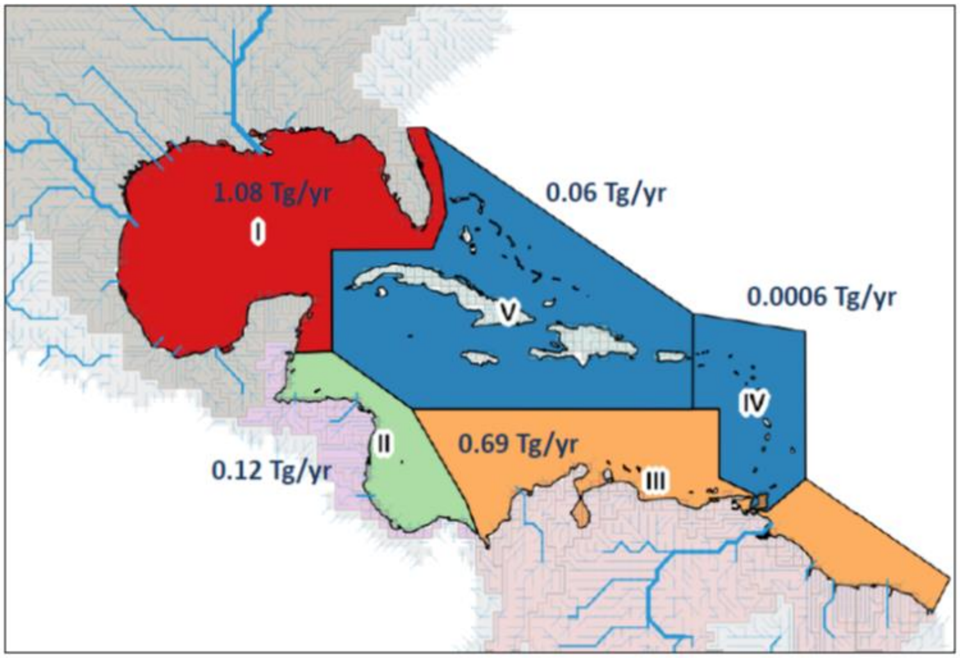

Figure 5.7. DIN inputs from watersheds to coastal areas in the five sub-regions, in Tg per year. Colours represent the range of values (red=highest; orange=high; green=medium; blue=lowest).

5.5. Sediment mobilization

Natural processes (including naturally occurring coastal erosion and local hydrodynamic and weather conditions) and human activities alter sediment fluxes and contribute to increase 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 10–20 years (Restrepo et al. 2016a) and the percentage of forest cover was estimated to have declined from 46% in 1970 to 27% in 1990. The Uraba´ region is Colombia's main producer of bananas 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 the year 2020 (Restrepo et al. 2016a). Estimates of loads of total suspended solids (TSS) are presented for each sub-region in UNEP CEP (2010a). The highest loads are from watersheds in sub-region I followed by sub-region 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 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 reduce the pH of seawater.

5.7. Industrial pollution and hazardous waste

Estimates of industrial pollution loads of Biological Oxygen Demand 5 (BOD_5), Chemical Oxygen Demand (COD), total suspended solids (TSS), total nitrogen, and total phosphorus discharged to 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 marine environment, although specific areas are known where such problems 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.

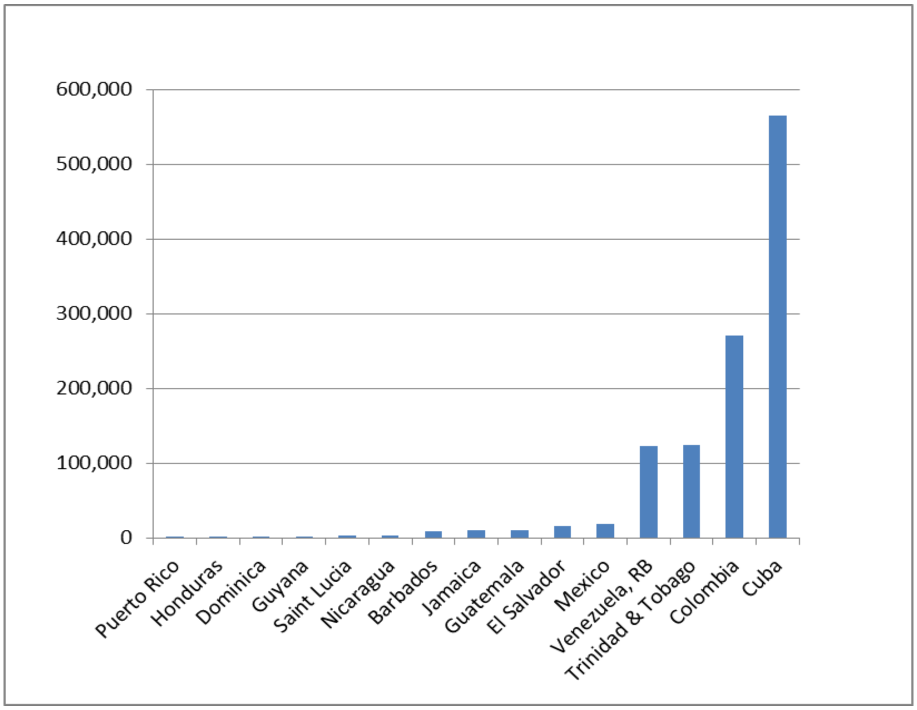

Figure 5.8. Hazardous waste (tons yr^{-1}) produced by selected countries in the WCR. Source: https://datacatalog.worldbank.org/dataset/what-waste-global-database (Hoornweg and Bhada-Tata 2012).

5.8. Emerging issues

For the purpose of this report, emerging environmental issues are considered as “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 presents 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, plasticiers, 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 usage of electronic goods by an already expanding population as well as rapid changes in new technology 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 our water and food supplies.

Sargassum: See chapter 7 of this report. Lingering uncertainties about the cause of the sargassum outbreak requires urgent research to help understand the cause of 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 impact that requires collaboration with national, regional and international counterparts and institutions.

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.

Microplastic in the marine environment: Discussed in Chapter 8 of this report.

In the following Chapter, the impacts of the core LBS parameters on the state of the marine environment are discussed.

6. 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 the 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 faecal 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 emanating 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).

For this SOCAR, the eight core LBS water quality indicators assessed are:

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 are included 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 SOCAR. It must be underscored that because of the spatial gaps in data due to the small proportion of countries submitting 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 modeling of DIN and DIP should be strengthened among the countries to enable robust monitoring and evaluation of the impacts of management measures and development of mitigatory actions.

DIN and DIP assessment ranges (cut 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	Continent 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, particularly 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.

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 except for the Dominican Republic, Puerto Rico, and specific regions of Colombia (Antioquia and San Andres), where 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), with the Magdalena River alone contributing 54% of DIN (33,883 t yr^{-1}) and 93% of phosphate (32,300 t yr^{-1}) inputs 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 neighboring Venezuela, Bustamante et al. (2015) reported that polluted small- and medium-sized rivers had DIN concentrations (278–6499 µg L^{-1}) that were between 2–60 times higher than that found in the Orinoco River. The Tuy River, which belongs to a watershed highly impacted by urban/industrial land use in Venezuela, had 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 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.

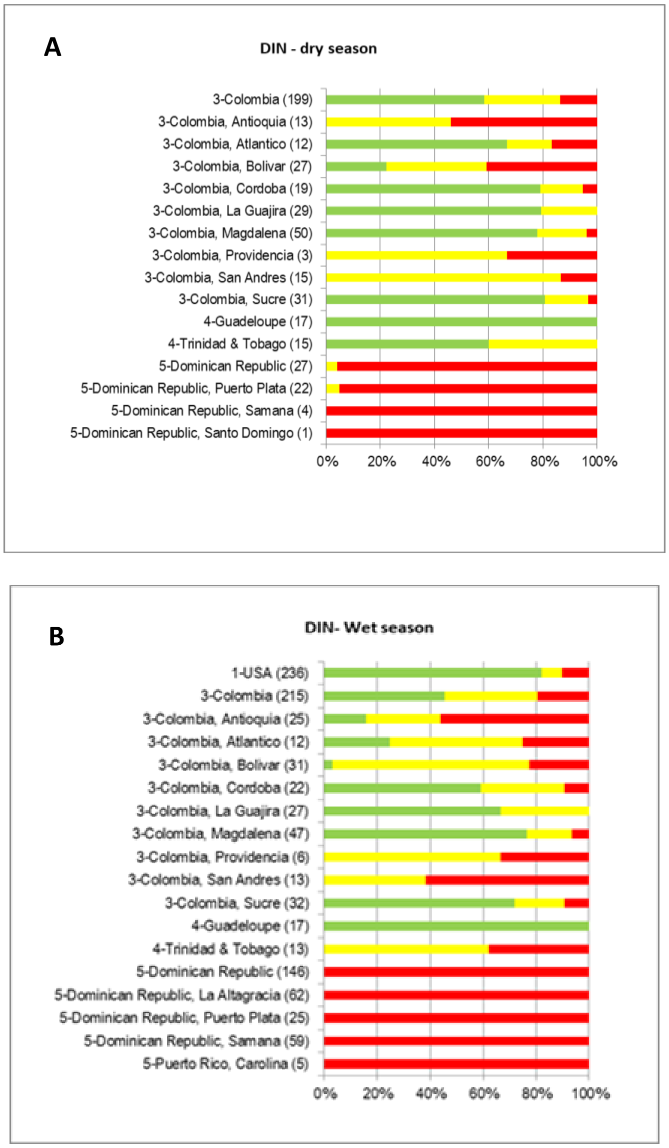

Figure 6.1. Proportion of sampling sites showing good, fair, and poor status in the dry (A) and wet (B) seasons for dissolved inorganic nitrogen (DIN). Number preceding the country and 1st level administrative unit is the SOCAR sub-region; number in brackets is the number of sampling sites. (Status: 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 in Antioquia, Providencia, and San Andres (Colombia), Dominican Republic, Jamaica, and Trinidad and Tobago. 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.

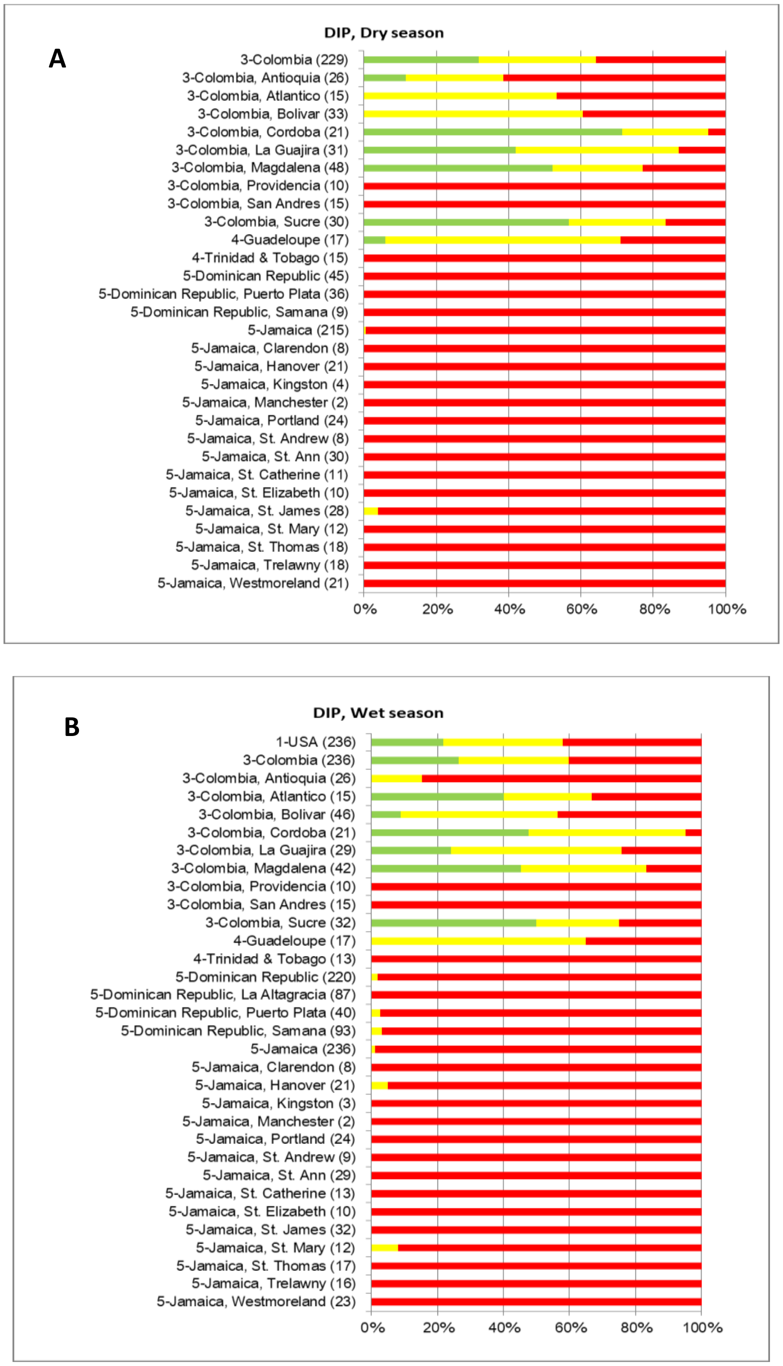

Figure 6.2. Percentage of sampling sites showing good, fair, and poor status in dry (A) and wet (B) seasons for dissolved inorganic phosphorus (DIP). Number preceding the country and 1st level administrative unit is the SOCAR Sub-region; number in brackets is the number of sampling sites. Status: Green: good; yellow: fair; red: poor

The high proportion of sites showing poor status with respect to DIP may be due in part to inputs of sewage, detergents, and industrial wastes 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, which included sites in Tampa Bay and Charlotte Harbor (Florida) where high DIP concentrations occur 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[21] (ICEP) 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 of development of potentially harmful (non-siliceous) algae (dinoflagellate[22]), while a zero or negative ICEP favours siliceous algae (such as diatoms[23]), which, unless they are in high abundance (high nutrient load rates), are generally not harmful. The ICEP has been adopted as an indicator for SDG Target 14.1. See Chapter 7 for further discussion of the ICEP.

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 Wider Caribbean 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	**Continent $\mu g\ l^{-1}$**	**Island $\mu g\ l^{-1}$**
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.

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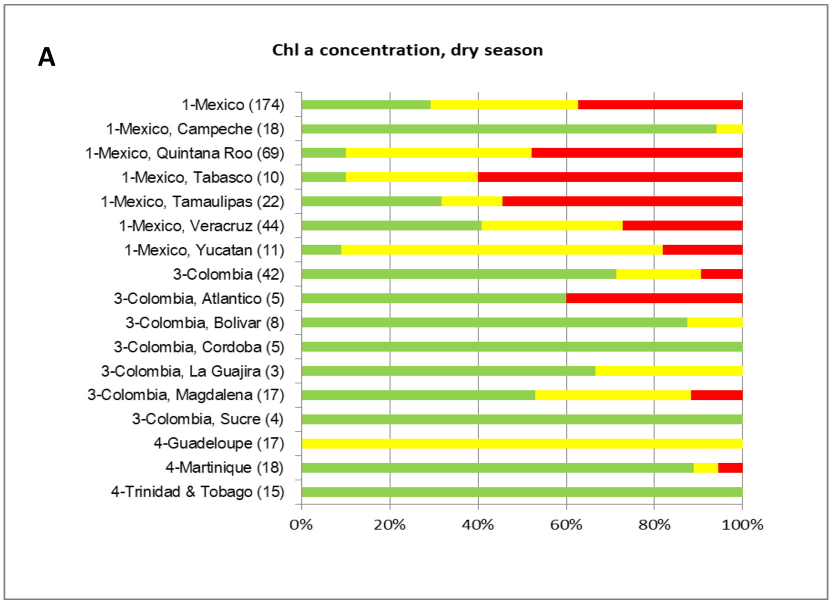
[21] Expressed in kilograms of carbon.km^{-2} of river basin area.day^{-1}

[22] Single-celled marine plankton (algae)

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



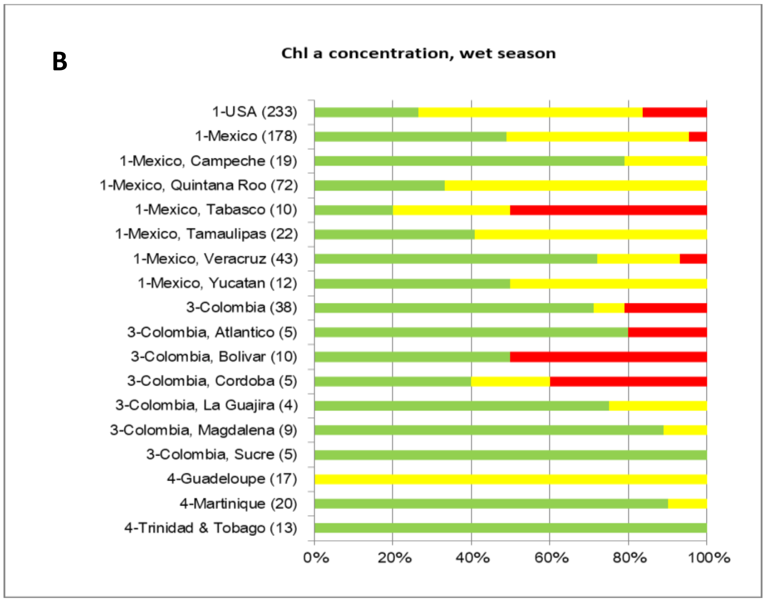


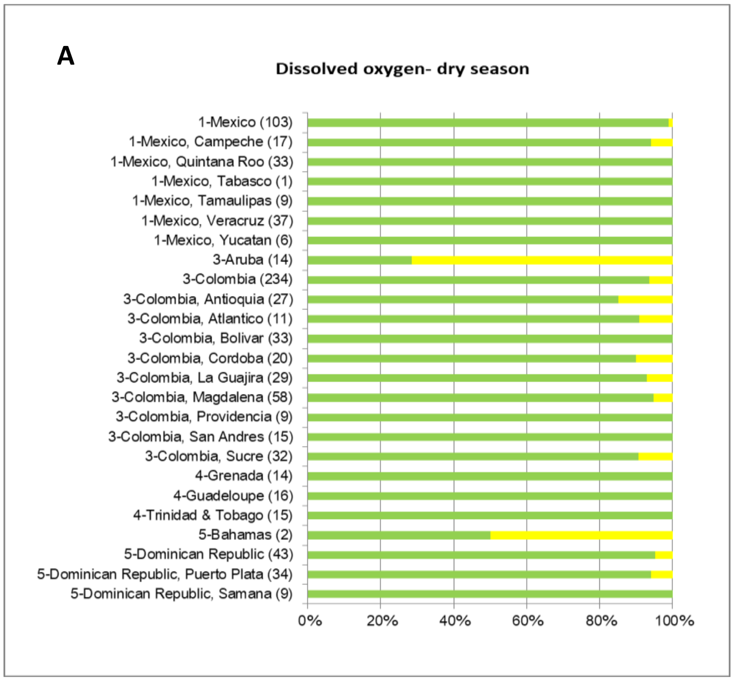
Figure 6.3. Percentage of sampling sites showing good, fair, and poor status in dry (A) and wet (B) seasons for chlorophyll-a (Chl-a). Number preceding the country and 1st level administrative unit is the SOCAR Sub-region; number in brackets is the number of sampling sites. (Status: Green: good; yellow: 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: Grijalva–Usumacinta Rivers (Tabasco) and Rio Grande (Tamaulipas) as well as underground rivers in Quintana Roo and karstic groundwater aquifers in the Yucatan Peninsula; and 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). Tosic et al. (2017) reported levels of Chl-a along with nitrate, phosphate, and total phosphorus in excess of recommended threshold values for marine conservation and recreational use in Cartagena Bay, Colombia.

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 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.



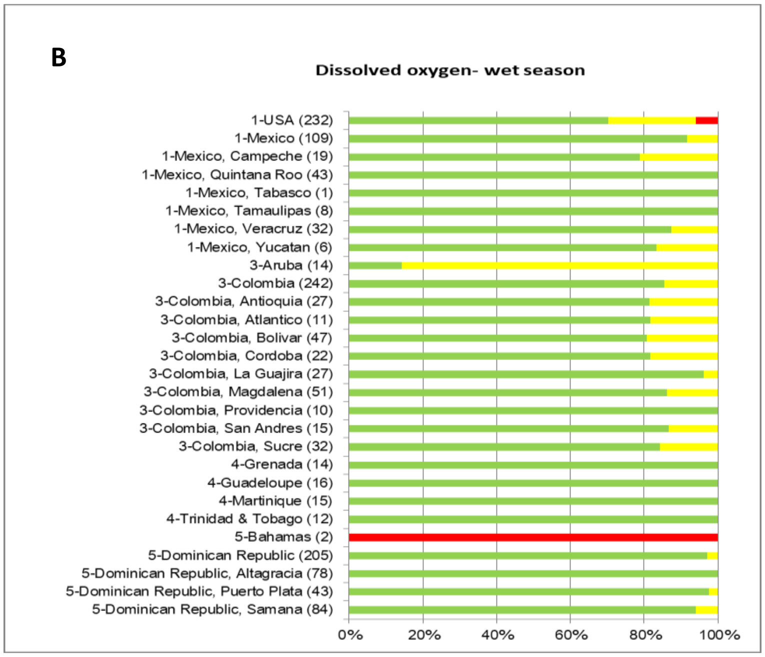


Figure 6.4. Percentage of sampling sites with good, fair, and poor status in dry (A) and wet (B) seasons for dissolved oxygen (DO). Number preceding the country and 1st level administrative unit is the SOCAR Sub-region; number in brackets is the number of sampling sites. Status: Green: good (> 5 mg.l^{-1}); yellow: fair (5- 2 mg.l^{-1}); red: poor (< 2 mg.l^{-1}), island and continental environments.

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 poor). 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, followed by phytoplankton blooms and their decomposition during which 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.

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, 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[24] or FNU[25]. Further,

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[24] Formazin Nephelometric Unit

[25] Nephelometric Turbidity Unit

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, overall, the proportion of sites outside the acceptable range increased in the wet season. The occurrence of high turbidity appears to be common in the region. Chollett et al. (2017) reported decreases in water visibility in all but one (Bonaire) of the stations assessed by CARICOMP, which were related to changes in human population density.

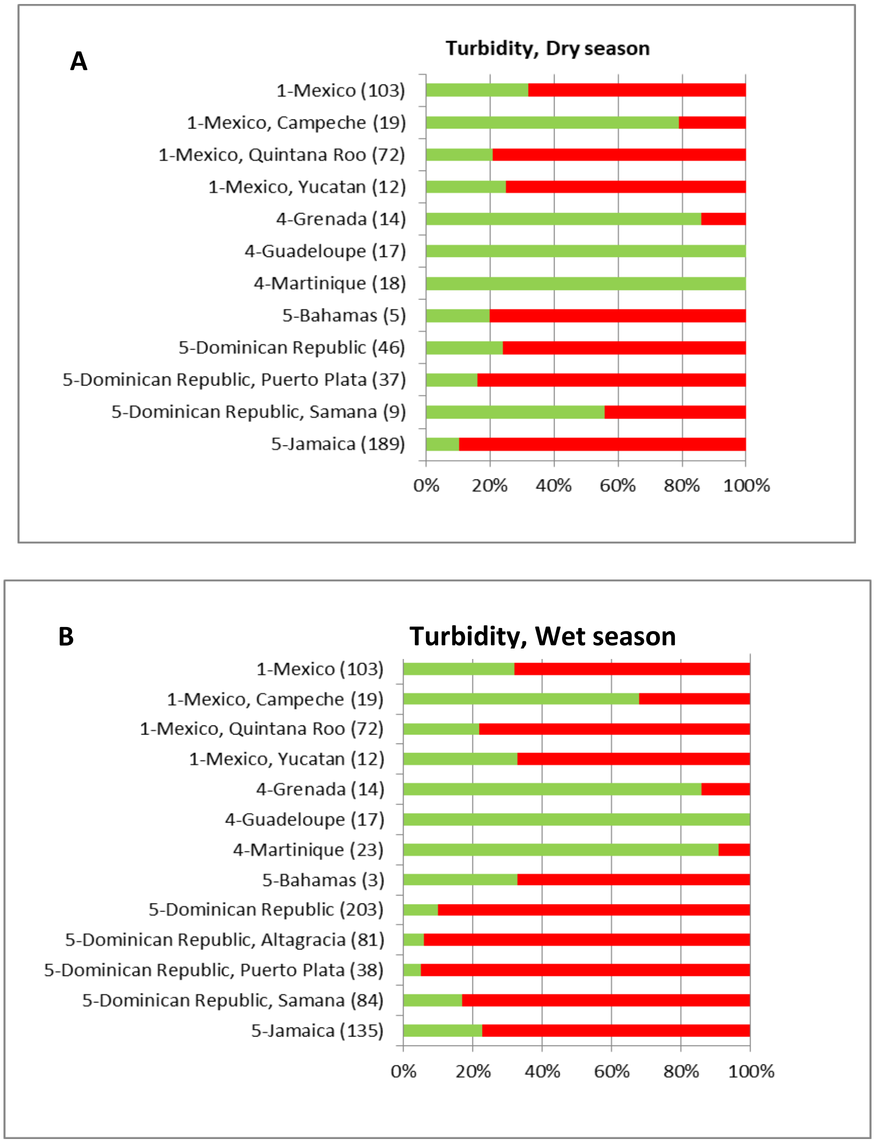
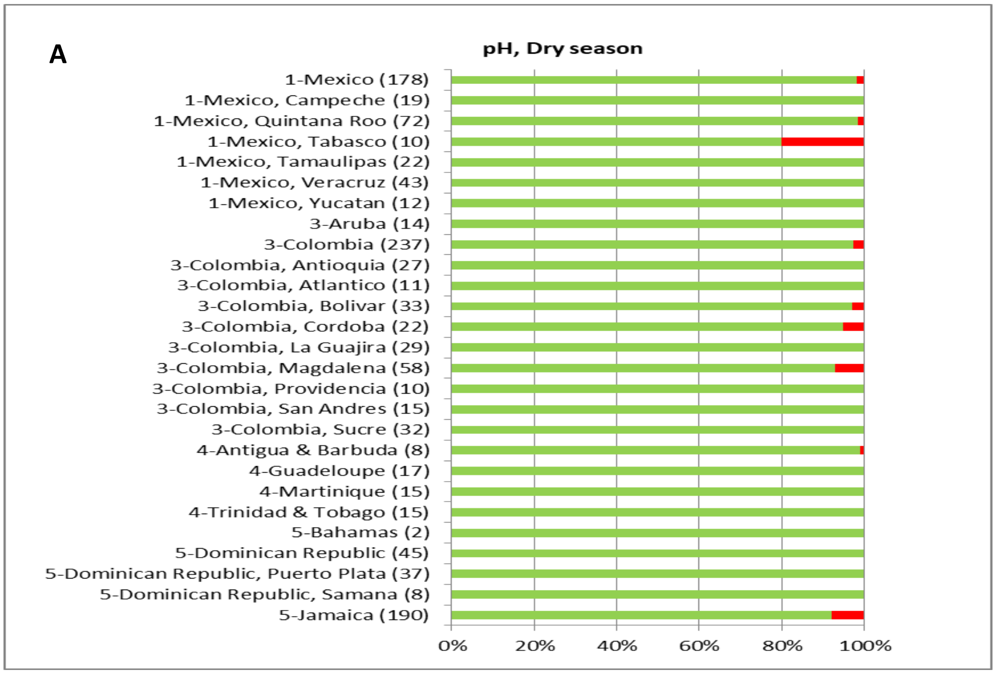


Figure 6.5 Percentage of sampling sites within and outside the acceptable range in dry (A) and wet (B) seasons for turbidity. Number preceding the country and 1st level administrative unit is the SOCAR Subregion; number in brackets is the number of sampling sites. Status: Green: acceptable (0-1.5 NTU); red: outside acceptable range

6.1.5. pH

pH is a measure of acidity or alkalinity, 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.

pH measurements 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 in the latter for the dry season was observed in Tabasco (Mexico), Magdalena (Colombia), and Jamaica (Trelawny and St. Thomas). For 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).



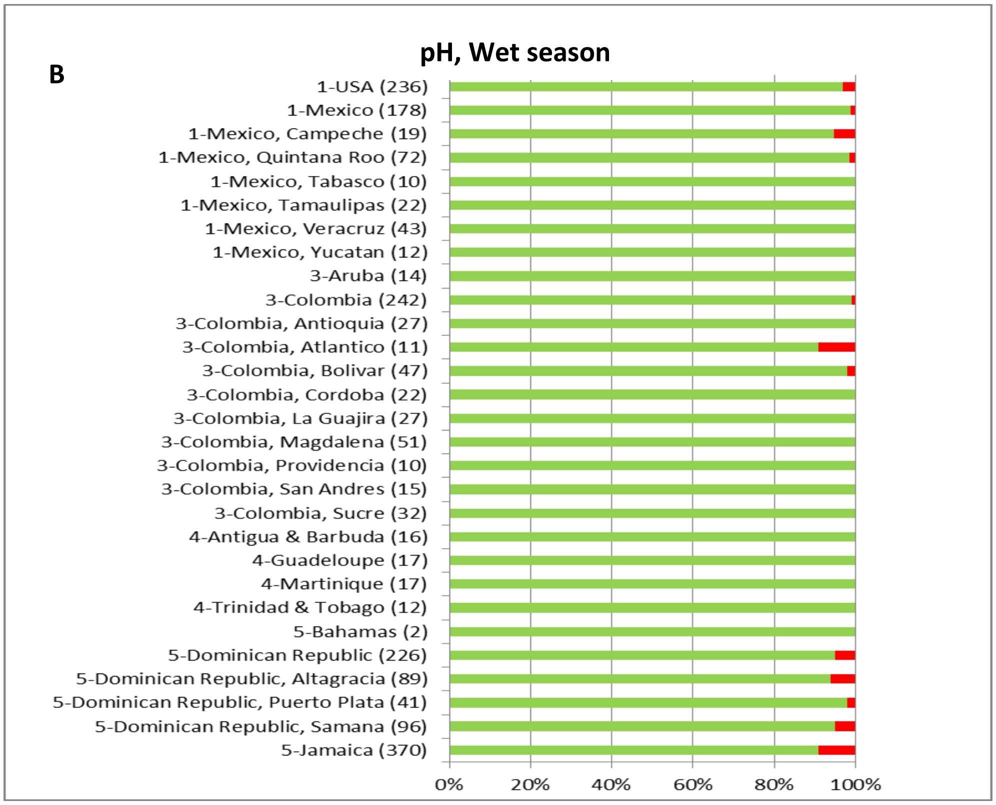


Figure 6.6. Percentage of sampling sites with acceptable and non-acceptable status in dry (A) and wet (B) seasons for pH. Number preceding the country and 1st level administrative unit is the SOCAR sub-region; number in brackets is the number of sampling sites. Status: Green: acceptable (6.5-8.5); red: outside acceptable range

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.

6.1.6. Faecal contamination indicators

Domestic wastewater is the main contributor of pollution in the Wider Caribbean marine environment (UNEP CEP 2010). Land-based wastewater discharges are the major contributors of bacterial loads and nutrients to near-shore waters (Nurse et al. 2012). Governments in the WCR have acknowledged that untreated sewage is one of the major threats to public health and the environment in the region.

The two commonly used indicators of human fecal pollution in water are *Enterococcus* species and *Escherichia coli. Enterococcus* is used as a proxy for polluted recreational waters and is the only faecal indicator recommended by the US Environmental Protection Agency (EPA) for brackish and marine waters. The most commonly monitored parameters among the countries are *Enterococcus* (15 countries), *E. coli* (12 countries), and fecal coliform (12 countries). This is likely related to the 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 regarding sharing of 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 in order 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*

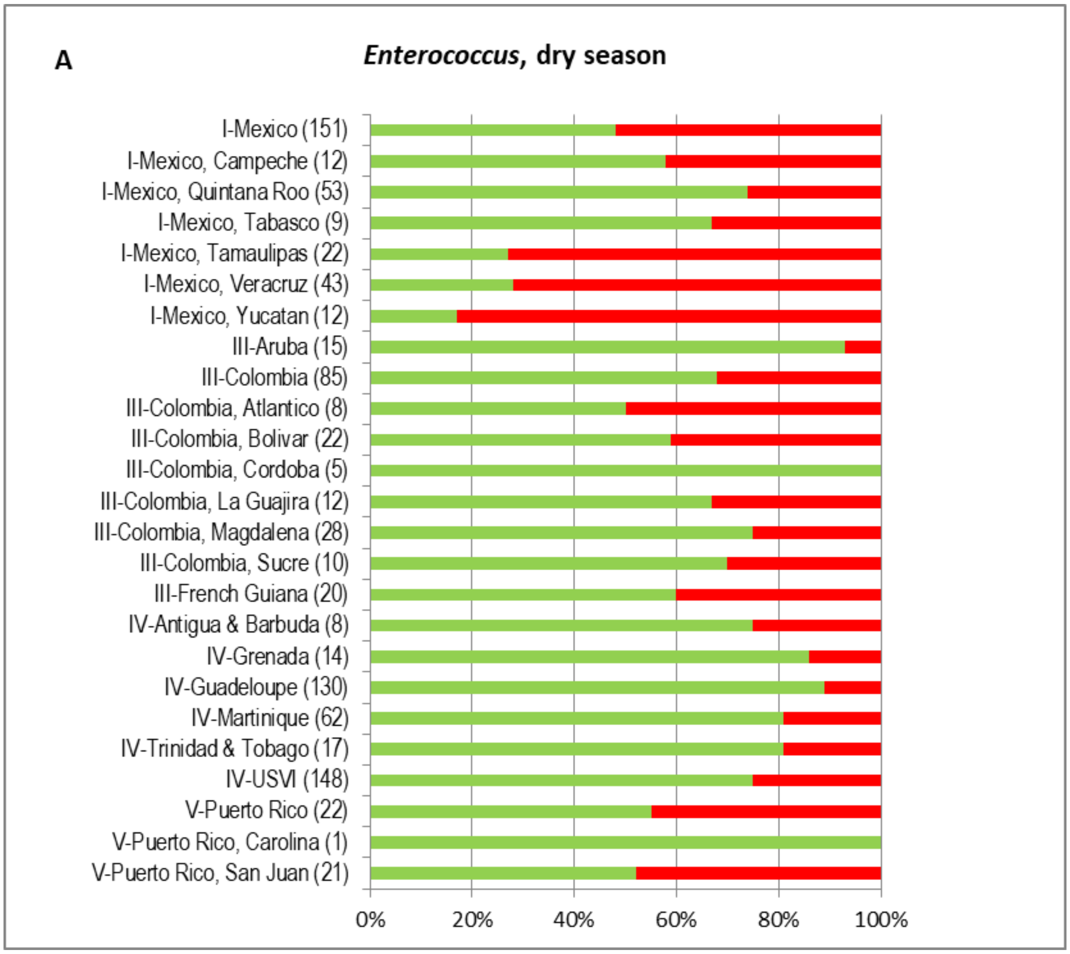
Organism	Acceptable range	Outside of acceptable range	References
Enterococcus	<35 CFU/100 ml	>35 CFU/100 ml	LBS Protocol Annex III - Discharges into Class I Waters UNEP-CAR (2014). Report of the Working Group on Environmental Monitoring and Assessment 2013- 2014. UNEP (DEPI)/CAR WG.35/INF.5 WHO (2003).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

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 and 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 40% and higher of sites with 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 the locations in all continental areas and certain island locations. Exceptions are Antigua and Barbuda, and USVI, which show a reduction in the number of poor sites in the wet season. Overflow of sewerage 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); and Magdalena River (Atlantico) and Canal del Dique (Bolivar). In Colombia, the highest domestic wastewater volume is emitted 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). La Guajira department has no major rivers and the high proportion may be linked to river outflow from outside of Colombia (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 runoff (Yucatan) may be attributed to high coastal populations/urban areas compounded by significant annual influx of tourists (as discussed in Chapter 4), coupled with low level of wastewater treatment.



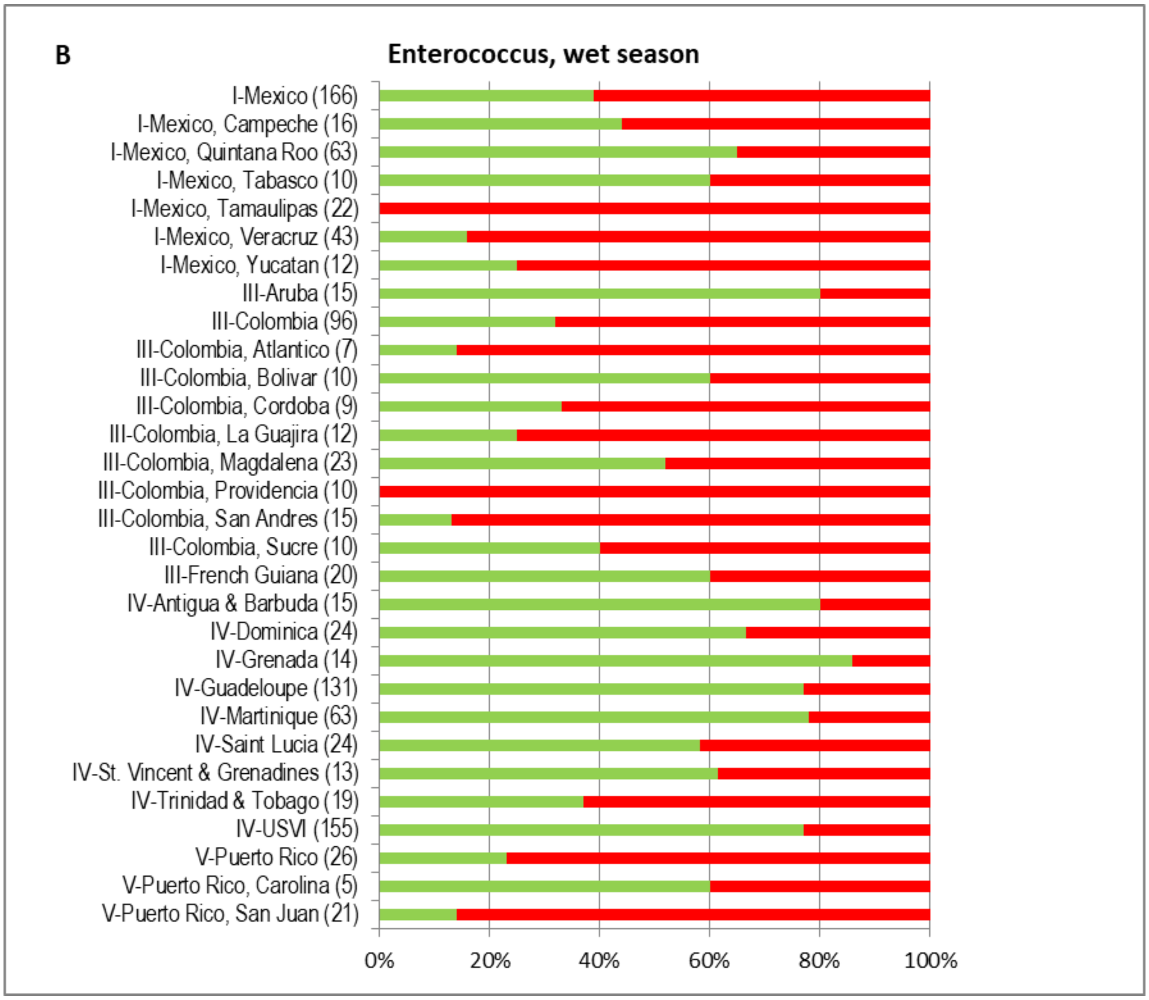


Figure 6.7. *Enterococcus*. Percentage of sampling sites within (green) and outside (red) of the acceptable range in the dry (A) and wet (B) seasons. Number preceding the country/territory and 1st level administrative unit is the SOCAR sub-region; number in brackets is the number of sampling sites.

Escherichia coli

The World Health Organization has designated *E. coli* as the principal indicator of faecal 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 (40% and above) of sites with poor status are found in Trinidad and Tobago as well as 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.

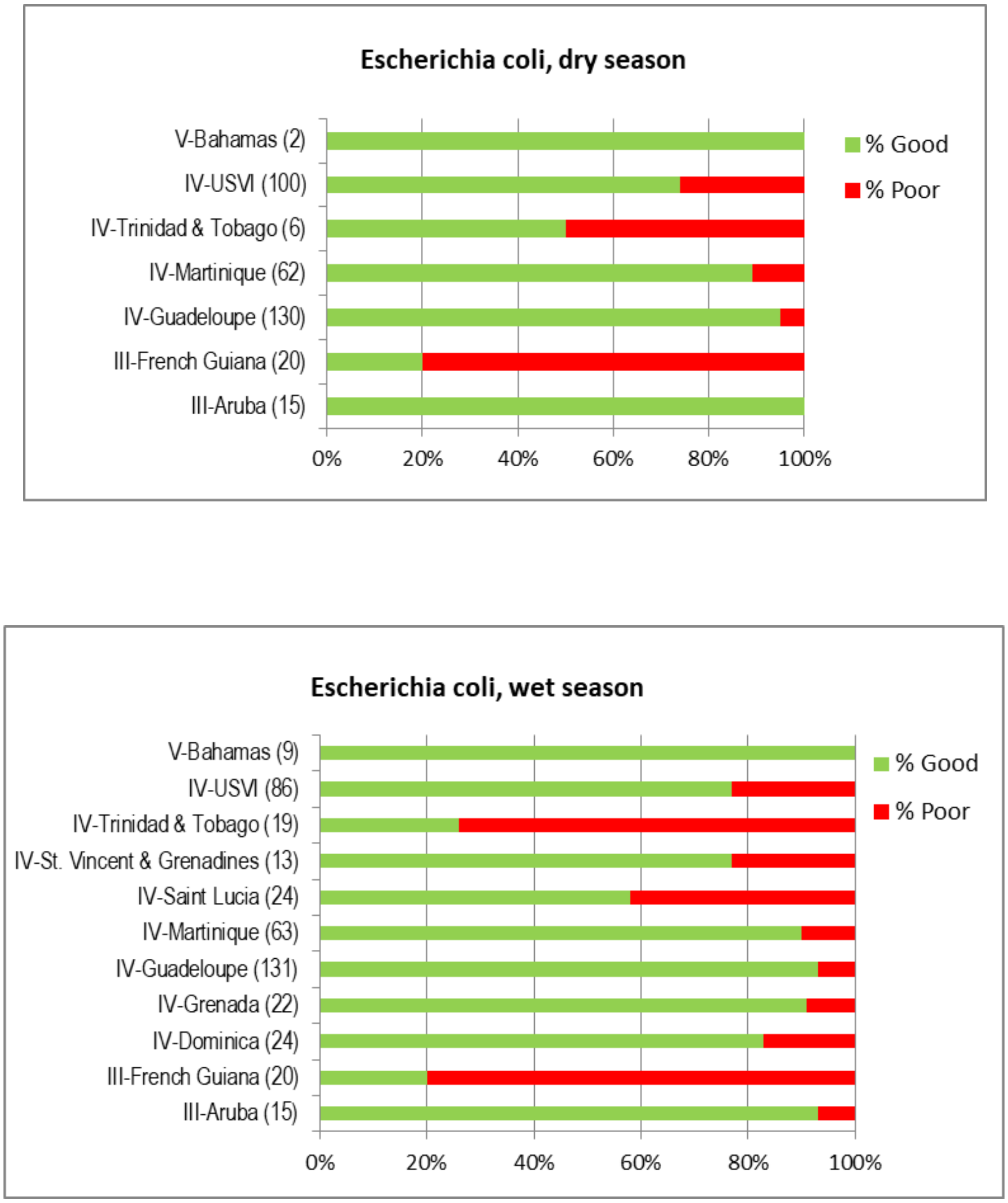


Figure 6.8. ***Escherichia coli*****. Percentage of sampling locations within (green) and outside (red) of the acceptable range in the dry season (A) and wet season (B), by country/territory.** Number preceding the country/territory is the SOCAR sub-region; number in brackets is the number of sampling sites.

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, overall, the 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.

The ecological and socio-economic impacts of changes in the state of the marine environment are discussed in the following chapter.

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.

Land-based pollution can potentially contribute to precipitate 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.

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.

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 abate 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 effect, 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 cost is fragmented. Ideally, monitoring of water quality, habitats, and biota is done within an integrated environmental monitoring and assessment framework. These important knowledge gaps should be addressed in future pollution research and monitoring programmes in which monitoring of water quality, habitats, and biota is done within an integrated environmental monitoring and assessment framework. 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 socio-economic 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.

Box 7.1. An existential threat to our coral reefs: Sint Maarten's coral reefs are dying due to disease, poor wastewater infrastructure

The Nature Foundation Sint Maarten recently confirmed the presence of 'Tissue Loss Disease' on several local coral reefs. In many locations some 90% of coral is either infected or dead. Additionally, the Nature Foundation again detected **poor water quality** in areas of Simpson Bay and the Simpson Bay Lagoon in addition to a **Harmful Algal Bloom** that the Foundation is also currently monitoring. "Local reefs have already been hit hard due to Hurricane Irma and human activities such as **pollution, nutrient run off, overfishing and climate change.** Therefore, ***the detected disease together with increased incidents of sewage and other pollutants being entered into the environment is an existential threat to our coral reefs.*** We have also seen **Nutrient Indicator Algae** appear in areas where it was largely absent, including in our coral nursery. We are now very concerned about our coral's capacity to recover," commented Nature Foundation Director Tadzio Bervoets.

'….we urgently need the support of decision makers and the wider community to make sure that we can continue our work of facing the challenges to the marine ecosystem head on. ***A sound wastewater infrastructure, holding those that dump wastewater in the ocean and wetlands accountable, increased monitoring, and a ban on single-use plastics and non-coral friendly sunscreen would go a long way***," concluded Bervoets.

25 February 2019

(http://listserv.gcfi.org/scripts/wa-GCFI.exe?A2=ind1902&L=CAMPAM-L&P=R215694)

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

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 increase in 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 perturbation of aquatic community composition, 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 of potentially harmful algal blooms 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). *needs further study (See Box 5.2).

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	

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 of potentially harmful algal development), which is consistent with high nutrient inputs from the Mississippi-Atchafalaya River Basin into the northern Gulf of Mexico and associated eutrophication risk. Sub-regions III and V show moderate risk of eutrophication, which may also be associated with discharge of nutrients to 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 runoff 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 runoff from rivers and coastal urban areas. These results apply to relatively large spatial scales (such as the entire LME-see following page) and there may be marked differences at smaller, localized scales. Further investigations on the ICEP including 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 the ‘Merged nutrient risk indicator’ for most of the world’s 66 LMEs in years 2000, 2030, and 2050. The Gulf of Mexico and North Brazil Shelf LMEs are at very high risk and the Caribbean LME at medium risk (year 2000). 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 (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 have been previously documented across the WCR (see Figure 7.4 below). Reductions in nutrient inputs to specific watersheds are required to lower the estimated risks (Seitzinger and Mayorga 2016). This can include, for example, increased nutrient-use efficiency in crop production, reduction in livestock and better management of manure, and increased treatment level to remove nutrients from human sewage before it is discharged into the environment.

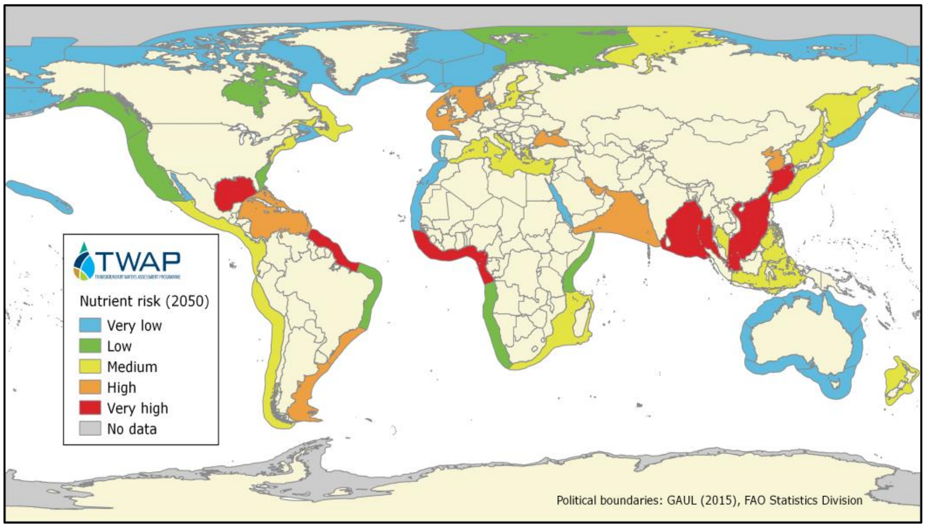


Figure 7.1. Merged Nutrient Risk Indicator projected to 2050 for LMEs (Transboundary Waters Assessment Programme TWAP- Seitzinger and Mayorga 2016. http://onesharedocean.org)

7.3. Harmful algal blooms

Excessive inputs of nutrients 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 and other marine fauna as well as to humans, hence the term 'harmful algal blooms' (HABs). The most conspicuous effects include mass mortality of marine fauna and reduction in the quality of recreational and shellfish harvesting areas, resulting in substantial economic losses. In addition, human exposure to HABs including consumption of tainted seafood (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, there has been a clear trend of increase in the occurrence of HABs in Latin America and the Caribbean region (Méndez et al. 2018). However, comprehensive information on the incidence and associated cost of the impacts of HABs is generally limited for the region, 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[26] 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 to perform retrospective analysis of HAB occurrence (Cuellar-Martinez et al. 2018).

HAB records from LAC countries in the network in the Harmful Algae Event Database (http://haedat.iode.org, 2018) indicated that between 1970 and 2007, about 7,800 human intoxications, including 119 human fatalities, were mainly associated with PSP in the Pacific and Atlantic coasts, and 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 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 HAB (red tide) outbreaks in Florida[27], 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[28]. 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 7.2. 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 was estimated to be nearly $163,000 annually. However, severe events such as the current one can be significantly costlier where total clean-up costs for all affected areas

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7.4. Ciguatera fish poisoning in humans

In the WCR, a well-known illness associated with the consumption of 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 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 7.3) and is associated with the consumption of 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).

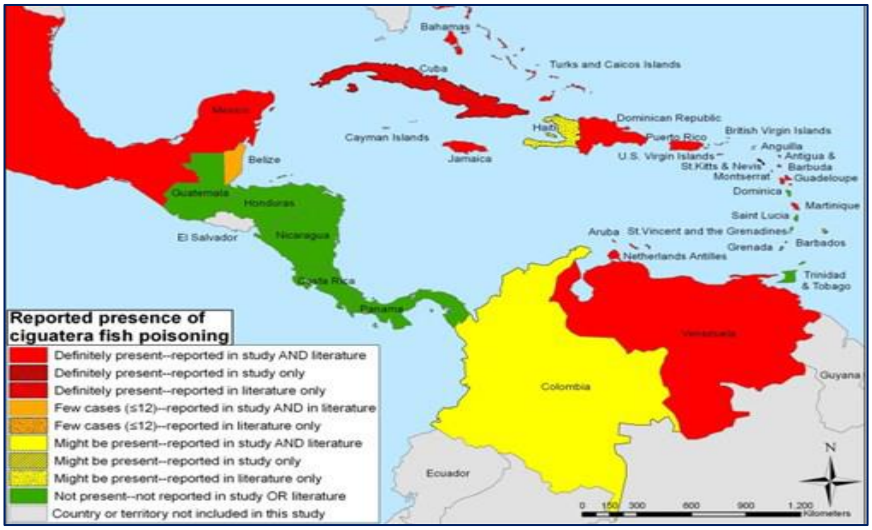
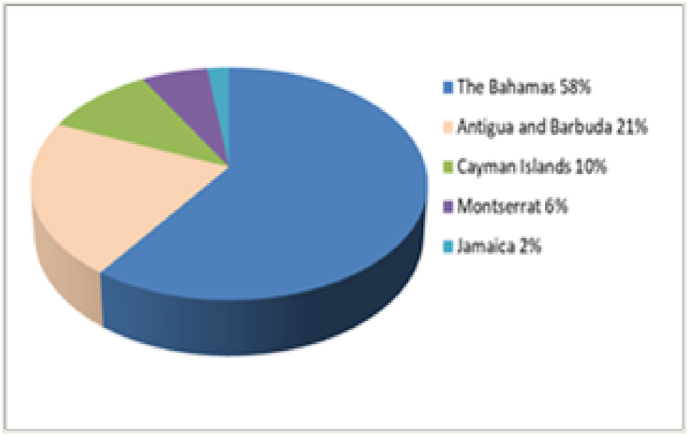


Figure 7.3. Ciguatera fish poisoning occurrence in the Caribbean reported by country from 1996 – 2006 (Source: Tester et al. 2014)

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 food borne disease (following salmonellosis) in member countries, a trend that has been observed since 2007. Effort should be made by WCR countries to improve documentation of the incidence of ciguatera and to estimate the associated economic costs.

Box 7.3. 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 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 shrimps. In anoxic (no oxygen) conditions the degradation of organic matter leads to the production of hydrogen sulphide (Breightburn et al. 2018a), which is toxic to most marine organisms. However, these zones are inhabited by microorganisms that can withstand low oxygen conditions. Numerous hypoxic zones have been recorded in the WCR (Figure 7.4).

Figure 7.4. Location of eutrophic, hypoxic, and improved hypoxic zones throughout the Wider Caribbean (Selman et al. 2008)

The largest hypoxic zone in this region is the seasonal hypoxic zone off Louisiana-Texas 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[29]. 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/snowfall melt in the upper watershed may contribute to the observed annual differences (Figure 7.5).

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; 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[30] to reduce, mitigate, and control hypoxia in the Northern Gulf of Mexico and improve water quality in the Mississippi River Basin.

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

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

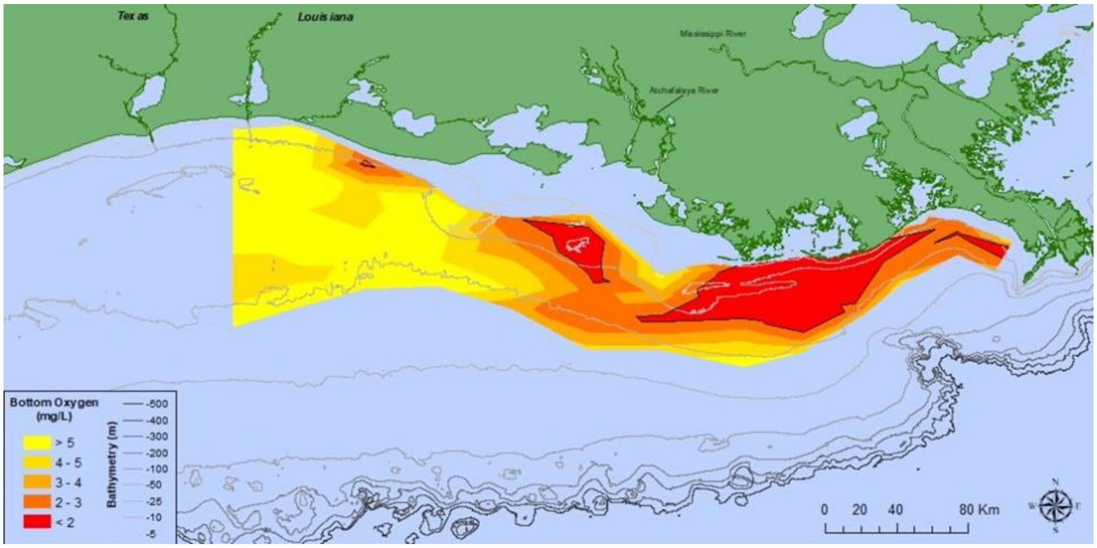

Figure 7.5. Gulf of Mexico bottom oxygen concentration on the Louisiana-Texas continental shelf, July 2018. (https://gulfhypoxia.net/)

Hypoxia can have pronounced adverse effects on marine communities and fisheries as well as on human communities. The United Nations Development Programme (UNDP) estimated 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 Yannick Glemarec 2012). Although difficult to quantify, the economic effects of hypoxia and HABs can be also 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 among the effects has been an increase in macroalgae on coral reefs and seagrass beds. Macroalgae overgrowth can smother corals, seagrasses, and sessile organisms. This is exacerbated by the reduction in the 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, location	**Nutrients, agric. runoff**	**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 it was largely absent (Sint Maarten Nature Foundation, 2019. http://listserv.gcfi.org/scripts/wa-GCFI.exe?A2=ind1902&L=CAMPAM-L&P=R215694)
Jamaica, Negril	✓	✓			All coastal waters had nutrient and chlorophyll concentrations 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, due to hypoxic (low oxygen) conditions and dead zone caused by inputs of nutrients 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 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 in water quality, and 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) attributed to the impacts of heavy sediment loads and freshwater discharges (Restrepo et al. 2006)
USA, Florida	✓				*Karenia brevis* red tides occurring with greater frequency, closer to shore, and during more months of the year. Attributed to greater inputs of nutrients into coastal waters from increased agricultural runoff 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- nutrient connection

Nutrient inputs to the ocean from land-based sources have been implicated, along with other factors acting synergistically, 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 7.6) and the tropical Atlantic and through 2018.

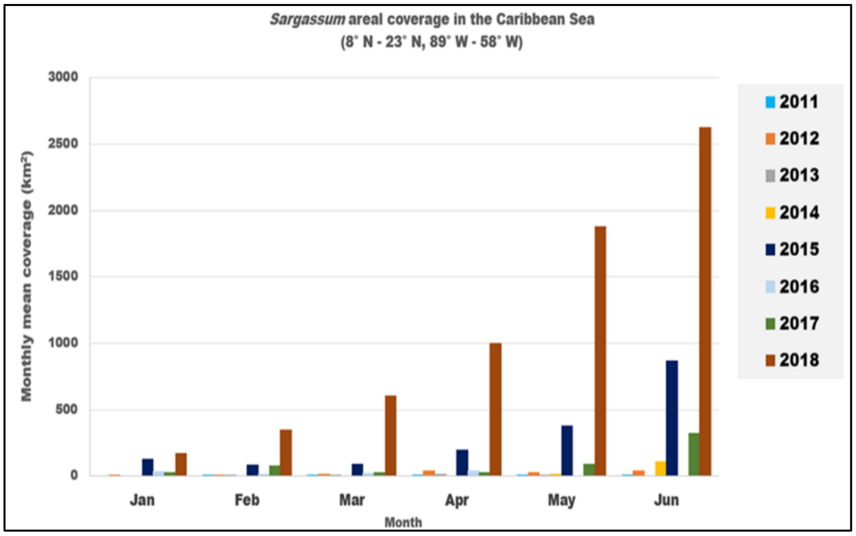

Figure 7.6. Monthly mean Sargassum areal coverage in the Caribbean Sea between 2011 and 2018 (University of South Florida Sargassum Watch System, https://optics.marine.usf.edu/projects/saws.html)

Researchers (e.g., Djakouré et al. 2017 and Sissini et al. 2017) have attributed the outbreaks to increase of 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 conditions (chemical, physical, or biological) 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 7.7).

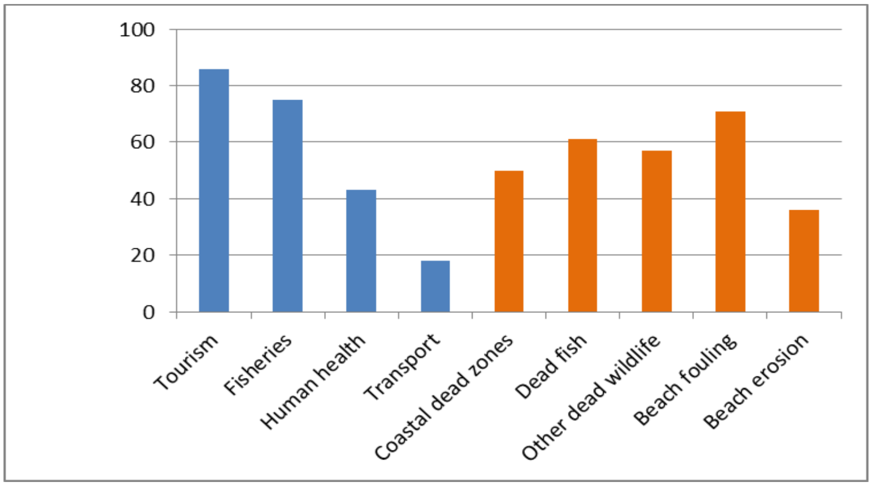

Figure 7.7. Percentage of territories where different economic sectors have been affected (blue bars), and where different ecological issues have occurred as a result of the outbreaks (orange bars). Data from UNEP CEP 2018, based on survey responses of national Focal Points from 28 territories in the 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 sulphide, 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 including 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 population explosions of bacteria 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 increase in other signs of compromised coral health relative to reefs with 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 of the impact of sedimentation and other stressors on coral reefs in the WCR are shown in Table 7.2. These studies underscore the importance of local stressors, such as runoff and dispersion of turbid plumes, as opposed to ocean warming, disease, and hurricanes, which have played a larger role on other coral reefs in the Caribbean (Restrepo et al. 2016). Hence, coral reef management across the WCR, especially in areas heavily influenced by continental fluxes, may be only 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 the countries.

7.9. Sewage threat 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 pressure causing coral reef deterioration worldwide (Wear and Vega Thurber 2015). These authors found that 104 out of 112 coral reefs delineated in the World Atlas of Coral Reefs are impacted by sewage, including in the WCR (Figure 7.8).

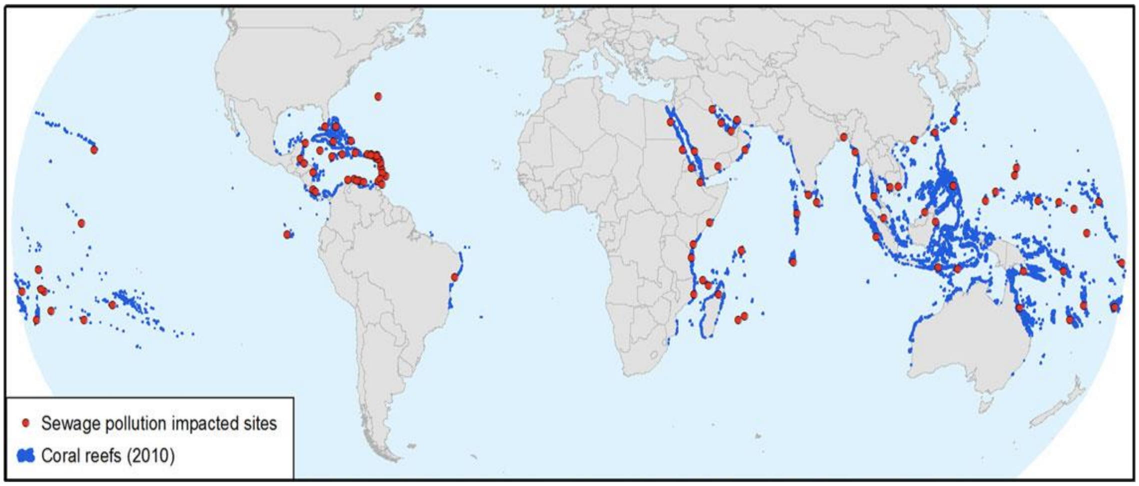

Figure 7.8. Coral reefs affected by sewage pollution worldwide (Wear and Thurber 2015)

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 faecal material and contamination by microorganisms of recreational water and seafood (particularly shellfish, which are often consumed raw) on human health (for example, gastrointestinal illness, 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).

Data for the WCR is limited, but Shuval (2003) estimated that globally, each year 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. In addition, there are about 4 million cases annually of infectious hepatitis A and E with 40,000 deaths and 40,000 cases of long-term disability, mainly chronic liver damage, from consuming raw or partially cooked shellfish harvested from polluted coastal waters. 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 harbor fecal pathogens and other harmful microbes, posing yet another threat to humans.

Sewage pollution can have potentially severe socio-economic consequences including decreased livelihoods and revenue from tourism and seafood production. Availability of data from across the WCR is limited, and the example in Box 7.4 is provided to illustrate the magnitude of the economic losses that wastewater pollution can cause.

Box 7.4. 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 from runoff from urban areas and farms, and uncontrolled sources of sewage and septic wastes (US EPA 2018).

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 2001-2009 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 decreases in property value and tourism revenues have been linked to declines in water quality. Environmental degradation (including to 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 Wider Caribbean.

8. 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 tons of plastic were introduced to 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 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 byproducts of its recycling and incineration. Further investigations are required on the long-term impacts of plastic on human and ecological health, and associated economic costs.

Plastic pollution is gaining increasing 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 under the Protocol. 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 the prevention and reduction side as well as better recycling is needed.

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, the issue of marine litter[31] was an emerging environmental concern. However, this has since changed, including the inclusion of plastic 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 of the time. Solid waste arises from various economic sectors and activities, either directly or indirectly. In addition, citizens' consumption of goods, personal habits (e.g., use of plastic bags and packaging), and 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, posing significant risk to public health and economic sectors such as tourism, fisheries, and shipping as well as to wildlife. Land-based sources contribute 80% and sea-based sources 20%, of marine litter. Plastics make up the majority of marine litter and it was estimated that in 2010, between 4.8-12.7 million metric tons of plastic entered into our oceans (UNEP 2016) and could reach 250 million tons by 2025 (Jambeck et al. 2015).

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

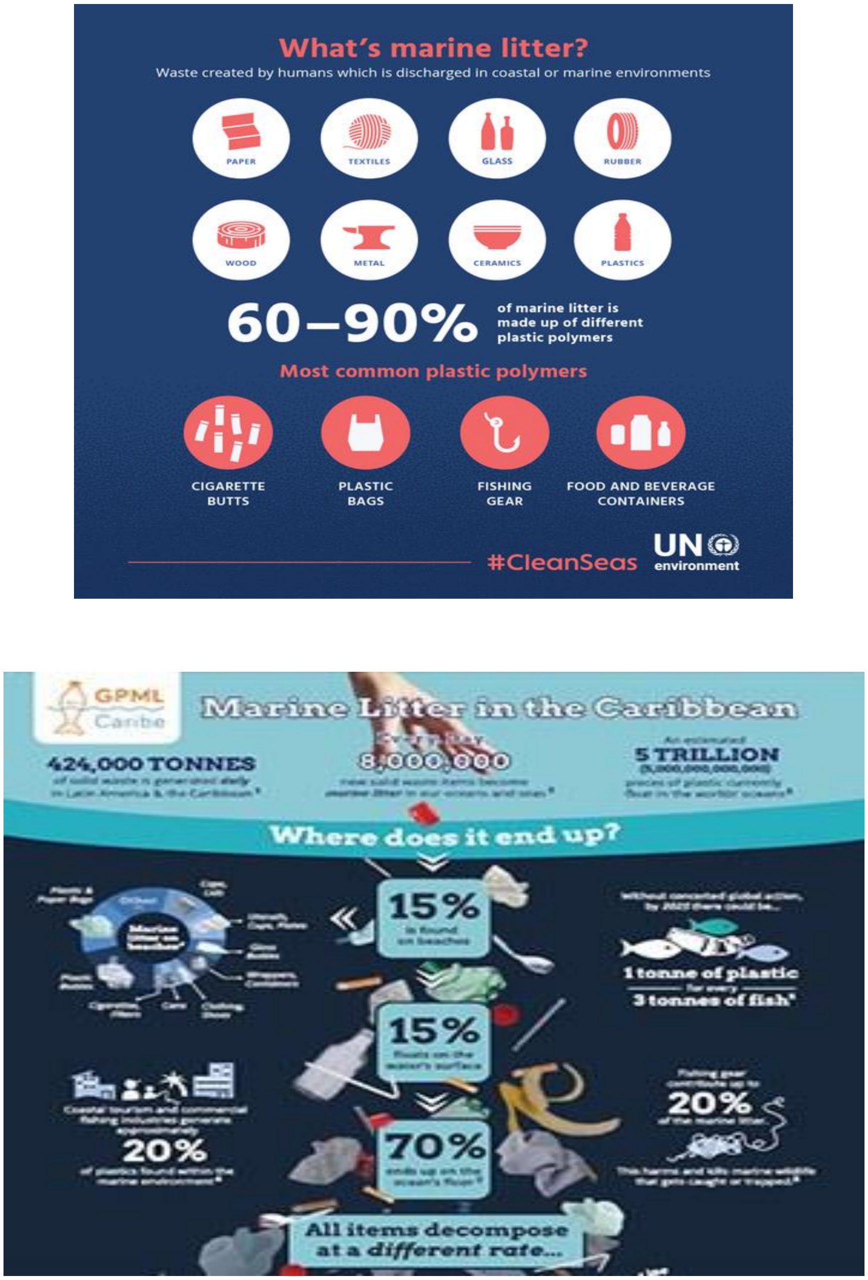
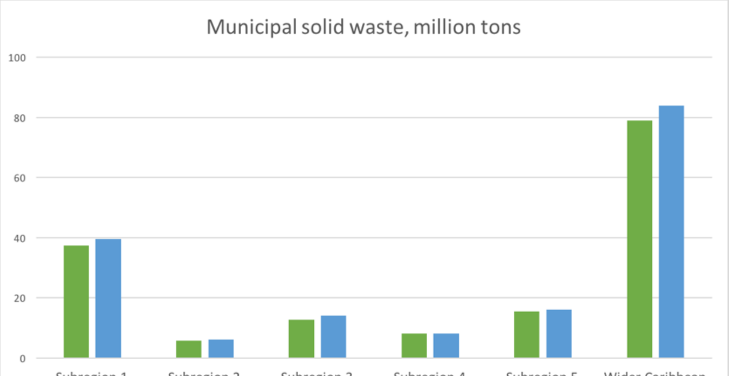


Figure 8.1. Sources and fate of marine litter in the Caribbean

8.2. Solid waste, plastic, and microplastic

For this assessment, solid waste generation in the WCR was estimated by Talaue-McManus 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 resident populations of the WCR generated 79 million tons of solid waste in 2015, which is projected to increase to 84 million 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 tons of plastics were introduced to coastal waters of the WCR in 2015 (Figure 8.2, bottom), with still unknown ecological consequences given their product lifespans lasting 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-regions 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, was 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 (Talaue-McManus, this study; see Annex 4.1. for technical notes). The combined solid waste from resident populations of ECCU member countries[32] amounted to 663,000 tons in 2015. Tourists added another 49,000 tons, 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 coverage of waste management and services can cope with demand. To implement an evidence-based planning, 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 in particular, including problematic plastic waste.



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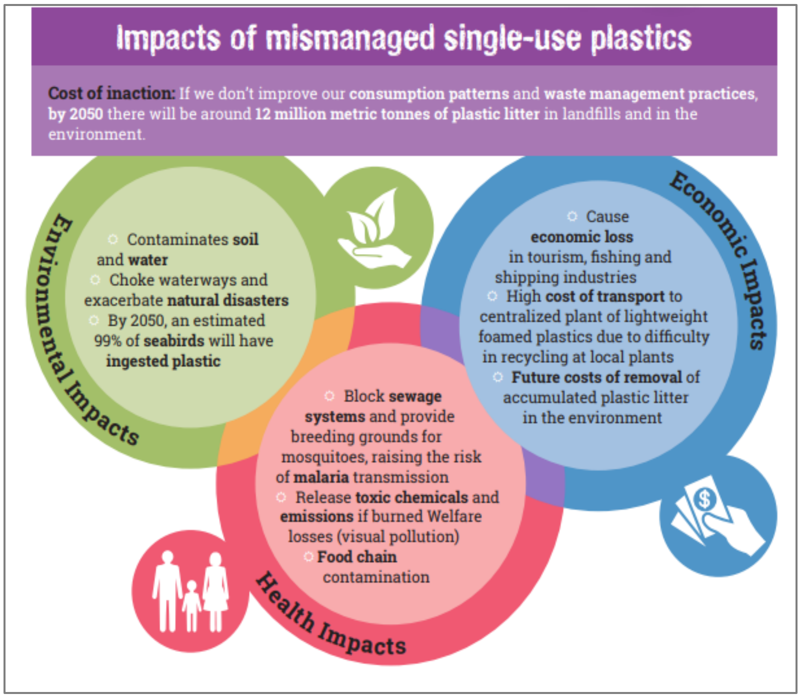
[32] Anguilla, Antigu s, Saint Lucia, and Saint
Vincent and the G

Figure 8.2. Municipal solid waste generated by resident populations of the WCR region (8.2A) and concomitant mismanaged plastic waste (millions of tons) that have 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 the small islands, countries in the wider Caribbean are struggling to deal with the vast quantities of waste produced. 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 service. 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 tons per day of waste are disposed in open dumpsites, including 17,000 tons per day of plastic (UN Environment 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.



Impacts of mismanaged single-use plastics

Cost of inaction: If we don't improve our **consumption patterns** and **waste management practices**, **by 2050** there will be around **12 million metric tonnes of plastic litter** in landfills and in the environment.

Environmental Impacts

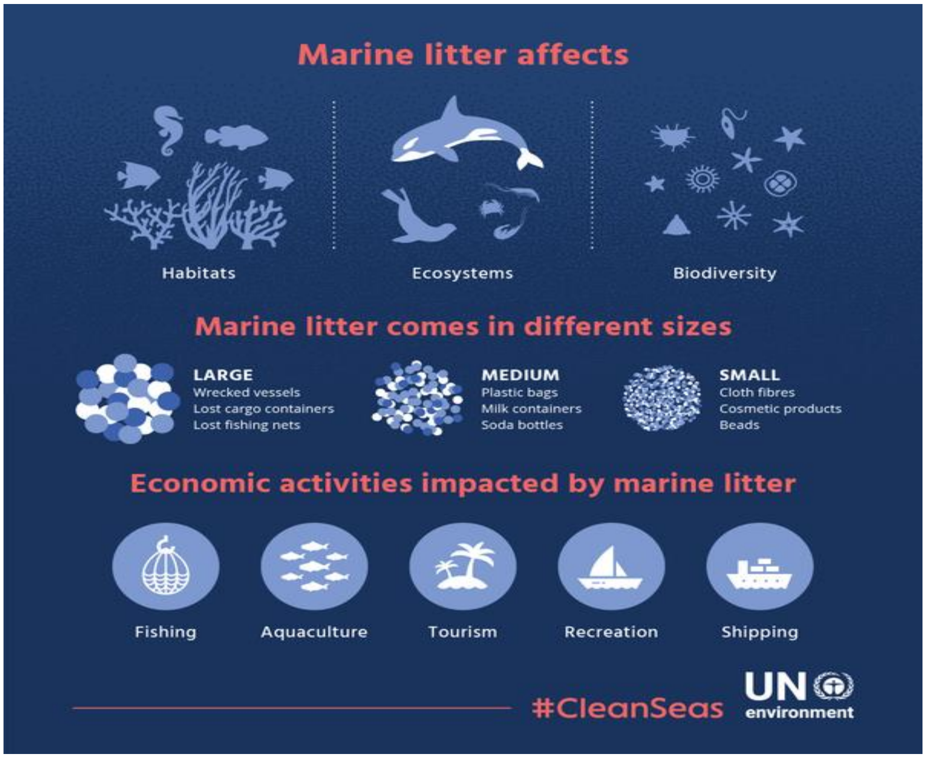
- Contaminates **soil** and **water**
- Choke waterways and exacerbate **natural disasters**
- By 2050, an estimated 99% of **seabirds** will have **ingested plastic**

Economic Impacts

- Cause **economic loss** in tourism, fishing and shipping industries
- High **cost of transport** to centralized plant of lightweight foamed plastics due to difficulty in recycling at local plants
- **Future costs of removal** of accumulated plastic litter in the environment

Health Impacts

- Block **sewage systems** and provide breeding grounds for mosquitoes, raising the risk of **malaria** transmission
- Release **toxic chemicals** and **emissions** if burned Welfare losses (visual pollution)
- **Food chain** contamination



Marine litter affects

Habitats

Ecosystems

Biodiversity

Marine litter comes in different sizes

LARGE
Wrecked vessels
Lost cargo containers
Lost fishing nets

MEDIUM
Plastic bags
Milk containers
Soda bottles

SMALL
Cloth fibres
Cosmetic products
Beads

Economic activities impacted by marine litter

Fishing

Aquaculture

Tourism

Recreation

Shipping

#CleanSeas

UN environment

8.3. Floating micro- and macroplastic

While some plastic is reused or recycled within a circular economy or go to controlled waste disposal, 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 tons of waste plastic enters the oceans every year. Large pieces of plastic (macroplastic) such as plastic bags and water bottles as well as micro- and nano-particles of plastic, are now ubiquitous in the ocean including in the most remote areas.

Modelled estimates of floating plastic abundance (items km^{-2}), for both micro-plastic (less than 4.75 mm) and macro-plastic (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 km^{-2}, respectively. These estimates place this region as among those with the highest plastic concentration in the world. While the modelled estimates of floating plastics are in broad agreement with sea-based direct observations and shoreline surveys, there is need to obtain empirical data for the WCR on the volume of plastic (floating and submerged), sources, and fate in the marine environment as well as for further investigation of the impact on ecosystems and human health and associated economic costs.

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 UN Environment 2016 for a review). Among the impacts of macroplastics are reduction in the 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. 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). The impacts of plastic including microplastics on humans and living marine organisms require further investigation.

Box 8.1. Dangers of microplastic in the marine environment

- Microplastics adsorb organic pollutants from the surrounding seawater and when ingested, can deliver harmful chemicals to marine fauna and humans.
- Owing to their small size, microplastics can easily enter the marine food chain and eventually be transmitted to humans. In Grenada, for example, in a recent study, microplastics were found in the gut of all species of marine fish analyzed.
- Plastic resin pellets (2 to 4 mm diameter) adsorb and concentrate persistent organic pollutants (POPs) from the surrounding seawater (Takada and Yamashita 2016). POPs were detected in all samples collected and analyzed under the International Pellet Watch Programme, including those from remote islands.

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—financial impacts resulting from issues such as pollution of the marine environment or air pollution caused by incinerating plastic. Over 30% per cent 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 the UN Environment, 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.

8.5. Addressing plastic pollution

Concern over the effects of plastics has ignited an environmental revolution across the world, which is perhaps unprecedented. 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 of single-use plastic bags and polystyrene foam products have swept across the region in the last year alone (Figure 8.3).

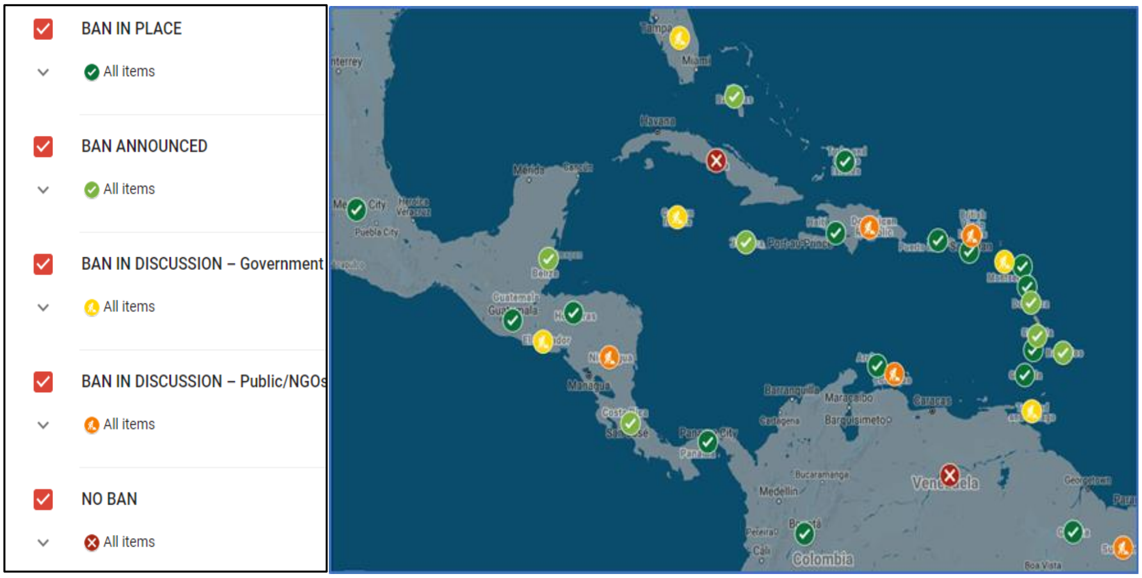


Figure 8.3. Bans of single-use plastic bags and polystyrene foamproducts in the Caribbean (UN Environment CEP, April 2019)

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 nongovernmental 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.
- Regional Action Plan for Marine Litter (RAPMaLi) for the Wider Caribbean Region 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 UN Environment 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 tourist. The main objective of the project is to develop a market readiness analysis to measure the maturity of the market of 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 UN Environment, aims at engaging stakeholders in addressing marine litter. Under the CleanSeas Campaign in October 2018, Guatemala introduced the installation of bio-fences to trap plastic trash in rivers. Some of the bio-fences are constructed of recovered plastic waste, and communities are generating income from the recycling and upcycling of plastic. Similar projects are being implemented in Honduras, Panama, and the Dominican Republic. In Panama, the Ministry of the Environment in partnership with ANCON, 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 reuse 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-labeling 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 result in minimal environmental impacts, and hence contribute to both economic and social well-being of dependent human communities. But the byproducts of plastic recycling can be just as or even more harmful than the plastic itself. There is a growing recognition of the need to reduce the production of new plastic (Box 8.2).

Box 8.2. Efforts to address the plastic crisis continue to focus on waste management and recycling, but there is compelling evidence that recycling of plastic 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, national monitoring programmes, amongst others, 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.

9. MERCURY

Key messages

Humans are exposed to the highly toxic mercury through different pathways including bio-accumulation and bio-magnification in the marine food chain and consumption of contaminated seafood. 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 can have major implications for countries and territories, particularly the 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 industry, the bauxite sector, 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, and 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 and exposure of both humans and animals to mercury in the environment (Box 9.1). Mercury in water becomes more hazardous 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 as 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 in the unborn child), digestive and immune systems as well as lungs and kidneys, and even death. Because of this, and the fact that mercury can be transferred from a mother to her unborn child, infants, children, and 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[33] 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 or slow degradation 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 runoff, 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 tons. Rivers are estimated to carry more than 2,800 tons of mercury each year, of which only about 380 tons are transported offshore with the rest trapped in estuaries. In addition, groundwater and re-mobilization from sediments provide 100-800 tons of mercury to the ocean each year.

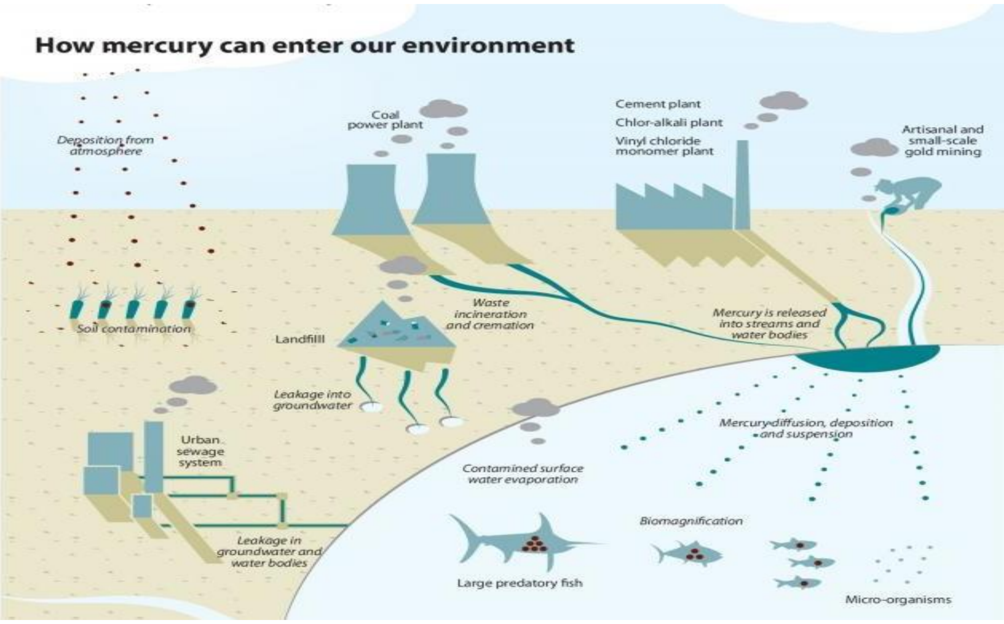


Figure 9.1. Sources and pathways for mercury to the marine environment. Downloaded from https://www.unenvironment.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-general-information

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 mercury emissions in this region (Figure 9.2).

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

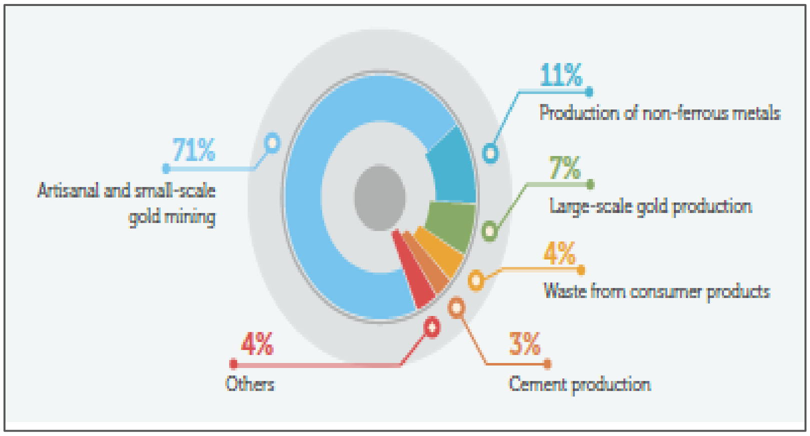

Figure 9.2. Main sources of mercury emissions to the atmosphere in Latin America and the Caribbean in 2010 (Source: Basel Convention Coordinating Centre, Stockholm Convention Regional Centre for LAC and UNEP 2014).

The updated global mercury assessment (UN Environment 2019) shows that in 2015 nearly 500 tons 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 (tons) from main sources to the atmosphere in the Americas in 2015 (UN Environment 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	**409**	18.4
North America	27	7.63	5.77	0	**40.4**	1.8

The Basel Convention Regional Centre (BCRC-Caribbean) recently completed four mercury initial assessments[34] 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.

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

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

Country	Top sources of mercury release
Trinidad and Tobago	1. Extraction and use of fuels/energy sources
	2. Waste incineration and burning
	3. Use and disposal of consumer products with mercury
Saint Lucia	1. Products and processes with intentional use of mercury (dental amalgam, manometers, etc.)
	2. Use and disposal consumer products with mercury
	3. Waste landfilling and wastewater system
Saint Kitts and Nevis	1. Use and disposal of consumer products with mercury
	2. Products and processes with intentional use of mercury (dental amalgam, manometers, etc.)
	3. Waste landfilling and wastewater system
Jamaica	1. Bauxite production
	2. Use and disposal of consumer products with mercury
	3. Waste landfilling and wastewater system

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 of countries in this region have industrial activities known to contribute to mercury releases such as the oil and gas industry, the bauxite sector, and artisanal and small-scale gold mining.

9.3. Mercury in our food chain

The World Health Organization (WHO), the US 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 and to develop consumption guidelines that indicate the number of seafood meals that could be eaten to stay within recommended 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 such as children and pregnant women, may have negative health effects.

Analyses to assess how mercury accumulates in the human body include testing of hair samples. A recent study estimated mercury levels in the hair of women of child-bearing 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 the participants exceeded the 1 ppm total mercury reference level and 58% exceeded the 0.58 ppm proposed reference level. The results for the Caribbean SIDS are shown in Figure 9.3.

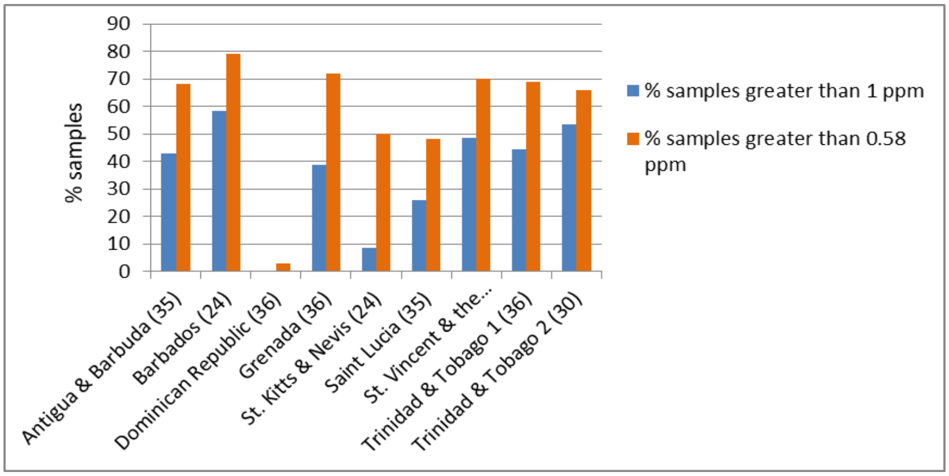

Figure 9.3. Proportions of all participants in Caribbean locations with mercury level (ppm) greater than the 1 ppm and the 0.58 ppm reference level (based on data in Bell 2018). Number in brackets after the country name is the sample size.

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 via the food chain. I On the other hand, in the Dominican Republic very few of the study participants reportedly ate fish frequently (or in some cases, not at all), and that those who did consume fish predominantly ate sardines (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 child-bearing 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, when they 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 UN Environment 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 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.

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. Within the WCR there are several institutions, legal frameworks, action plans, programmes, and projects 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.

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.

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, and 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.

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, for example, by 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 human society to address land-based pollution and its impacts. Responses can be viewed within the broader realm of environmental governance. UN Environment 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 pollution of the marine environment. 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

Within the WCR exists a multitude of institutions, legal frameworks, international non-binding and binding agreements, action plans, programmes, legislation and regulations, and projects 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 or are developing and enacting policies, legislation, national strategies and action plans, and other measures for improving 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 framework and processes in the WCR related to pollution of the marine environment.

Table 10.1. Overview of the institutional framework and processes in the WCR related to land-based pollution of the marine environment
(Note: The material presented in this table serves as examples only and is not intended to be an exhaustive list; the institutions in column 2 are not necessarily linked to the processes in the same row, and the table should be read vertically instead of horizontally)

Level	**Institutional framework**	**Processes**			
	Institutions, Associations, & 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 & indicators
	UN Environment, 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	UN Env Caribbean Environment Programme (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 (AMEP) Programme (CEP), 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 & CLME+ Projects, Gulf of Mexico LME Project, Trash Free Waters-Caribbean	GEO LAC, CARICOMP, SOCAR LBS parameters and cut values (thresholds)
	Caribbean Water & Wastewater Association (NGO) Caribbean Water & Sewerage Association North American Marine Environment Protection Association Caribbean Marine Environment Protection Association				
Subregional	*CARICOM *OECS *SICA-CCAD	St. George’s Declaration (OECS)		MAR2R (CCAD)	
	CARPHA				Epidemiological studies, Environmental assessments,

					Environmental Health Laboratory
National	Gov't 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 national level, participation in regional projects	National effluent & water quality standards, monitoring programmes, Colombia REDCAM, US EPA Coastal Condition report, National 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 mentioned in Chapter 1 of this report, the most important regional legal framework regarding pollution of the marine environment 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 the protection and development of the WCR. For details of 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 conducted in 2013 under the GEF CReW Project of the status of the LBS Protocol in selected Caribbean countries revealed a great disparity among the countries (Corbin 2013). While many of them have sought, to some extent, to prevent, reduce, and control pollution of the marine environment from land-based sources and activities, some have made more progress than others. Further, 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 for the preparation of this report revealed that many of the same challenges and needs have persisted in some of the countries, although considerable progress has been made.

Box 10.1. Challenges and needs of countries 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;
- Accessing and adopting more appropriate and cost-effective technologies;
- Establishing 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; and
- Guidance on the development of wastewater permitting systems.

The above challenges, among others, are described in a multitude of reports and publications produced over the past years by UN Environment, UN Environment CEP, the World Bank, and others. Addressing these challenges in a coherent and coordinated manner across the region should be among the 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 in which WCR countries participate to varying degrees. The key frameworks and initiatives relevant to land-based pollution are presented below along with internet links to information on each one.

- 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 architecture (institutional framework) 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 a number of factors that should be addressed in order 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, and 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 the 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 SDG Goals and Targets are pertinent to pollution of the marine environment, particularly Goal 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 SDG Goals and 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, UN Environment 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 Co-ordinating 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). (http://www.cep.unep.org)

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. One of the six SAP Strategies (Strategy 1) relates to protection of the marine environment with respect to the three priority issues (www.clmeproject.org).

Regional Nutrient Reduction Strategy, Investment Plan, and Action Plan

With support from the UNDP/GEF CLME+ Project, UN Environment CEP is leading the development of a Regional Nutrient Reduction Strategy and associated Investment Plan and Action Plan (ongoing). This will be informed by the information on nutrients in this SOCAR. 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 directive of the UN Environment Programme (through its Regional Seas Programme) in response to growing global concerns of litter accumulation in the oceans. RAPMaLi is designed to serve as a comprehensive toolkit to assist SIDS in incorporating components of proper waste management across all sectors.

Projects

Examples of recent and ongoing projects (GEF- funded) that are relevant to pollution of the WCR marine environment are:

- 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 http://www.clmeproject.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
- Integrated Ridge-to-Reef Management of the Mesoamerican Reef (MAR2R) Project

10.2.6. Governance Effectiveness Assessment Framework

To assess environmental governance, one must look not only at governance arrangements and processes, but also outcomes and impacts (Fanning and Mahon 2018). Mahon et al. (2012) developed a Governance Effectiveness Assessment Framework (GEAF) that comprises seven categories of indicators (Figure 10.1) aimed at assessing whether good governance arrangements are in place and whether they are effective (achieving what they set out to do). The GEAF links improved socio-economic and ecosystem conditions back to enhanced governance arrangements and more effective policy cycle implementation.

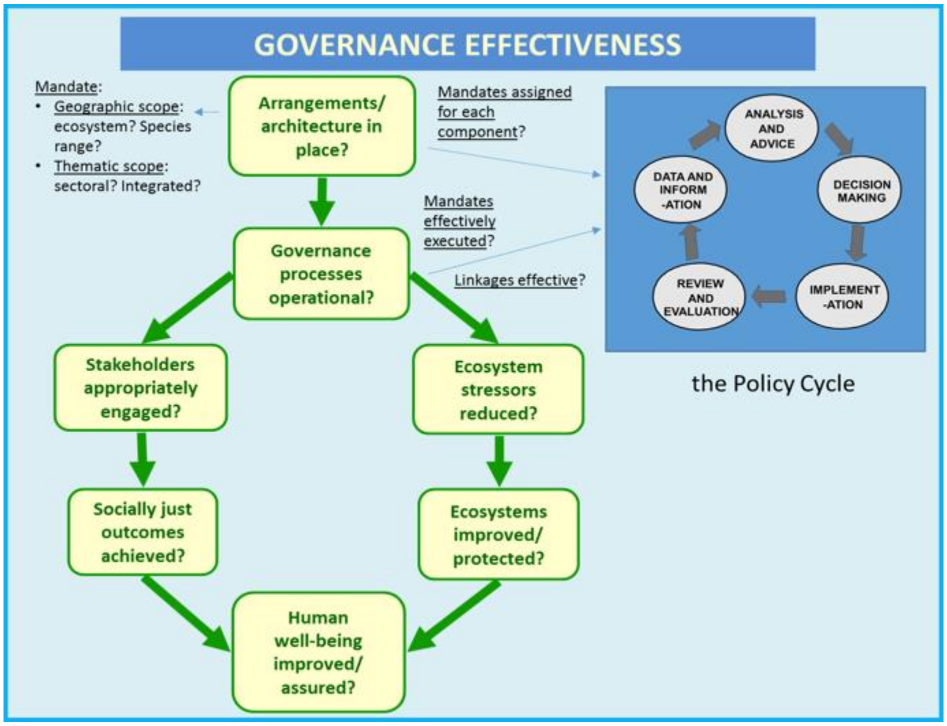

Figure 10.1. Governance Effectiveness Assessment Framework (Mahon et al. 2012, Fanning and Mahon 2018).

The GEAF has been adopted by the countries and intergovernmental organizations participating in the UNDP/GEF CLME+ Project for monitoring and evaluation of 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 wellbeing.

10.3. Stress reduction measures and best practices

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 exist that the 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. See also UN Environment 2018 for case studies and examples of (solid) waste management practices in the region, and UN Environment 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, these can provide high-value 'green infrastructure' for regulating water flows and maintaining water quality by reducing sediment loadings, through the prevention of soil erosion, and by capturing and retaining pollutants. Soft engineering technology has been adopted in a number of countries. For example, wetlands in the Fond D'Or Watershed in Saint Lucia to remove nutrients and contaminants from the wastewater; in Tobago (Trinidad and Tobago), an artificial wetland system was developed to filter wastewater from a fish processing plant. 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 as well as to 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 reuse in economic production and ecological cycles. Colombia, for example, has joined the Zero Waste Initiative with its own project and NGO 'Basura Cero Colombia'. This country has adopted a holistic programme on 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, reuse, 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% (UN Environment 2018).

10.3.3. Reduce/recycle/reuse

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, etc. are given priority over traditional end-of-pipe treatments.

Recycling and reusing 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 reuse 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 UN Environment 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 runoff, best environmental practices/sustainable agricultural practices are implemented to minimize non-point sources (for example, more efficient use of fertilizers, manure, and pesticides). 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 following the introduction of technological innovation and good agricultural practices. 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 (see, for example, www.edf.org/ecosystems/sustainable-agriculture/precision-agriculture; www.pnas.org/agricultural_innovations; and 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 wastes and 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 as well as substantially reduce total suspended solids and biological oxygen demand. The first two CEPT treatment plants in Rio de Janeiro have been constructed and began 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 by the countries to implement effective solutions to the pollution issue. As stated in UNEP CEP (2010b) most countries in the region have failed to take a long-term, integrated approach to wastewater management and few have made adequate budgetary provisions for and investments in sewerage infrastructure, policy reform, and public education. Thus, 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 (such as wastewater treatment facilities).

Diverse financial mechanisms have been developed, and include 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 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, provided 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 foresaw GEF CReW funds leveraging $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, within the WCR, considerable progress has been made at all levels to develop institutional and policy frameworks and initiatives that address a range of environmental issues including pollution of the marine environment. 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, etc. 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 the countries, updated estimates of domestic wastewater and nutrient loads, and drawing on published information sources.

Human populations and their production and consumption patterns are major drivers of change in the condition of the marine environment and 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 and inadequate wastewater treatment facilities and solid waste management as well as unsustainable land-use and agricultural practices. The region's coastal waters continue to receive discharges of substantial volumes of untreated domestic wastewater and agricultural runoff, which introduce significant loads of sewage, nutrients, and other potentially harmful substances to coastal waters. These discharges, together with inputs 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 assessed. Six of these indicators—dissolved inorganic nitrogen, dissolved inorganic phosphorus, and chlorophyll-a (nutrient pollution); *E.coli* and *Enterococcus* (faecal 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 plastic, 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 socio-economic development and the wellbeing 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, etc. 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, *inter alia*:
    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, ocean acidification, electronic waste, marine litter and micro-plastics on the marine environment and human health including 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 preventative and reduction measures.
    d. Use the data from SOCAR and other sources, and the conceptual framework of the economic burden of disease developed by the WHO (WHO 2009) 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 to assess 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 in particular, on the assessment of chemical contaminants such as POPs and Heavy Metals and to 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 state of marine habitats report, SOMEE and reporting on international goals such as the SDGs (in particular 14) and 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 on an ongoing basis and develop periodic interim information products for submission to the STACs and 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 through the collection of epidemiological data and application of the International Health Regulations (IHR).

2. Capacity Building and Training

Contracting Parties:

1. Develop the laboratory capacity for monitoring of microplastics and coastal acidification including through use of the RACs and RAN, and with support from other regional and international laboratories.
2. Consider including national data on plastics and/or microplastics in future SOCARs.

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 for endorsement by Contracting Parties.
4. Work with Contracting Parties and Donor agencies to facilitate laboratory capacity building including *inter alia*:
    a. Enhancing laboratory quality assurance (QA) and quality control (QC) measures;
    b. Facilitating a programme for the gradual accreditation of laboratories including developing 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 execution of national coastal marine surveys to ensure the collection of SOCAR-related data.
5. Work with the RACs and RAN to facilitate training in 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 *inter alia* through Memorandum of Understanding (MOU) with universities, research institutes, private sector and non-governmental agencies to assist in collection of data for future SOCAR.
2. Ensure partnership agreements for data generation include requirements for the use of and/or dissemination of such data.
3. Develop National Pollution Prevention Action Plans to assist in the implementation of 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 in the design and implementation of 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 SOCARs, to ensure buy-in and ownership of the assessment and increase the likelihood of uptake of the results in decision-making.

The Secretariat should:

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 for the housing of SOCAR data and information and other relevant resources.
4. Develop guidance on reporting on the state of monitoring programmes implemented by Parties, in accordance with Article VI of the LBS Protocol with support of the RACs and the Working Group on Monitoring and Assessment including assessing the challenges in sharing sensitive water quality data.

5. Sustainability

Contracting Parties:

1. Establish a policy identifying the role of inter-governmental organizations (IGOs) as partners in the development of future SOCARs and in the overall implementation of the LBS Protocol.
2. Continue discussions including through the Working Group and the STAC on additional monitoring parameters 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 their national laboratories, which should *inter alia* include the institutionalisation and legal designation of the laboratory, and the establishment of a financial mechanism for laboratory operations.
5. Review and as appropriate develop and/or 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

Annex 1.1. LBS Working Group Members

Monitoring and Assessment -State of the Convention Area Report

NAME	JOB TITLE	ORGANISATION
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Lisa Kirkland	Manager, Environmental Management Sub-division	National Environment & 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 main parameters covered. No data was submitted from sub-region. (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**	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 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 the water quality of the Cartagena Convention Area. A number of these indicators such as nutrient sources, domestic waste water 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 socio-economic and biophysical indicators in support of State of Convention Area Report (SOCAR), Cartagena Convention
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 2011-2015 period
8. Fisheries: average landed value and catch by fishing sector for the period 2010 to 2014
9. Average fishing economic impact as % sub-regional or Group GDP, 2010-2014
10. Fish protein as average % of national total animal protein supply, averaged from 2004 to 2013
11. Agriculture contribution to national GDP, national averages over 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 an aim to stimulate 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 so their influence on soil nutrient budgets and the eventual conveyance of these via surface runoff and groundwater, in the case of nitrogen, may be appropriately modeled 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 was 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 with 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 subregional 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 a map shown in **Figure 4.5**.

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5. Built-up surfaces as % 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 area 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, km^2 and percent 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 subregion, total WCR, total continental countries, and total island nations and territories in **Figure 4.6** and **Annex 4.2**

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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.

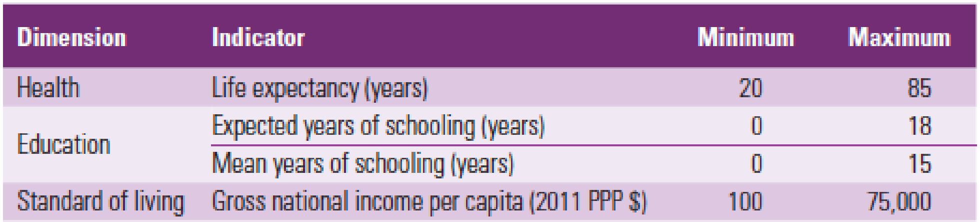
Data sources

- 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:

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



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 percent national contributions, tourism contributed 25% to the region.
e. Note that the individual percent contribution of Tourism to the GDP of each country is reckoned from each national GDP. The average percent contribution then shows the value that Tourism added to the national GDP of an 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's is meaningful at NATIONAL scale, the preferred computation is as described in Step (e).
g. When simple averaging of percent contributions was done among islands only, estimate rose to 33% of GDP.
h. With simple averaging of percent 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%.

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.**

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

$$\textit{Total economic impact of fishing} = \textit{Total Landed value X economic impact multiplier}$$

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:

$$\textit{Fishing impact on household income} = \textit{Total landed value X Income multiplier}$$

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

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 it 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 percent 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 percent 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 are 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 waste water 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, as well as 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
Talaue-McManus (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

Talaue-McManus (this study) using Beusen et al 2016 modelled data for year 2000 from 429 drainage basins	2000	0.51	0.07	3434 billion m^3 of river basin discharge

Definitions (FAO Aquastat)

- ***Municipal water withdrawal***: Annual quantity of water withdrawn primarily for the 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 that part of the industries and urban agriculture, which is 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 runoff, generated within urban areas.
- ***Treated municipal wastewater***: Treated wastewater (primary, secondary and tertiary) annually produced by municipal wastewater treatment facilities in the country.
- ***Unit for volume:*** 10^9 m^3 yr^{-1} , equivalent to km^3
- ***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 (SS), 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 on 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 originally present in the raw wastewater and some of the heavy metals (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 percent) 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 5.1. 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 5.1. 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 5.1 reference list). Values are shown in Column 6, Annex 5.1.

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 5.1.

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 5.1 and associated country references.**

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 (Talaue McManus, 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 (Talaue-McManus, this study) 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 runoff • **0.34 Tg TP = 56% of Total TP load to the coast for model year 2000** = fro agricultural surface runoff

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 estimate 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.**

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

Key Results (Talaue-McManus, 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 runoff 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 runoff (agricultural) • Surface runoff (natural) • Groundwater (agricultural) • Groundwater (natural) • Allochthonous organic matter input from wetlands and floodplains to rivers • Aquaculture	Sources of Phosphorus (kg^3 P yr^{-1}: • Surface runoff (agricultural) • Surface runoff (natural) • Weathering • Allochthonous organic matter input to rivers • Aquaculture • Wastewater discharge

	• Direct deposition on surface water • 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 Phosphorous 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) (Talaue-McManus, 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.**

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 tons of solid waste** was generated in 2015 in the WCR of which 10 million tons were plastics. Anywhere from 2 to 50% of solid waste was mismanaged, causing around **1.3 million tons** 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 center 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 (Talaue-McManus, this study)

Data sources

- WCR coastal population, 2015 (Talaue-McManus, 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 tons yr^{-1}, 2015

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

To estimate rural urban waste in tons 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).

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

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

$$Total\ coastal\ country\ waste = Urban\ waste + Rural\ waste$$

c. To estimate Plastics waste generated in tons, 2015

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

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

$$Marine\ Plastics = \%\ Mismanaged\ plastics\ waste\ X\ Plastics\ waste$$

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 shows that tourists in the ECCU countries contributed almost 50,000 tons of waste to 663,000 tons 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 (refs to be added), 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 tons yr^{-1}, 2015:

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

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

$$Solid\ waste_{excursionists} = Annual\ no\ excursionists\ X\ 1.75$$

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

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

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

$$Solid\ waste_{charter\ boat} = Annual\ no\ yachters\ X\ 90\ X\ 1.75$$

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 and built up areas in continental countries, island states and territories of the Wide Caribbean Region. Coastal populations are residents within the 100 km coast of continental countries. (Talaue-McManus, this study; See Annex 4.1 for data sources and technical notes).

Country/Territory	**Coastal population**			**% Urbanization**			**Density per km2**		**Caribbean Coastal Area, km2**	**National Area, km2**	**Built 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 I 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%
Guyana	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 1	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 Eeastern 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%
Subregion 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 (Talaue-McManus, 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 (Talaue-McManus, 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, constant 2010 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 5.1. Municipal wastewater calculations (Talaue-McManus, this report). 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 reference table below.

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 Grena	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***
Bahamas, The	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 5.1 References used in determining proportion of population connected to a wastewater treatment plant, values for which are also shown in column 6 of Annex 5.1. (See technical notes in Annex 4.1).

Country/ Island territory	% Population connected to wastewater treatment plant	Reference
Mexico	0.36	Zurita et al 2012
US (Gulf States only)	0.61	US EPA 2012 Profiles for Gulf States: Alabama. Florida, Louisiana, Mississippi. Texas
Belize	0.00	Grau et al. 2013.
Costa Rica	0.04	Guzman-Arias & Calvo-Alvarado 2013
Guatemala	0.05	GEF CReW 2010
Honduras	0.10	Aquastat for year 2007
Nicaragua	0.10	Nicaragua National Institute of Development Information 2008
Panama	0.15	GEF CReW 2010
Colombia	0.01	Campuzano Ochoa et al 2015
French Guiana		
Guyana	0.05	GEF CReW 2010
Suriname	0.00	GEF CReW 2010
Venezuela, BR	0.00	Campuzano Ochoa et al. 2015
Aruba		
Bonaire		
Curacao		
Anguilla		
Antigua and Barbuda	0.00	ECLAC 2007, USACE 2004
Barbados	0.04	Construction Caribbean, 2018
British Virgin Islands		
Dominica	0.00	USACE 2004; ECLAC 2007
Grenada	0.00	ECLAC 2007; CEP TR 55 2010
Guadeloupe		
Martinique		
Montserrat		
Sint Maarten (Dutch part)		
Saint Kitts and Nevis	0.00	USACE 2004
Saint Lucia	0.00	CEP TR 55 2010
Saint Martin (French part)		CEP TR 55 2010
Saint Vincent and the Grenadines	0.00	GEF CReW 2010
Trinidad and Tobago	0.05	WRI 2014 in Cariri website
Virgin Islands (U.S.)		
Bahamas, The	0.07	GEF CReW 2010
Cayman Islands		
Cuba	0.04	Westbrook and De Freitas Alves 2016
Dominican Republic	0.12	Grullon 2013
Haiti	0.00	Herscher 2017
Jamaica	0.08	GEF CReW 2010
Puerto Rico	0.64	US EPA 2012
Turks and Caicos Islands		

Annex 5.2. Modeled values of nitrogen by source for each sub-region and WCR for year 2000 (Talaue-McManus, this report; input data from Beusen et al 2016).

Sub-region	**Atmospheric deposition**	**Vegetation in floodplains**	**Surface runoff (agriculture)**	**Surface runoff (natural)**	**Groundwater (agriculture)**	**Groundwater (natural)**	**Sewage**	**Aquaculture**	**All N inputs**
I	45.14	255.38	755.24	21.77	1800.24	231.79	294.32	3.13	3407.01
	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	1611.31
	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	1083.15	63.60	2195.23	798.97	509.42	9.59	5467.76
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. Modeled values of phosphorus by source for each sub-region and the WCR for year 2000 (Talaue-McManus, this report; data input data from Beusen et al 2016).

Sub-region	**Weathering**	**Vegetation in floodplains**	**Surface runoff agriculture**	**Surface runoff 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 (10^3 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 (Talaue-McManus, this study).

COUNTRY	POP100KM 2015	% Urban 2015	Urban Residents 2015 in kg/per/day	Urban waste in tons/yr	Rural waste at 75% of rate in tons/year	Total waste 2015 in tons/yr	% Plastic in waste stream	Plastic waste generated in tons 2015	% Mismanaged plastic waste	Plastic waste to ocean 2015 in tons
Mexico	17,486,689	0.53	1.24	4,172,511	2,806,473	6,978,984	7	488,529	14	68,394
United States	33,713,411	0.82	2.58	26,087,265	4,245,490	30,332,756	13	3,943,258	2	78,865
Belize	355,922	0.45	2.87	169,309	152,653	321,962	6	19,318	31	5,988
Guatemala	479,819	0.50	2.00	175,029	131,429	306,458	14	42,904	38	16,304
Nicaragua	624,350	0.58	1.10	145,117	79,170	224,287	13	29,157	47	13,704
Honduras	3,749,099	0.55	1.45	1,094,689	667,141	1,761,830	13	229,038	42	96,196
Costa Rica	3,255,766	0.77	1.36	1,242,182	280,485	1,522,667	19	289,307	18	52,075
Panama	3,675,524	0.67	1.21	1,082,738	405,418	1,488,156	12	178,579	20	35,716
Guyana	710,323	0.26	5.33	365,374	762,393	1,127,767	12	135,332	17	23,006
Suriname	504,179	0.66	1.36	165,331	63,707	229,039	12	27,485	17	4,672
French Guyana	223,018	0.84	1.20	82,522	11,370	93,892	12	11,267	27	3,042
Colombia	9,338,870	0.74	1.20	3,046,549	782,907	3,829,456	12	459,535	23	105,693
Venezuela BR	23,043,369	0.93	0.86	6,698,048	401,449	7,099,497	12	851,940	7	59,636
Aruba	103,889	0.43	2.10	34,329	33,977	68,305	12	8,197	3	246
Bonaire	18,398	0.75	2.76	13,837	3,504	17,341	12	2,081	2	42
Curacao	157,203	0.89	2.10	107,663	9,625	117,288	12	14,075	2	281
British Virgin Is	30,113	0.47	2.59	13,260	11,405	24,666	12	2,960	2	59
Virgin Is (US)	107,710	0.95	3.74	140,165	5,127	145,291	12	17,435	2	349
Anguilla	14,611	1.00	1.20	6,400	0	6,400	12	768	4	31
Saint Martin	31,754	1.00	2.10	24,339	0	24,339	12	2,921	2	58
Sint Maarten	38,824	1.00	2.10	29,759	0	29,759	12	3,571	2	71
Saint Kitts and Nevis	54,288	0.31	5.45	33,294	56,024	89,318	12	10,718	8	857
Antigua and Barbuda	99,923	0.25	5.50	50,149	112,835	162,984	12	19,558	8	1,565
Montserrat	5124	0.09	1.20	203	1,531	1,734	12	208	14	29
Guadeloupe	450418	0.98	1.20	194,205	2,308	196,514	12	23,582	27	6,367
Dominica	73,162	0.70	1.24	23,040	7,555	30,595	12	3,671	21	771
Martinique	385842	0.89	2.10	263,156	24,444	287,600	12	34,512	2	690
Saint Lucia	177,206	0.19	4.35	52,080	171,959	224,039	12	26,885	22	5,915
Saint Vincent and the Grenadines	109,455	0.51	1.70	34,610	24,980	59,590	13	7,747	23	1,782
Barbados	284,217	0.31	4.75	153,988	254,080	408,068	12	48,968	6	2,938
Grenada	106,823	0.36	2.71	38,039	50,719	88,758	12	10,651	20	2,130
Trinidad and Tobago	1,360,092	0.53	14.40	3,811,657	2,502,740	6,314,397	25	1,578,599	5	78,930
Cuba	11,282,863	0.77	0.81	2,565,214	577,924	3,143,137	11	345,745	25	86,436
Haiti	10,584,527	0.52	1.00	2,025,556	1,378,348	3,403,903	9	306,351	49	150,112
Dominican Republic	10,507,413	0.79	1.10	3,314,653	678,055	3,992,708	12	479,125	27	129,364
Jamaica	2,871,934	0.55	1.50	862,138	532,684	1,394,822	19	265,016	29	76,855
Puerto Rico	3,473,177	0.94	2.35	2,789,050	142,551	2,931,601	12	351,792	49	172,378
Bahamas, The	386,838	0.83	3.25	379,729	59,368	439,097	12	52,692	3	1,581
Turks and Caicos Islands	34,339	0.92	2.10	24,268	1,540	25,808	12	3,097	2	62
Cayman Islands	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). (Talaue-McManus, 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 per person per day)**	**2015 Visitors**	**Solid waste generated in 2015 (tons)**
Stay-over Visitors by Air	8			
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	1.75	132,310	232
Cruise ship Passengers	0.5	3.5	2,860,932	5,007
Yacht Passengers	90	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%