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Regional Nutrient Pollution Reduction Strategy and Action Plan for the Wider Caribbean Region

For public health and safety reasons associated with the COVID-19 pandemic, this meeting is being convened virtually. Delegates are kindly requested to access all meeting documents in electronic format for downloading as needed.

Regional Nutrient Pollution Reduction Strategy and Action Plan for the Wider Caribbean Region

[Reviewed version for endorsement by the Contracting Parties to the Land-based Sources (LBS) Protocol, Cartagena Convention, June 2021]

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ACRONYMS AND ABBREVIATIONS

ACP	African, Caribbean, and Pacific States
ACTO	Amazon Cooperation Treaty Organization
AIS	Automatic Identification System
ANCA	Algas Nocivas en el Caribe y Regiones Adyacentes (Harmful Algae in the Caribbean and Adjacent Regions- Network)
ASP	Amnesic Shellfish Poisoning
AWTS	Advanced Wastewater Treatment System
BEP	Best Environmental Practice
BMP	Best Management Practice
BOHESI	Banana Occupational Health and Safety Initiative
BWDO	Bottom Water Dissolved Oxygen
CAFO	Concentrated Animal Feeding Operation
CAR RCU	Caribbean Regional Coordinating Unit (UNEP)
CARICOM	Caribbean Community
CARPHA	Caribbean Public Health Agency
CBD	Convention on Biological Diversity
CC	Canary Current
CEP	Caribbean Environment Programme
CERMES	Centre for Resource Management and Environmental Studies
CFP	Ciguatera Fish Poisoning
Chl-a	Chlorophyll a
CIMAB	Center for Research and Environmental Management of Transport
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
COP	Conference of Parties
CReW	Caribbean Regional Fund for Wastewater Management
CRFM	Caribbean Regional Fisheries Mechanism
DDT	dichloro-diphenyl-trichloroethane
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
DOP	Dissolved Organic Phosphorus
DPSIR	Driver-Pressure-State-Impact-Response Framework
DSA	Degree of Ship Activity
DSP	Diarrheic Shellfish Poisoning
ECCU	Eastern Caribbean Currency Union
ECLAC	UN Economic Commission for Latin America and the Caribbean
EEZ	Exclusive Economic Zone
EHSD	Environmental Health and Sustainable Development Department (CARPHA)
EPA	Environmental Protection Agency (US)
EU	European Union

FANSA	Floraciones Algales Nocivas en Sudamérica (Harmful Algae in South America – Network)
FAO	Food and Agriculture Organization
FOE	Friends of the Earth
GCFI	Gulf and Caribbean Fisheries Institute
GDP	Gross Domestic Product
GEAF	Governance Effectiveness Assessment Framework
GEF	Global Environment Facility
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GNC	Global Nutrient Cycling Project
GNM	Global Nutrient Model
GO2NE	Global Ocean Oxygen Network
GOM	Gulf of Mexico
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPNM	Global Partnership on Nutrient Management
GPS	Global Positioning System
HAB	Harmful Algal Bloom
HABs	Harmful Algal Blooms
HAEDAT	Harmful Algae Event Database
HDI	Human Development Index
HTF	Hypoxia Task Force
IASI	Infrared Atmospheric Sounding Interferometer
ICEP	Index of Coastal Eutrophication Potential
ICM	Interim Coordinating Mechanism
IGO	Intergovernmental Organization
IMA	Institute of Marine Affairs
IMAGE-GNM	Integrated Model to Assess the Global Environment- Global Nutrient Model
IMO	International Maritime Organization
INI	International Nitrogen Initiative
INMS	International Nitrogen Management System
INVEMAR	Instituto de Investigaciones Marinas y Costeras
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IOCARIBE	IOC Sub-Commission for the Caribbean and Adjacent Regions
IODE	International Oceanographic Data and Information Exchange
ITCZ	Inter-Tropical Convergence Zone
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
IWLEARN	International Waters Learning Exchange and Resource Network
IWRM	Integrated Water Resources Management
JCEF	Jamaica Credit Enhancement Facility
K	Potassium
LAC	Latin American and Caribbean
LBS	Land-based Sources
LME	Large Marine Ecosystem
MAR	Mesoamerican Reef
MAR2R	Integrated Ridge to Reef Management of the Mesoamerican Reef Ecoregion Project

MARB	Mississippi-Atchafalaya River Basin
MARPOL	International Convention for the Prevention of Pollution from Ships
MEA	Multilateral Environmental Agreement
MRB	Mississippi River Basin
MSD	Marine Sanitation Device
N	Nitrogen
NEC	North Equatorial Current
N-ICEP	Nitrogen-Index of Coastal Eutrophication Potential
NANI	Net Anthropogenic Nitrogen Inputs
NASA	National Aeronautics and Space Administration (US)
NBS LME	North Brazil Shelf Large Marine Ecosystem
NEWS 2	Nutrient Export from Watersheds 2
NGO	Non-Governmental Organization
NIC	National Inter-ministerial Committee
NOAA	National Oceanic and Atmospheric Administration (US)
NOx	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
Nr	Reactive Nitrogen
NTU	Nephelometric Turbidity Units
NUE	Nitrogen Use Efficiency
NWC	National Water Commission (Jamaica)
OECS	Organization of Eastern Caribbean States
OPRC	International Convention on Oil Pollution Preparedness, Response, and Co-operation
OSL	Oxygen Stress Level
P	Phosphorus
P-ICEP	Phosphorus-Index of Coastal Eutrophication Potential
PAH	Polycyclic Aromatic Hydrocarbons
PAHO	Pan American Health Organization
PCB	Polychlorinated Biphenyls
PCR-GLOBWB	PC Raster Global Water Balance
PES	Payment for Ecosystem Services
pH	potential of Hydrogen
POPS	Persistent Organic Pollutants
PROA	Pollution Reduction Opportunity Analysis
PSC MoU	Port State Control-Memorandum of Understanding
PSP	Paralytic Shellfish Poisoning
PUE	Phosphorus Use Efficiency
RAC	Regional Activity Centre
RAN	Regional Activity Network
REMPEITC	Regional Marine Pollution Emergency Information and Training Center for the Wider Caribbean
REPCar	Reducing Pesticide Run-off to the Caribbean Sea Project
RNPRSAP	Regional Nutrient Pollution Reduction Strategy and Action Plan
SAMOA	SIDS Accelerated Modalities of Action Pathway
SAP	Strategic Action Programme
SDG	Sustainable Development Goal
Si	Silica
SICA/CCAD	Central American Integration System/Commission for Environment and Development

SIDS	Small Island Development States
SIR	Sargassum Inundation Report
SNMI	Sustainable Nitrogen Management Index
SO	Strategic Objective
SOCAR	State of the Cartagena Convention Area Report
SOLAS	Safety of Life at Sea
SOMEE	State of the Marine Environment and Associated Economies
SPAW	Protocol Concerning Specially Protected Areas and Wildlife
STAC	Scientific and Technical Advisory Committee
SWMM	Stormwater Management Model
Tg	Teragram; 1 Tg = 10^{12} grams = million tons
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TWAP	Transboundary Waters Assessment Programme
UNCCD	UN Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEA	United Nations Environment Assembly
UNECLAC	UN Economic Commission for Latin America and the Caribbean
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change
US	United States of America
UWI	University of the West Indies
WCR	Wider Caribbean Region
WHO	World Health Organization
WTA	Western Tropical Atlantic

EXECUTIVE SUMMARY

1 RATIONALE FOR A NUTRIENT POLLUTION REDUCTION STRATEGY FOR THE WIDER CARIBBEAN

1.1 Value of the Caribbean Sea and current threats

The wider Caribbean Sea (Figure ES 1) provides a diverse array of valuable ecosystem goods and services that underpin socio-economic development and the blue economy in the bordering countries and territories. A conservative estimate of the gross revenues generated in 2012 by the ocean economy in the Caribbean Sea was over US$400 billion. Nevertheless, the Wider Caribbean Region's (WCR) marine ecosystems are facing unprecedented pressures from increasing human populations, poorly planned coastal urbanization, and harmful production and consumption patterns as well as climate change impacts, with potentially serious consequences for human health, livelihoods, and national economies.

A major concern is pollution of the region's marine environment, which is reflected in the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention) and its Protocols on Pollution from Land-Based Sources and Activities (LBS Protocol), Oil Spills, and Specially Protected Areas and Wildlife (SPAW).

Figure ES 1 The Wider Caribbean Sea and the Cartagena Convention Area. (LME: Large Marine Ecosystem)

The State of the Convention Area (SOCAR) report on land-based pollution, which was commissioned by the Contracting Parties to the LBS Protocol, showed that several sites in coastal waters throughout the area covered by the SOCAR (Caribbean and Gulf of Mexico LMEs) had poor status with respect to selected water quality indicators, including nutrients (nitrogen and phosphorus). In addition to land-based sources, ocean-based activities such as shipping, cruise tourism, fisheries, and the oil and gas industry also contribute substantially to pollution of the Caribbean Sea. Marine pollution in the WCR is likely to intensify under a 'business as usual' scenario.

1.2 Fertilizing the ocean

Human activities have been accelerating the discharge of excessive loads of nutrients such as nitrogen and phosphorus to aquatic ecosystems from both terrestrial and marine sources and activities. The excessive use of nutrients is at the centre of an intricate web of development benefits and environmental problems (Figure ES 2). On the one hand, half of the world's food security depends on the use of synthetic nitrogen and phosphorus fertilizers. However, excessive and improper use of synthetic fertilizers in agriculture results in the loss of significant quantities of nutrients to the environment. Globally, around 200 million tons per year of total nitrogen are wasted, equivalent to an economic loss of US$200 billion annually. On the the other hand, excess nutrients from fertilizers, fossil fuel burning, and wastewater from human communities, livestock, aquaculture, and land- and ocean-based industries produce threats to air, water, soil, and biodiversity, and generate greenhouse gas emissions. Enrichment of marine waters by excessive nutrients (eutrophication) is a leading cause of overall deterioration of the health and productivity of marine ecosystems, as manifested by phenomena such as algal blooms, hypoxia (low oxygen levels in the water), and dead zones. Although not conclusive, increased nutrient inputs to the ocean combined with abnormal ocean currents and wind patterns linked to climate change are thought to contribute to the proliferation and influx of Sargassum into the wider Caribbean Sea.

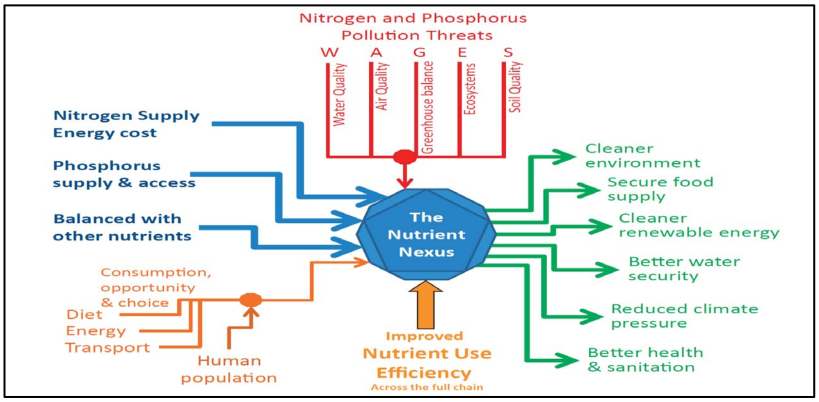


Figure ES 2 The 'Nutrient Nexus'. Nutrient cycles represent a key nexus point between global economic, social, and environmental challenges. Improving nutrient use efficiency is the key to delivering multiple benefits.

1.3 The Nutrient Challenge and the Global Development Agenda

The realization of the major implications of nutrient management and nutrient pollution on sustainable development has elevated nutrients on the global agenda, including the 2030 Sustainable Development Agenda (Figure ES 3).

Figure ES 3 Illustration of the multiple ways in which sustainable nitrogen management can contribute to meeting the SDGs, highlighting the potential of an ambitious aspiration to Halve Nitrogen Waste globally from all sources of nitrogen pollution by 2030 (Colombo Declaration on Sustainable Nitrogen Management).

Global Targets and Resolutions on nutrient pollution include:

- 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).
- Target 6 of the Convention on Biological Diversity Post-2020 Global Biodiversity Framework (By 2030, reduce pollution from all sources, including reducing excess nutrients, to levels that are not harmful to biodiversity and ecosystem functions and human health).
- United Nations Environment Assembly (UNEA) Resolutions (2019): Resolution on Sustainable Nitrogen Management, calling for the mobilization of a coherent, multi-sector, multi-impact approach to nitrogen management.
- The Colombo Declaration on Sustainable Nitrogen Management (under the UN Global Campaign on Sustainable Nitrogen Management), which sets an ambitious target to halve global nitrogen waste by 2030. This is expected to lead to immediate benefits in combatting climate change, air pollution, and biodiversity loss, US$100 billion in savings and innovations in sectors like farming, energy, and transport.

Under the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), the Global Partnership on Nutrient Management (GPNM) has been established. The regional GPNM Platform for the Caribbean was launched in 2013, with the purpose of driving policy and encouraging implementation in the countries of best nutrient management practices to minimize adverse impacts on the marine environment. When fully operational, the GPNM Caribbean Platform along with the LBS Protocol will become the major regional platform for harmonized nutrient management in the WCR.

1.4 The Regional Nutrient Pollution Reduction Strategy and Action Plan

In October 2019, the UNEP Caribbean Environment Programme (CEP) Regional Coordination Unit (CAR RCU)/Cartagena Convention Secretariat initiated the development of a Regional Nutrient Pollution Reduction Strategy and Action Plan (RNPRSAP) for the WCR. One of its goals is to establish a collaborative framework for the progressive reduction of impacts from excess nutrient loads on priority coastal and marine ecosystems in the WCR. The RNPRSAP responds to and supports the Cartagena Convention and its Protocols, the CLME+ Strategic Action Programme, the UNEP CEP Regional Strategy for the Protection and Development of the Marine Environment of the WCR, the 2030 Sustainable Development Agenda, relevant UNEA Declarations particularly on Sustainable Nitrogen Management, Regional Seas Programmes, Small Island Developing States Accelerated Modalities of Action (SAMOA Pathway), Convention on Biological Diversity (CBD) Post-2020 Global Biodiversity Framework, and the UN Convention to Combat Desertification (UNCCD), among others.

2 SOURCES OF NUTRIENT POLLUTION

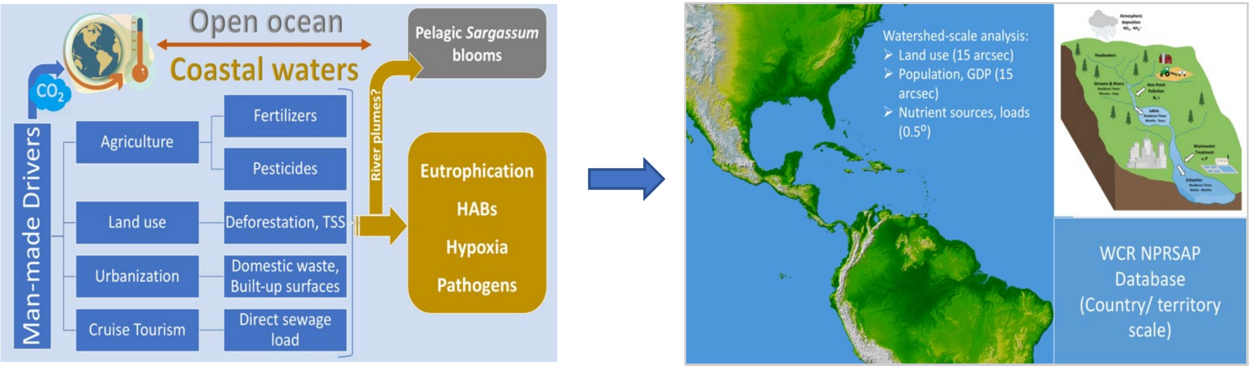


Figure ES 4 Conceptual framework and analytical approach used in this report for assessing nutrient sources and impacts.

2.1 Analytical Approach

Agriculture, land use change and urbanization on land, and cruise tourism and shipping at sea, drive nutrient pollution in the Wider Caribbean Region (WCR), under a changing climate regime. A watershed approach is used in this document to examine land-based sources, fluxes and ecosystem impacts of excess nutrients. Spatially explicit data on land use (year 2000) and population (year 2010), as well as modeled (year 2000) and inventory-based data are analyzed at watershed or country scale, to provide the scientific basis for a nutrient pollution reduction strategy and action plan. This analysis builds on and complements the results of the State of the Cartagena Convention Area (SOCAR) report, which assessed marine pollution from land-based sources and activities in the region (UNEP CEP, 2019). Watershed data, aggregated at country or territory scale is organized into a Regional Nutrient Pollution Reduction Strategy and Action Plan (RNPRSAP) database to seed and encourage the assembly and updating of watershed data as evidence base for policy formulation and implementation. In keeping with the view to examine the full water continuum, a preliminary analysis of sea-based sources is made, even if proper quantification of ship-based nutrient discharges remains a major data gap.

2.2 Fertilizer surplus

At regional scale, net changes in agricultural land showed a gradual increase from 1961 to 2018, the period for which harmonized country-scale data from the Food and Agriculture Organization (FAO) of the United Nations (UN) is available. Over this period, cropland among WCR countries increased from 2.5 million km^2 to nearly 2.8 million km^2, accounting for just 12% of aggregate national land areas; and 13% of WCR watershed area. The short harmonized records for forests indicate a net loss of over a million km^2 of forest, 88% of which was cleared in Brazil. Currently, Latin American and Caribbean countries contribute 14% of the global food production, and 23% of agricultural and fish exports. The contributions are projected to increase to more than 5% by year 2028, and a nagging question is the extent of environmental tradeoffs these increases in food production might cause.

Fertilizers and pesticides are major agrochemicals that are applied in farmlands to boost crop production. At the same time, they also cause major perturbations in the natural biogeochemical cycling of plant biomass given the massive amount of anthropogenic additions to the biosphere. A measure that has been designed to quantify the contribution of fertilizer application to increases in agricultural yield as well as to nutrient pollution is the Nutrient Use Efficiency, defined as the proportion of nutrient used up by the harvested crop relative to total nutrient inputs. Such an index allows for determining the amount of fertilizers and inputs (such as atmospheric deposition for nitrogen) that enhance plant growth, and evaluating the surplus that is not assimilated and flows as excess nutrient polluting surrounding ecosystems.

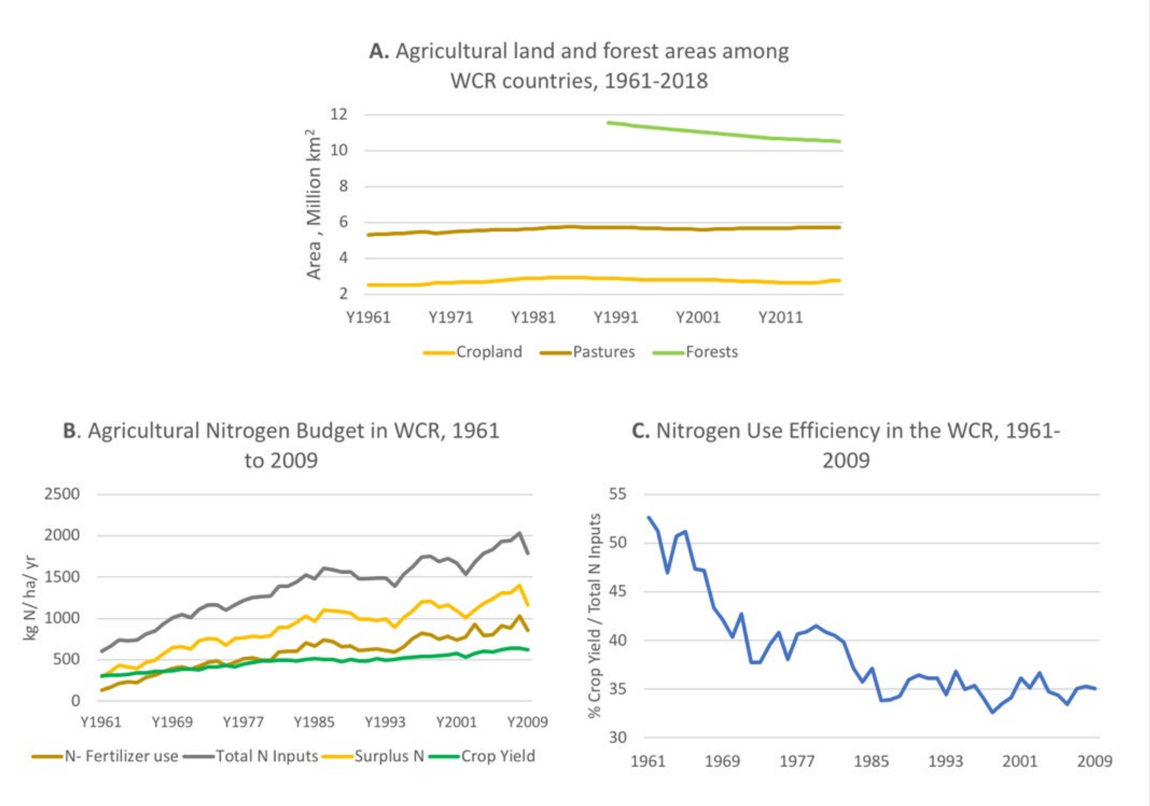
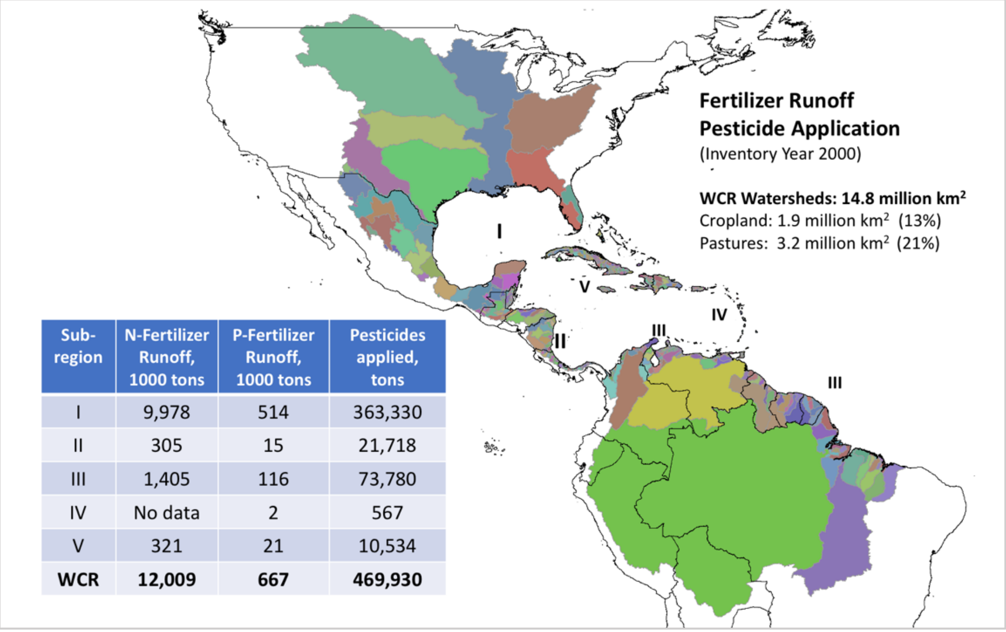


Figure ES 5 A. Land use, 1961 to 2018. B. Agricultural Nitrogen Budget, 1961 to 2009. C. Nitrogen Use Efficiency in the WCR, 1961 to 2009 (simple unweighted average among 22 WCR countries with NUE data).

Figure ES 5 shows the chronologies in regional land use changes (1961 to 2018) (A), nitrogen budget (B) and nitrogen use efficiency from 1961 to 2009. Increasing nitrogen inputs (grey line, Figure ES 5B) from 1961 to 2009 shows an increase in crop yield, but not in a proportional manner (Figure ES 5B, green line). which meant that the amount of excess nitrogen (orange line, Figure ES 5B) was increasing. As a consequence nitrogen use efficiency was decreasing, here computed as a simple unweighted average among 22 WCR countries with data (Figure ES 5C).



Sub-region	N-Fertilizer Runoff, 1000 tons	P-Fertilizer Runoff, 1000 tons	Pesticides applied, tons
I	9,978	514	363,330
II	305	15	21,718
III	1,405	116	73,780
IV	No data	2	567
V	321	21	10,534
WCR	**12,009**	**667**	**469,930**

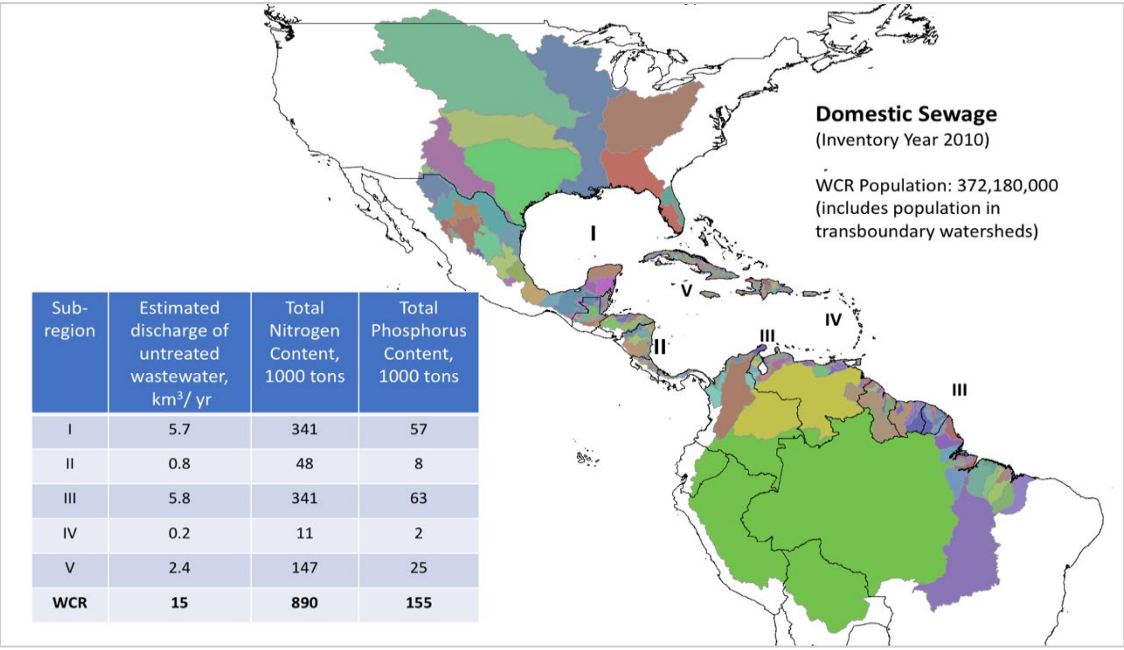
Figure ES 6 Fertilizer runoff and pesticide application in WCR watersheds for Inventory year 2000.

The resulting nitrogen and phosphorus surplus runoff are shown in Figure ES 6 for inventory year 2000. Surplus nitrogen amounting to 12,009,000 tons flowed from 1.9 million km^2 of cropland. Excess phosphorus at 667,000 tons is estimated to have flowed from cropland and 3.2 million km^2 of pastures in the WCR. About 470,000 tons of pesticides were used this year. The inventory method used in calculating surplus nutrient fluxes does not account for losses due to denitrification for nitrogen, other nutrient losses due to transformation, adsorption or retention.

2.3 Domestic wastewater

Spatial population data WCR watersheds for year 2010 along with percentages served by sewers connected to sewage treatment plants from SOCAR (UNEP CEP, 2019) were used to inventory domestic wastewater discharge. An aggregate of 372,180,000 inhabitants in the WCR watersheds (inclusive of transboundary watersheds located in non-WCR countries such as Bolivia, Ecuador and Peru) most likely released untreated sewage in the order of 15 km^3 (1 km^3 = 10^9 m^3), containing 890,000 tons of Nitrogen and 155,000 tons of P for inventory year 2010 (Figure ES 7). These values are conservative in that they exclude contributions from partially treated sewage when these are discharged to the environment at point sources such as sewage outfalls. These estimates also do not account for losses due to geochemical transformations, adsorption or retention.

Pathogens released with discharged sewage pose serious public health risks especially when these contaminate surface and sub-surface freshwater ecosystems that are tapped for human use.



Sub-region	Estimated discharge of untreated wastewater, km^3/ yr	Total Nitrogen Content, 1000 tons	Total Phosphorus Content, 1000 tons
I	5.7	341	57
II	0.8	48	8
III	5.8	341	63
IV	0.2	11	2
V	2.4	147	25
WCR	**15**	**890**	**155**

Figure ES 7 Domestic sewage generated by over 372,000,000 inhabitants and discharged in WCR watersheds for inventory year 2010, contributing 890,000 tons of nitrogen and 155,000 tons of phosphorus.

2.4 Nutrient source estimates using integrated models

Unlike inventory methods, integrated models include algorithms which constrain fluxes by accounting for nutrient retention, removals, chemical species transformation, and biological uptake, during nutrient transport. Results from the Integrated Model to Assess the Global Environment – Global Nutrient Model (IMAGE-GNM) are shown in Figure ES 8. The results also allow comparison of patterns in the WCR which is heavily influenced by agriculture, with those in the North Brazil Shelf LME, which still has 75% of its forest cover. The total amounts of both nitrogen and phosphorus released in the WCR and the NBS LME are comparable; but the allocation by origin or source is distinctly different. The WCR is 60% dominated by nutrients coming from agriculture; those in the NBS LME come from floodplain vegetation and natural runoff at 90%.

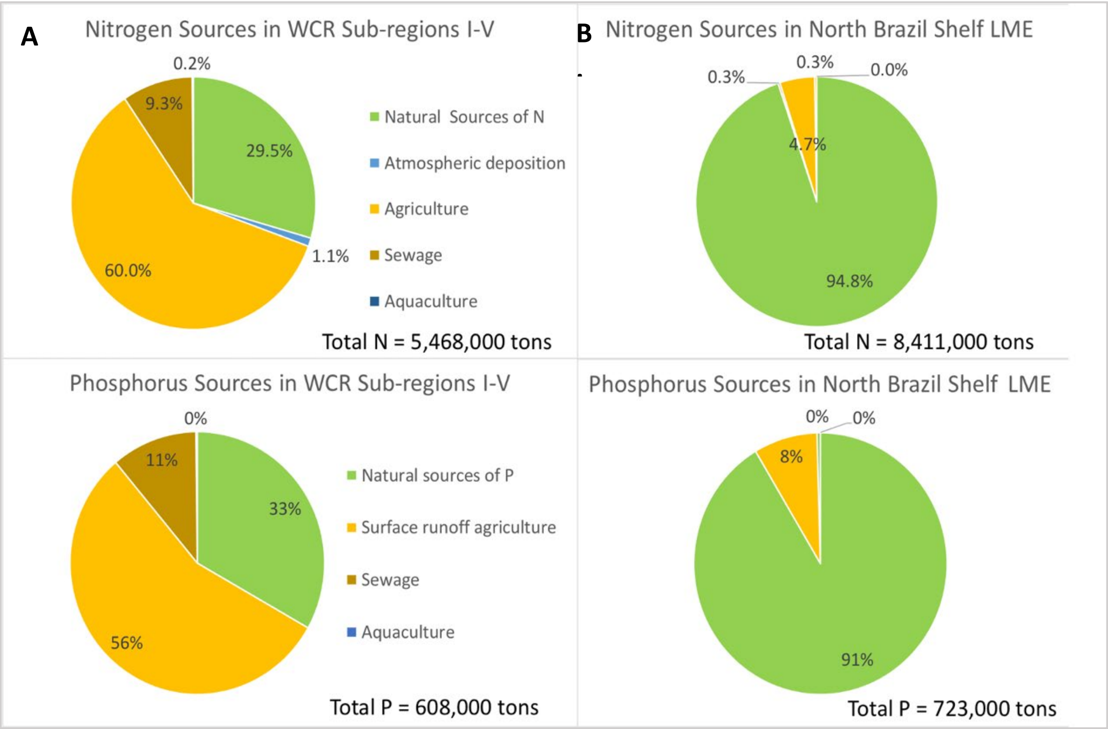


Figure ES 8 Estimates of nutrient sources using the Integrated Model to Assess the Global Environment – Global Nutrient Model (IMAGE-GNM). A. WCR sub-regions I-V generate more than of half of nutrient flow from agricultural runoff, both surface and groundwater. B. For watersheds draining to the North Brazil Shelf Large Marine Ecosystem, 90-95% of nutrients come from natural sources such as floodplain vegetation and natural runoff.

2.5 Sea-based sources of nutrient pollution

While agriculture is the singular land-based driver of nutrient pollution on land, shipping maybe roving collective point sources of nutrient-laden wastewater that can potentially be discharged directly to marine waters. Cruise ship tourism in particular with around 100 megaships, each carrying on average 4000 passengers and 500 crew members, can contribute significantly to direct loading of nutrient-enriched wastewater. It is the most lucrative form of tourism to date, with revenues reaching US$ 40 billion in 2016; and 24 million passengers arriving in over 30 choice Caribbean island destinations. Average waste streams estimated by the US Environmental Protection Agency include 80 m^3 of sewage, 645 m^3 of graywater and 12 m^3 food waste per ship per day, and solid and hazardous waste. In addition to cruise ships, cargo ships that ply trade routes through the WCR can contribute to nutrient pollution. Protection of the Wider Caribbean Region against garbage dumping is regulated by its designation as a MARPOL Special Area under MARPOL Annex V-Garbage. Application for the protection of the WCR as a Special Area designee under MARPOL Annex IV-Sewage should be sought to reach the same protection status as the Baltic Sea, and to reduce potentially threatening sewage dumping by the shipping industry.

3 IMPACTS OF NUTRIENT POLLUTION

The Wider Caribbean Region is experiencing unequivocal impacts of nutrient pollution including nitrogen-based eutrophication, harmful algal blooms, hypoxia and those resulting from a complex and not fully understood phenomenon of recurrent nuisance *Sargassum* blooms. These ecosystem scale responses have consequential effects on livelihoods and human health, not to mention the impairment of ecosystem services that underpin vulnerable island economies.

3.1 Eutrophication

Coastal waters subject to or undergoing eutrophication can be gauged by examining nutrient loads of total nitrogen (i.e. dissolved inorganic, dissolved organic, and particulate forms), total phosphorus, and dissolved silica, as these are delivered at the river mouths. A second modeled data set generated by the Global Nutrient Export from Watersheds (NEWS) 2 provides input data of nutrient loads required for estimating nutrient-specific Indices of Coastal Eutrophication Potential (ICEP) for model year 2000. These nutrient-specific eutrophication potentials measure new production of non-siliceous algal biomass that can be potentially sustained by nitrogen or phosphorus delivered in excess of silica. Excess nutrients are determined by deviations from nutrient molar ratio know as Redfield ratios that silica-bearing phytoplankton known as diatoms, “the grass of the sea” require. The reference Redfield ratio for diatoms is Carbon C: Nitrogen N: Phosphorus P: Silica Si of **106C: 16N: 1P: 20Si.** For this report, Nitrogen- and Phosphorus- ICEPs were computed for each of 261 WCR-draining basins resolved by the Global NEWS 2 Model. Sixty-three basins showed excessive nitrogen fluxes (red filled circles, Figure ES 9). In addition to the ICEP assessment, documentation of hypoxic and eutrophic events is denoted by open red circles in Figure ES 9.

3.2 Harmful algal blooms (HABs)

The loading of nutrients, nitrogen and phosphorus, and other micronutrients, in non-Redfield ratios and in flows that are in excess relative to silica paints a simplified set of dynamics for the onset of non-siliceous and often harmful algal blooms (HABs). Two Regional Working Groups of the International Oceanographic Commission (IOC), Algas Nocivas de America Central y el Caribe (ANCA), and the Floraciones Algales Nocivas en Sudamerica (FANSA), are responsible for documenting HAB events in the WCR, using the Harmful Algae Event Database (HAEDAT). The latter is used to chronicle events that have caused severe adverse social, economic, environmental or health impacts. Less impactful HAB events are not as systematically documented.

HAB events are undeniable consequences of excess nutrient flows. In the WCR, Information from 1950 to 2010 show a rapidly increasing number of HAB events beginning in the 1980s for both the ANCA and

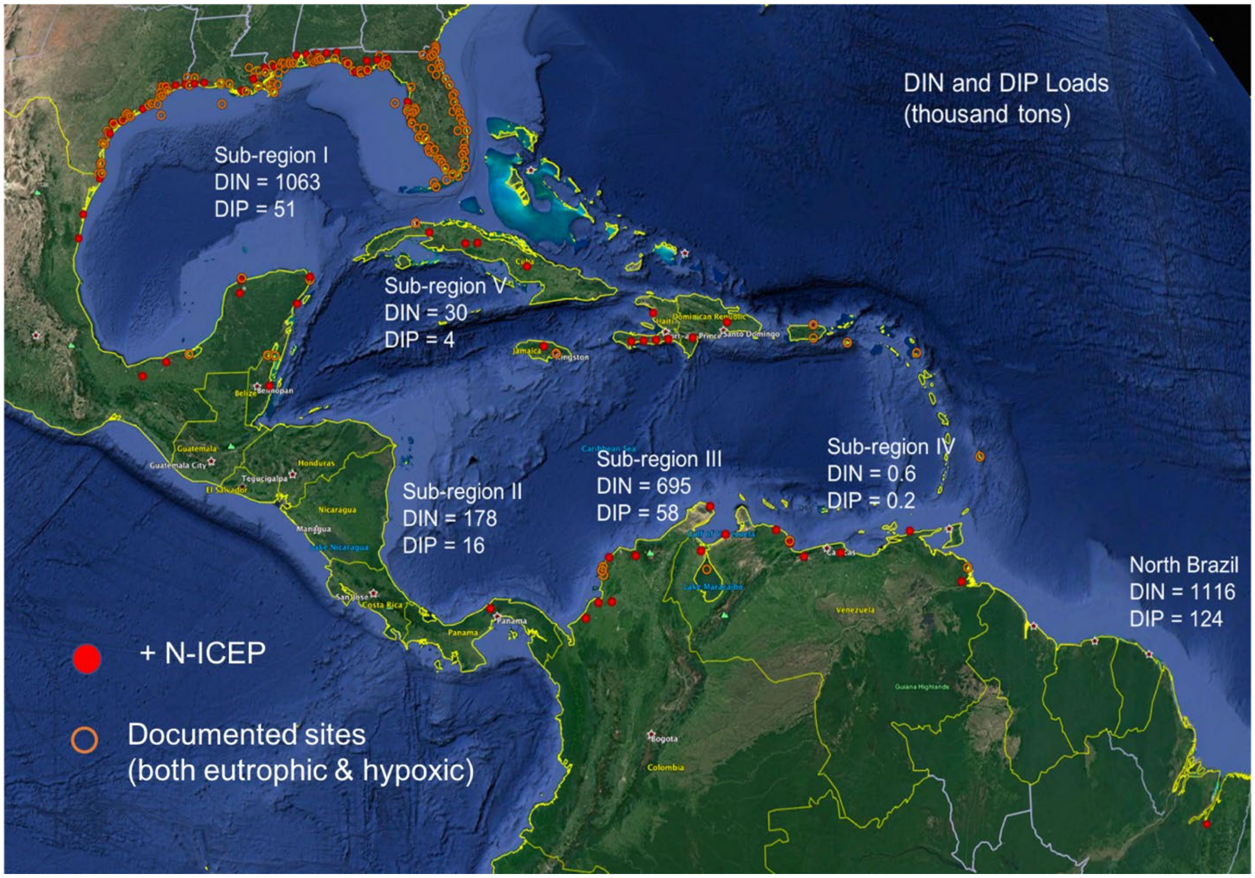
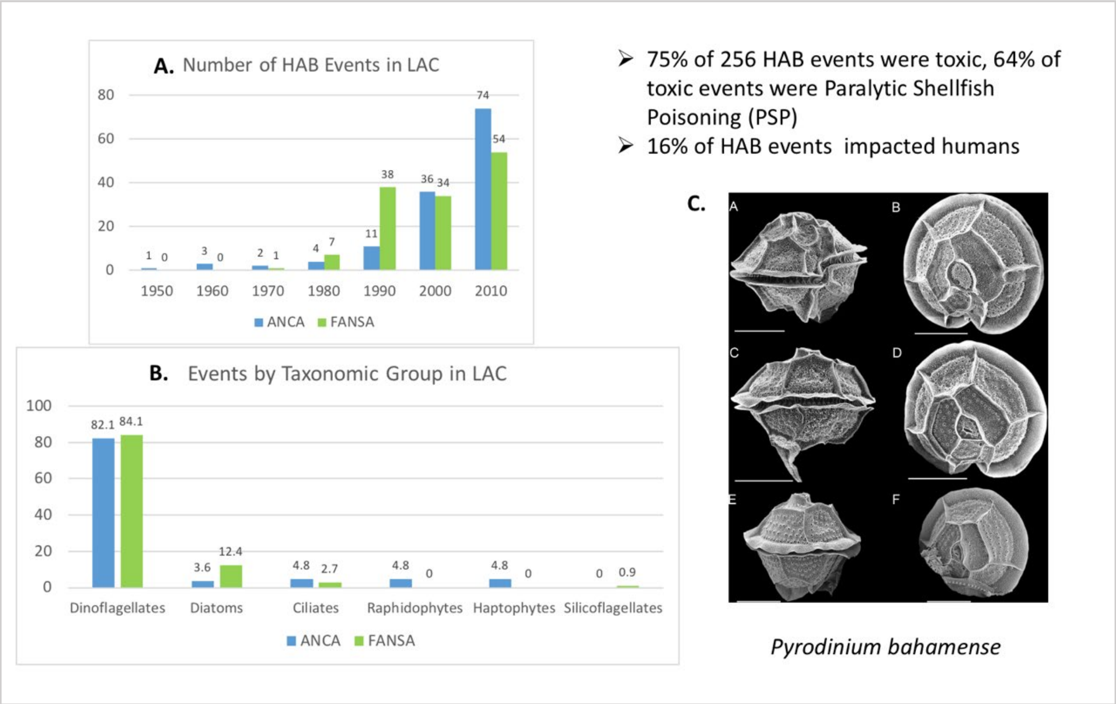


Figure ES 9 Model estimates of dissolved inorganic forms of nitrogen (DIN) and phosphorus (DIP are aggregated by sub-region. The orange open circles are documented eutrophic (i.e. N or P or both exceeding silica requirements of diatoms) sites that are also hypoxic (i.e. bottom dissolved oxygen equal to physiological limit of 2 mg/L of O_2) (n=164, Diaz et al. 2011), and the red filled circles are river mouths that have been assessed in this report to have a positive potential to become eutrophic because of nitrogen excess over silica.

FANSA regions (Figure ES 10A). Over the same event domain of 265 events, dinoflagellates dominated 80% of HAB events. Seventy-five percent were toxic events, with Paralytic Shellfish Poisoning (PSP) accounting for 64% of such toxic events. Among the causative dinoflagellate species for PSP are *Pyrodium bahamense* (Figure ES 10C) and *Gymnodium catenatum*.



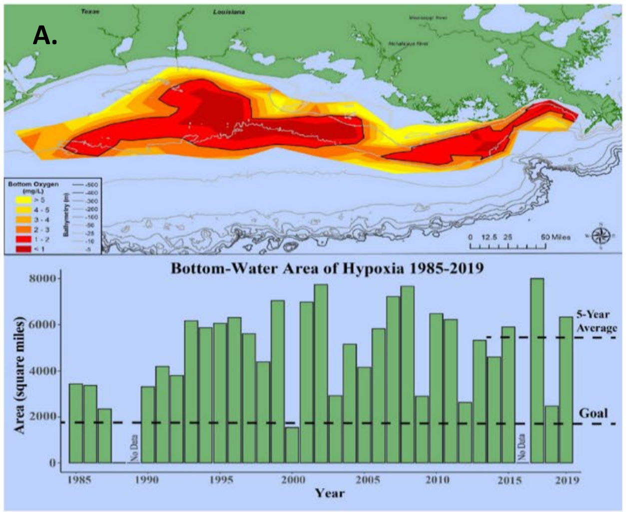
- 75% of 256 HAB events were toxic, 64% of toxic events were Paralytic Shellfish Poisoning (PSP)
- 16% of HAB events impacted humans

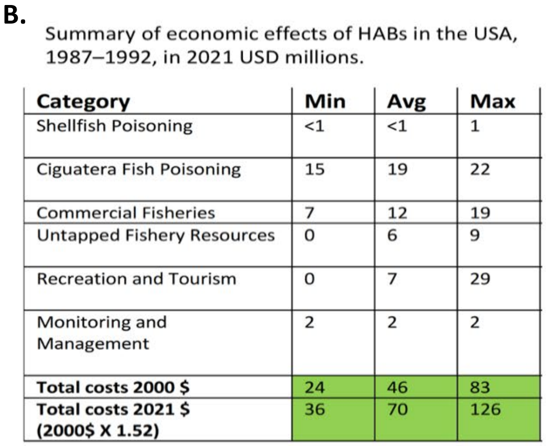
Pyrodinium bahamense

Figure ES 10 A. Number of HAB events in LAC. B. Events by taxonomic group. C. Pyrodinium bahamense, causative organism for Paralytic Shellfish Poisoning (PSP).

3.3 Hypoxia and hypoxic zones

In coastal waters where microalgal blooms occur in response to excess nutrient loads, predation by phytoplankton-consuming herbivores is not sufficient to control algal populations in bloom. Unconsumed algal biomass accumulate in the ocean floor and are decomposed by microbes through aerobic respiration, using up dissolved oxygen in the process. For eutrophic areas to also become hypoxic, i.e. when bottom-water dissolved oxygen (DO) concentrations are below 2 mg DO L^{-1}, water stratification and sustained nutrient loads in excess have to be coincident in space and time. Empirical monitoring programs are needed to identify the occurrence and extent of hypoxic zones. Figure ES 9 plots 164 sites of documented eutrophic and hypoxic events within the WCR. Some sites assessed to be eutrophic by this report, appear to lack documentation, such as sites along the coasts of Central America, Venezuela, Hispaniola and Cuba.




B.

Summary of economic effects of HABs in the USA, 1987–1992, in 2021 USD millions.

Category	Min	Avg	Max
Shellfish Poisoning	<1	<1	1
Ciguatera Fish Poisoning	15	19	22
Commercial Fisheries	7	12	19
Untapped Fishery Resources	0	6	9
Recreation and Tourism	0	7	29
Monitoring and Management	2	2	2
Total costs 2000 $	24	46	83
Total costs 2021 $ (2000$ X 1.52)	36	70	126

Figure ES 11 A. Hypoxic zone in the Gulf of Mexico. B. Economic impacts of HABs in the USA, 1987-1992.

Figure ES 11A shows the annual changes in the size of the hypoxic zone in the Gulf of Mexico, as driven by the amount of freshwater discharge and the nitrate-nitrogen load in the previous May, and further influenced by mixing processes via hurricanes or storms. In addition to present-day nutrient flows, eutrophication and hypoxia can be exacerbated by legacy nutrients, nutrients which have accumulated from historical nutrient flows, such as those percolating from groundwater nutrient pools.

Monitoring hypoxic zones are critical as oxygen levels can impact economically important fisheries via depressed growth and reproduction, if not outright mortality. While fish and non-sessile benthos can move where oxygen is not limiting, sessile life forms or those with limited movement can be at risk. Modeling to identify eutrophication hot spots can help to streamline monitoring. Optical signatures of blooms can be detected through satellite imagery, but the extent of hypoxic zones can only be delimited by bottom oxygen measurements.

Measurements of the social, public health and economic impacts of eutrophication, HABs and hypoxic events as systemic responses to nutrient pollution have yet to mature in methodology. Figure ES 11B shows costing of HAB toxic syndromes and sectoral impacts on fisheries, tourism, and monitoring and management during a five year period of HAB events in the US. Estimates ranged from US$ 36 to 126 million.

3.4 Nuisance *Sargassum* bloom

The inclusion of *Sargassum* bloom as one of the systemic responses to nutrient pollution in this report is based on a common perception that it is a phenomenon that is too big to ignore. While so much about it is not known, the severity of its impacts is felt throughout the region. What has been borne by observations is its first occurrence in 2010-2011, and its seeming recurrence annually since then. The driving and sustaining mechanisms of the bloom, and the origin, spread and genetics of the seeding population remain unexplained to date, but hypotheses are emerging. The role of river plume nutrients from the Amazon and Orinoco River in sustaining the bloom, has been recently disputed, based on a 15-year decreasing trend in phytoplankton biomass in these plumes for the period 2004 to 2018. The Sargasso Sea populations are considered oligotrophic, and the populations that have arrived in coastal waters have yet to be classified for their nutrient level preferences.

Despite the scientifically enigmatic status of *Sargassum* bloom, its toll on livelihoods and wellbeing is steep. Figure ES 12 is a perception mapping of the severity of *Sargassum* strandings based on survey responses by 22 National Focal Points, combined with satellite observations. The map highlights the islands of the Lesser Antilles as the most impacted, including Hispaniola, Turks and Caicos, the US Gulf Coast and Caribbean Mexico. To aid in estimating and predicting extent and severity of coastal inundation by *Sargassum* racks, the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the US National Oceanic and Atmospheric Administration (NOAA), NOAA/CoastWatch/OceanWatch and the University of South Florida (USF) developed the weekly Sargassum Inundation Report (SIR), which classifies coastal areas in 5 subregions (Gulf of Mexico, Greater Antilles, Lesser Antilles, Central America and South America) into 3 risk levels of coastal inundation by Sargassum: low (blue), medium (orange) and high (red) (Figure ES 13).

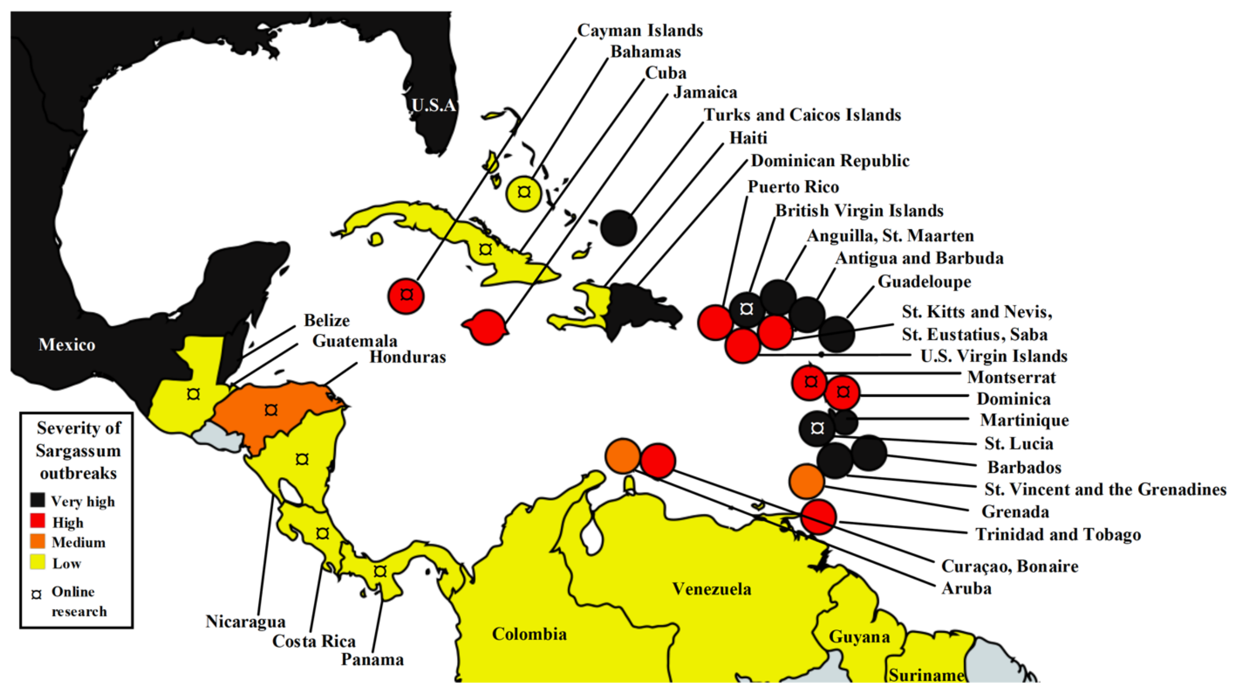
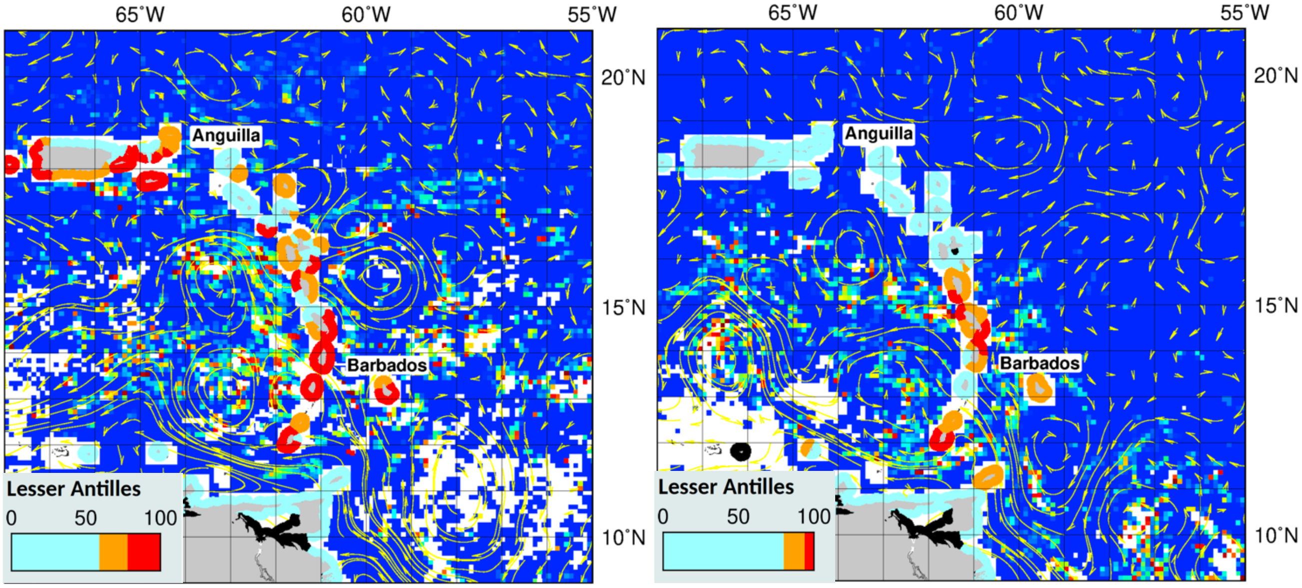


Figure ES 12 Severity of *Sargassum* strandings in the Wider Caribbean Region based on survey responses by 22 National Focal Points, satellite observations and online searches. (Source: UNEP CAR/RCU, 2018).



A. Lesser Antilles, April 2021

B. Lesser Antilles, April 2020

Figure ES 13 Comparing risk levels due to *Sargassum* coastal inundation in the Lesser Antilles in April 2021 (A) and April 2020 (B).

It remains unclear whether recurrent nuisance bloom of *Sargassum* presents a new normal for residents and tourists in the Wider Caribbean. Clean-up costs, hospitalizations due to noxious gases from decomposing Sargassum (ammonia and sulfuric acid), damages to coral reefs and seagrasses, lost tourism and fishery revenues, loom large for the future. Initiatives to use Sargassum racks as a resource for novel likelihoods are at experimental stage.

Nutrient pollution appears to be best addressed at source, and not where impacts are most widespread when nutrients have been transported and conveyed to receiving basins. Prudence in agricultural practices and in creating cost effective household technologies for minimizing the discharge of untreated domestic waste appear as doable pathways to curb excess nutrients. Regulating dumping of sewage, graywater and food waste by ships by getting a MARPOL Special Area Designation under Annex IV (Sewage) may promote better compliance. Monitoring impacts and understanding mechanisms through which systems react to excessive nutrient availability should compel the design and implementation of tighter at-source controls.

4 EXISTING FOUNDATION FOR ADDRESSING NUTRIENT POLLUTION IN THE WCR

Most of the information on the existing foundation originated from published sources as well as studies and surveys conducted in the countries and territories by the CAR RCU and the LBS Protocol Regional Activity Centres (RAC).

4.1 Governance framework

Institutional framework**:** A wide array of institutions and mechanisms that are relevant to pollution of the marine environment exists, although most do not explicitly address nutrient pollution, and many aspects need strengthening. Improved coordination among the existing institutional frameworks and mechanisms will be required. Among the institutional mechanisms are:

- The Cartagena Convention Secretariat/UNEP CAR RCU, which is the main regional body with a mandate related to pollution of the marine environment;
- The GPNM Caribbean Platform, which, along with the LBS Protocol (UNEP CAR RCU) will become the major regional platform for harmonized nutrient management in the region;
- The sub-regional political integrating mechanisms – Caribbean Community (CARICOM), Central American Integration System (SICA)/ Central American Commission for Environment and Development (CCAD), the Organization of Eastern Caribbean States (OECS), and the Amazon Cooperation Treaty Organization (ACTO);
- The Caribbean Public Health Agency (CARPHA)/ Environmental Health and Sustainable Development Department (EHSD);
- Within the countries and territories, various institutions and mechanisms perform different environmental monitoring, protection, and management functions. However, multi-agency and multi-sectoral mechanisms that explicitly address nutrient pollution are absent in most of the countries and territories. An exception is the USA with its multi-agency Gulf of Mexico Hypoxia Task Force. Joint mechanisms are also required for nutrient management of the region's many transboundary rivers and groundwater aquifers.

Policy and legislation: Collectively, the WCR countries have ratified several relevant multilateral environmental agreements (MEA) (Figure ES 14) and each has policies and legislation related to pollution.

- The Cartagena Convention is the only major regional policy framework that addresses protection and sustainable use of the Caribbean Sea. To date, only 26 countries have ratified the Convention and 16 have ratified the LBS Protocol, with the latter being the lowest level of ratification among the various MEAs. While nutrient pollution is addressed in Annexes III and IV of the LBS Protocol, this issue needs to be more explicitly reflected in the Protocol, including the establishment of regional criteria and standards.

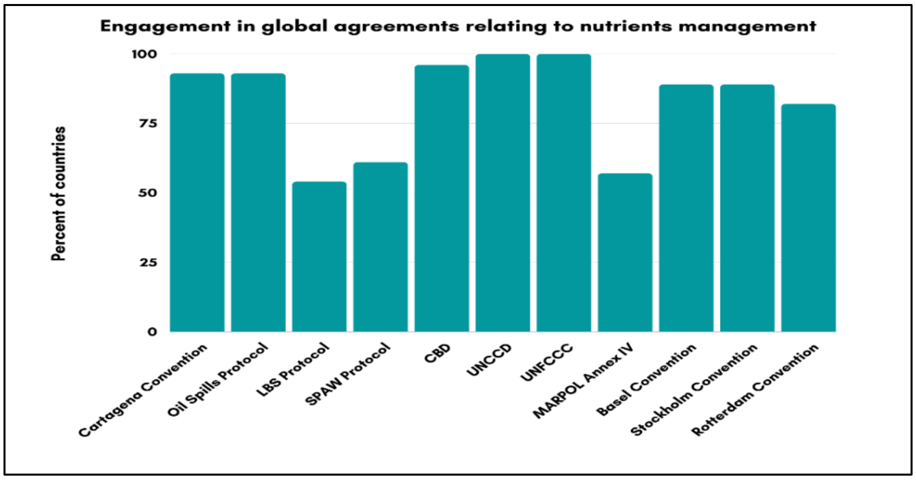


Figure ES 14 Proportion of countries engaged in MEAs of relevance to nutrients.

- At the national level, various instruments have been established for environmental management. However, the extent to which these explicitly address nutrient pollution varies among the countries, ranging from not targeting nutrients to comprehensive nutrient pollution reduction strategies and action plans for the US Mississippi River basin and the European Union Nitrates Directive (French territories).
- Among major land-based sources, the highest number of laws for pollution related to domestic wastewater but not specifically to nutrients in most cases, while the lowest number was for nutrients in agricultural run-off and sediment run-off.
- The proportion of countries with "no agreed level" of treatment was highest for nutrients in agricultural run-off. Slightly over 10 percent of respondents considered the level of nutrients in agricultural run-off to be "not applicable".
- In general, fertilizer application rates are not regulated, and chemical nitrogenous fertilizer use is the most widespread and subsidized by agricultural programmes and local governments, but without the necessary education, extension or support for an improvement in nutrient use efficiency.
- All the countries/territories have some form of legislation and regulations for maritime activities, but the extent to which they cover nutrient pollution varies.
- Many of the countries/territories relying on command-and-control mechanisms to regulate pollution. Enforcement is often inadequate owing to various factors including limited human capacity and financial resources.
- Several countries have policies and programmes for integrated watershed or coastal area management, but many countries lack a comprehensive national policy for integrated management across sectors.
- There is little harmonization among the regulations and their responsible agencies, and water quality monitoring and enforcement are weak.

Stakeholder engagement, outreach, and advocacy

- Lack of communication and low awareness of nutrient pollution were identified as a priority by several WCR countries and territories. Few countries conduct explicit programmes on nutrient pollution that target the public and vulnerable communities. However, more than half the countries and territories conduct programmes targeting sectors that may cause nutrient pollution (e.g., programmes for farmers on best practices and use of agricultural chemicals and to assist local communities with compliance related to collective water treatment facilities).

- Many activities related to stakeholder awareness, outreach, and advocacy on the environment are conducted through donor-funded projects. However, the extent to which these initiatives address nutrient pollution varies according to the project's objectives.
- Private sector engagement is generally weak among the countries, although some countries have initiatives and programmes with the tourism, agriculture, and public sanitation sectors. Engagement with the private sector, development banks, and other key stakeholders will be critical for the success of the RNPRSAP.

4.2 Monitoring and data availability

Criteria, standards, and monitoring effort

- The LBS Protocol has not yet established regional criteria, standards, and limits for effluent discharges and freshwater and coastal water quality standards for nutrients.
- There is wide heterogeneity in the existing criteria and standards for effluents and coastal water quality and in the monitoring effort among countries. This will present challenges for the definition of regional standards and criteria for the discharge of nutrients to the WCR marine environment and for water quality.
- There is wide disparity among the countries in the maximum permissible concentrations for the different forms of nitrogen and phosphorus, even for similar types of receptor water bodies; the monitoring effort, which in most cases is sporadic, with spatial and temporal gaps; the forms of nitrogen and phosphorus monitored in coastal waters; and in sampling and laboratory protocols.
- About half of the countries/territories conduct coastal water quality monitoring that includes nutrients and most countries do not have the technical capacity for monitoring and modelling of nutrient loads and impacts. About 59 percent of the countries/territories have analytical environmental laboratories, but accreditation needs to be improved.
- In some of the countries, multiple agencies monitor different parameters and media, which creates challenges in coordination and reduces cost-effectiveness.

Data and information availability

- Sharing of national pollution data and information considered to be sensitive by countries constrains regional efforts.
- There is no central regional repository for comprehensive environmental data in general and for nutrient pollution in particular. However, a single, central repository for data and information on may not be feasible, given the large number of governmental and non-governmental entities involved. A more realistic solution may be a central repository in each country/territory, that is indexed regionally.
- A critical gap is the lack of comprehensive data and information on the socio-economic costs and impacts of nutrient pollution at the national and regional levels.
- The first regional assessment of nutrient pollution is the SOCAR. Several of the WCR countries conduct national state of environment/marine environment assessments, with varying degrees of coverage of nutrient pollution.

4.3 Challenges and needs

The sub-regional studies conducted in support of the RNPRSAP identified many challenges and barriers to effective management of nutrient pollution. These relate to human and institutional capacity, waste treatment infrastructure, policy and legislation, scientific research, laboratory and other technical services, monitoring and data sharing, financial resources and investments, and stakeholder education and awareness, among others. The Second Regional Planning Meeting of the Caribbean Platform for Nutrient Management held in 2016 identified priorities at the regional and country levels as knowledge generation (assessment and monitoring); technical services (best practices in agriculture; wastewater management); governance and policy; and outreach and advocacy.

4.4 Potential opportunities

Making better use of nutrients, including the reduction of losses and waste, will reduce pollution threats while improving food and energy production. Opportunities include:

- Recycling and reusing sanitation waste in the water, agriculture, and energy sectors.
- Recovery and reuse of nutrients from agriculture and combustion sources.
- Upscaling existing technologies and developing new ones that improve the management of nutrient resources and nutrient pollution.
- Institutional and policy reforms, sustainable financing, stakeholder engagement and public-private partnerships.

5 REGIONAL NUTRIENT POLLUTION REDUCTION STRATEGY AND ACTION PLAN (2021-2030)

The final chapter presents the regional nutrient pollution reduction strategy and action plan (RNPRSAP) for the WCR. It is underpinned by Chapters 1-4, which provide the background and scientific foundation for the strategy.

5.1 Goal, objectives, and guiding principles

Goal: To establish a collaborative framework for the progressive reduction of impacts from excess nutrient loads on priority coastal and marine ecosystems in the WCR.

Overall Objectives:

1. To assist in defining regional standards and criteria for nutrient discharges including regional indicators for monitoring those discharges to the coastal and marine environment;

2. To support institutional, policy and legal reforms relating to nutrients and sediments management including supporting integrated, high-priority interventions to reduce discharge of untreated sewage, nutrients and sediments, and promote recovery of nutrients from wastewater;

3. To contribute to relevant regional and global commitments including the Cartagena Convention and its LBS Protocol, UNEA Resolution on Sustainable Nitrogen Management, and SDGs 6 and 14;

4. To contribute to the operationalization of the Caribbean Platform for Nutrient Management under the GPNM;

5. Contribute to the UN Global Campaign on Sustainable Nitrogen Management.

Guiding principles include:

1. Science-based approach, using the best available science, data and information, and incorporating local/traditional knowledge;
2. A ridge to reef, integrated watershed approach that considers nutrient sources in watersheds to their impacts in coastal waters, and the heterogeneity among the WCR countries and territories in terms of biogeophysical characteristics and sectors contributing to nutrient pollution;
3. Balancing ecological, social, and economic imperatives in decision-making throughout the upstream-downstream continuum;
4. Alignment of objectives and targets with relevant national, regional and global policies, frameworks and targets to achieve multiple benefits;
5. Engagement of all key stakeholders including the private sector.

5.2 Approach, scope, and structure of the RNPRSAP

Approach

- Considers the watershed as the geographical management unit on the terrestrial side and incorporates major marine sources of nutrient pollution.
- An integrated, watershed approach that acknowledges the connections between upstream and downstream areas, and between terrestrial, freshwater (surface and groundwater), and coastal marine waters.
- Considers all the major sources of nutrients and the processes promoting their loss to the natural environment and transport across the entire continuum from land to freshwater systems and their eventual deposition in coastal waters, and ecological and socio-economic consequences.

Geographic scope and structure

The geographic scope of the RNPRSAP is the Gulf of Mexico, Caribbean, and North Brazil Shelf LMEs (Figure ES 1), with focus on the major land and sea-based sources of nutrient pollution in these LMEs. It is centred around nine Pillars, each with specific objectives and associated targets and indicators (Figure ES 15).

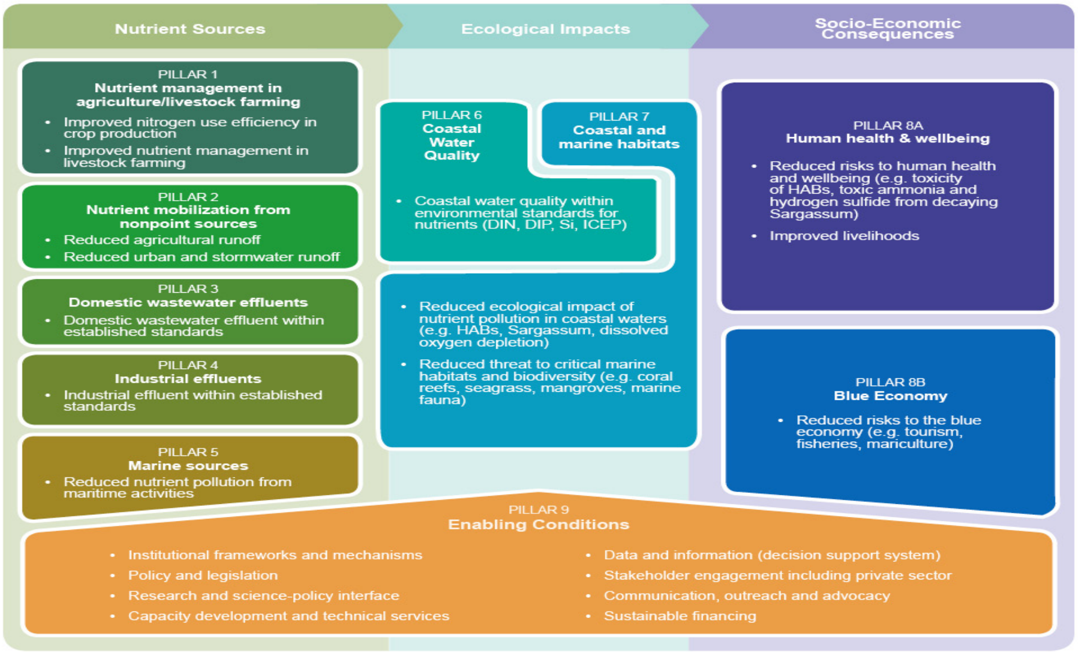


Figure ES 15 Structure of the RNPRSAP showing the nine Pillars and associated objectives.

Pillars 1-8 cover the entire continuum from nutrient inputs from land and sea-based sectors, to their loss through major point and nonpoint sources to freshwater bodies and marine areas, and the associated ecological impacts in coastal waters and consequences for human wellbeing and economies. Many of the Targets in Pillars 1-8 are reflected in the LBS Protocol Annexes and aligned with at least 23 SDG Targets (and associated indicators) as well as with other global targets (CBD Post-2020 Global Biodiversity Framework and the UNCCD), as indicated in Table ES 1.

Table ES 1 Alignment of the RNPRSAP objectives with SDG Targets

	PILLARS	OBJECTIVES	SDG Targets												
			2.4	3.9	6.3	6.6	11.6	11.7	12.3	12.4	12.5	14.1	14.2	15.2	15.3
1	Nutrient management in agriculture/ livestock farming	Improved nitrogen use efficiency in crop production (Halve nitrogen waste by 50%)	✓						✓			✓			
		Improved nutrient management in livestock farming													
2	Nutrient mobilization from nonpoint sources	Reduced agricultural runoff	✓											✓	✓
		Reduced urban and stormwater runoff					✓	✓							
3	Domestic wastewater effluents	Domestic wastewater effluent within established standards (LBS Annex III limits for TSS)			✓										
4	Industrial effluents	Industrial effluent within established standards			✓					✓	✓				
5	Marine sources	Reduced nutrient pollution from maritime activities													
6	Coastal water quality	Coastal water quality within environmental standards for nutrients			✓							✓			
7	Coastal and marine habitats	Reduced ecological impact of nutrient pollution in coastal waters			✓	✓						✓	✓		
		Reduced threat to critical marine habitats and biodiversity			✓	✓						✓	✓		
8a	Human health and wellbeing	Reduced risks to human health and wellbeing		✓											
		Improved livelihoods													
8b	Blue economy	Reduced risks to the blue economy													

Although many of these global targets do not directly address nutrient pollution, they contribute to several of the objectives under Pillars 1-8. Global targets that explicitly address nutrient pollution sources and impacts are included in the RNPRSAP, notably:

Pillar 1: Sustainable nutrient management in crop production and livestock farming
Colombo Declaration on Sustainable Nutrient Management target: Halve nitrogen waste from all sources by 2030. This requires improvements in nitrogen use efficiency (NUE) in crop production (the fraction of nitrogen input harvested as product) aimed at increasing crop production, thereby contributing to food security, while minimizing nutrient losses and ultimately eutrophication and its impacts.

Pillar 3: Domestic wastewater effluent
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. Indicator: Proportion of domestic and industrial wastewater flows safely treated.

Pillar 6: Coastal water quality

- *LBS Protocol Annex III (Domestic wastewater) and Annex IV (Agricultural non-point sources of pollution):* Calls on the Contracting Parties to take measures to protect the Convention Area from nutrient pollution.
- *SDG 14.1*. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including nutrient pollution. Indicator: Index of coastal eutrophication potential (ICEP).
- *CBD Post-2020 Global Biodiversity Framework Target 6:* By 2030, reduce pollution from all sources, including reducing excess nutrients to levels that are not harmful to biodiversity and ecosystem functions and human health.

Some targets will require national and regional standards to be established, e.g., for domestic and industrial effluents and water quality. Global targets and indicators will need to be adapted to the appropriate scale (local, national, sub-regional, regional). A description of the type of strategies and best management practices (BMP) to achieve each objective is included in the accompanying BMP compendium. These include sustainable agricultural and land use practices, nature-based solutions (green engineering), integrated approaches, and technological solutions.

Pillar 9 identifies key enabling conditions that need to be established at the regional and national levels to support implementation of the strategy, as shown in Figure ES 15. Establishing these conditions will require collective action by and the support of international, regional, and sub-regional organizations as well as national governments and the private sector.

5.3 Implementation of the RNPRSAP

A proposed institutional framework and an action framework for implementation of the strategy are described. Implementation will be incremental and primarily through actions at the national level, with the support of international, regional, and sub-regional institutions and partners. Several mechanisms and opportunities to facilitate implementation already exist, as described. Other opportunities are presented by the Regional Strategy and Action Plan for the Valuation, Protection and/or Restoration of Key Marine Habitats in the Wider Caribbean (2021-2030) (UNEP CEP, 2020); the UN Decade on Ecosystem Restoration (2021-2030); and the UN Decade of Ocean Science for Sustainable Development (2021-2030).

Institutional framework

Implementation will require a multiscale institutional framework involving participation by stakeholders representing all stages of the policy cycle and from local/national to sub-regional and regional to global levels (Figure ES 16).

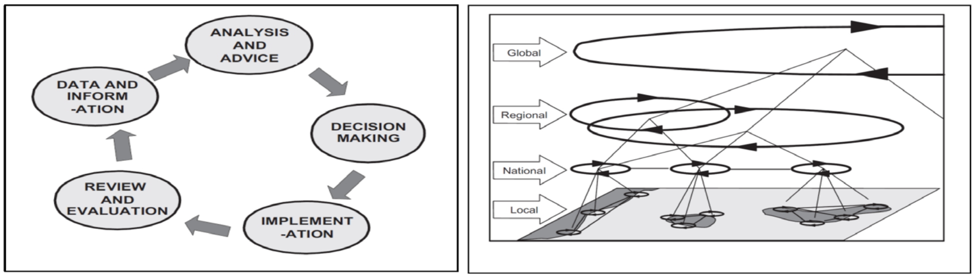


Figure ES 16 A generic policy cycle (left) and the multi-scale governance framework (right) with vertical and horizontal linkages among the different policy cycles (Fanning et al., 2007)

Among the key actors at the different levels are:

- Global level: UNEP, FAO, UNDP, IMO, GPA, GPNM, PAHO/WHO.
- Regional level: UNEP CAR RCU/ Cartagena Convention Secretariat (coordination of the RNPRSAP implementation).
- Sub-regional level: Sub-regional political integrating mechanisms (CARICOM, OECS, SICA/CCAD, and ACTO).
- National level: Cartagena Convention and LBS Protocol Contracting Parties and non-contracting countries.
- Private sector, academia, civil society, and financial institutions.

Action and Monitoring Framework

Ultimate success in addressing nutrient pollution depends on actions at the national and local levels, supported by actions at the regional and global levels. As appropriate, multiple activities should be executed in parallel, rather than sequentially. The RNPRSAP must be adapted to the local/national contexts including the main source(s) of nutrient pollution and priority geographic areas as well as the existing capacity. The 2021-2030 timeframe for implementation is divided into two blocks of 5 years each, with the first period (2021-2025) focusing primarily on establishing the enabling conditions and the second (2025-2030) on implementation on the ground. However, the timeframe is flexible to accommodate differences in context and circumstances among the countries with respect to nutrient pollution and its management and activities/targets that can be achieved within a shorter timeframe.

The action framework consists of regional and national level lines of action, activities, and the associated timeframes. Lines of action include:

Strengthening institutional, policy, legislation, and regulatory frameworks; Establishing mechanisms for joint management of transboundary river basins and groundwater aquifers; Stakeholder engagement and communication/public awareness; Characterizing and prioritizing watersheds; Monitoring, data collection, assessments, and research; Capacity building; Developing incentive programmes; Identifying sources and mobilizing financial resources; Setting nutrient reduction targets and allocation of allowable pollution loads; Development of national nutrient pollution reduction strategy and action plans; Implementation of national action plans; and Monitoring and adaptive management.

For implementation of the RNPRSAP at the national level, countries should adapt and mainstream the strategy into their respective national development and environmental management programmes. This will include developing their respective national or watershed nutrient pollution reduction strategies and action plans based on the regional strategy.

A monitoring framework presents the targets, indicators, and timeframe to track progress in implementation of the strategy and its results. The monitoring framework will assist Member States of the Cartagena Convention and LBS Protocol fulfil their reporting obligations. Similarly, alignment of the RNPRSAP with global targets and indicators will contribute to harmonization and cost-effectiveness of the required monitoring and reporting.

NEXT STEPS/RECOMMENDATIONS FOR ROLLING OUT THE RNPRSAP

1. Preparation of a plan by UNEP CEP for incrementally rolling out the strategy, in collaboration with Member States, LBS RACs, and sub-regional bodies. This should include assigning the LBS Monitoring and Assessment Working Group to address key tasks for facilitating implementation;

2. Establishment of a regional, multi-disciplinary advisory group (including relevant technical experts) focusing on nutrient pollution;

3. Facilitate sharing of knowledge and experiences among Parties of the Convention;

4. Full integration of the RNPRSAP into the UNEP CEP Strategy and identification of synergies with other relevant strategies and frameworks including the Regional Habitats Strategy, and modalities for their implementation using a more programmatic and less project-focused approach;

5. Prioritization of needs and actions at the national, sub-regional, and regional levels to accelerate implementation of the strategy and finalization of the timeframe for actions;

6. Strengthen efforts to operationalize the GPNM-Caribbean;

7. Identification of nutrient pollution hotspots and opportunities to develop pilot projects, including through ongoing and planned projects;

8. Mainstreaming of the RNPRSAP into countries' national planning and development frameworks and preparation by countries of national action plans for nutrient pollution reduction, based on the RNPRSAP;

9. Estimation of the cost of implementing elements of the strategy and identification of funding opportunities including though the private sector and development banks;

10. Identification of opportunities through the Decade of Ocean Science and UN Decade on Ecosystem Restoration to establish/strengthen enabling conditions;

11. Development of a communication strategy and utilization of existing platforms for communication;

12. Undertake advocacy and stakeholder engagement activities to obtain buy-in and facilitate collaboration and effective implementation of the RNPRSAP.

1 WHY A NUTRIENT POLLUTION REDUCTION STRATEGY AND ACTION PLAN FOR THE WIDER CARIBBEAN REGION

1.1 INTRODUCTION

The wider Caribbean Sea encompasses three Large Marine Ecosystems (LMEs) that together span a vast marine area of 4.4 million km^2, from The Bahamas and the Florida Keys in the north to the Parnaiba River estuary in Brazil in the south (Figure 1.1). These LMEs provide a diverse array of ecosystem goods and services that underpin social and economic development as well as the blue economy in the 26 Independent States and 18 Overseas Territories that share this vast marine area. Major economic sectors including tourism, fisheries, maritime transportation, and trade are all inextricably linked to the Caribbean Sea. A conservative estimate of the gross revenues generated in 2012 by the ocean economy in the Caribbean was US$407 billion and US$53 billion for the Island States and Territories (Patil *et al*., 2016).

Figure 1.1 The Wider Caribbean Sea and the Cartagena Convention Area (LME: Large Marine Ecosystem)

Increasing human populations, poorly planned coastal urbanization, and harmful production and consumption patterns are generating unprecedented pressures on the marine environment of the Wider Caribbean Region (WCR). 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 important economic sectors such as tourism and fisheries, and hindering development of a blue economy by degrading its natural resource base (UNEP CEP, 2019). Moreover, the associated economic costs of marine pollution can be significant. For example, the annual cost of damage from coastal hypoxia (low oxygen concentration in the water) arising from nutrient pollution has been estimated at between US$200 billion and US$800 billion per year, which represents a major drag on economic progress and poverty reduction (Hudson and Glemarec, 2012). According to the United Nations Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), an estimated 80 percent of marine pollution originates from land-based sources. This includes solid waste, domestic and industrial wastewater, plastics, nutrients, sediments, and toxic by-products from various industries including mining. Other major pollution sources are ocean-based activities such as shipping, cruise tourism, fisheries, and oil and gas exploration and extraction (Diez *et al*., 2019; UNEP CEP, 2019).

Pollution of the WCR marine environment is likely to intensify under a 'business as usual' scenario and be compounded by climate change impacts, which are already evident throughout the region.

Concern over pollution is so significant and widespread that the issue is reflected in every international environment and sustainable development framework related to the environment and sustainable development that has been created in recent decades (Annex 1.1). Notable among these are several Sustainable Development Goals (SDG) and Targets as well as the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention) and its three Protocols:

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

Annex III of the LBS Protocol calls on Contracting Parties to take into account the impact that nitrogen (N) and phosphorus (P) and their compounds (nutrients) may have on the degradation of the Convention area and, to the extent practicable, take appropriate measures to control or reduce the amount of total nitrogen and phosphorus that is discharged into, or may adversely affect, the Convention area.

In 2010, the Contracting Parties to the LBS Protocol agreed to produce the State of the Convention Area (SOCAR) report on land-based pollution. The SOCAR report presents the first regional assessment of the state of the marine environment in the Caribbean and Gulf of Mexico Large Marine Ecosystems (LME) with respect to land-based pollution including nutrients and associated impacts (UNEP CEP, 2019). By providing a quantitative baseline for monitoring and assessment of the state of the marine environment with respect to LBS pollution, SOCAR aims to assist the Contracting Parties to fulfil their reporting obligations and to assess progress towards relevant goals and targets including the SDGs, particularly SDG 14.1. This assessment will also help to inform regional and country-level decisions to address land-based sources of pollution, including the development of a regional strategy and investment/action plan for nutrient pollution reduction in the WCR.

1.2 FERTILIZING THE OCEAN: NUTRIENT POLLUTION AND ITS CONSEQUENCES

1.2.1 Nutrients in the ocean

All living organisms require nutrients such as nitrogen, phosphorus, iron, carbon, hydrogen, oxygen, and calcium for survival. In aquatic ecosystems, the relative proportions of these elements must be in balance to sustain ecological health and productivity. The vast majority of oceanic surface waters is depleted in inorganic N, P, iron and/or silica (Si), which are the nutrients that limit primary production in the ocean (Bristow *et al.*, 2017). However, outside high-nutrient, low-chlorophyll areas, productivity in most of the ocean (about 75 percent) is limited by the availability of inorganic nitrogen, despite very low concentrations of iron and, in some cases, phosphate. Nitrogen in the form of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) can be directly utilized by marine plants. DIN is also the form of nitrogen that increases the most in rivers (and is subsequently delivered to coastal areas) as a result of human activity (Seitzinger *et al.*, 2010).

Since the green revolution and the industrial revolution began in the last century, human activities have been accelerating the discharge of excessive loads of nutrients such as N and P to aquatic ecosystems from both terrestrial and marine point and non-point sources as well as atmospheric deposition. Why is nutrient enrichment of marine waters a problem? This phenomenon (eutrophication) changes the natural balance of nutrients in the ocean and is a leading cause of hypoxia and deterioration of the health and productivity of many of the world's freshwater and marine ecosystems (see Section 1.3 and Chapter 3). Nitrogen is of paramount importance both in causing and controlling eutrophication in coastal and marine ecosystems (Howarth *et al*., 2000).

1.2.2 External sources of nutrients

A detailed discussion of sources and loads of nutrients in coastal waters in the WCR is given in Chapter 2. The major anthropogenic sources of nutrients to coastal areas are untreated domestic wastewater (sewage), run-off of agricultural fertilizers, livestock production, and atmospheric nitrogen deposition (Seitzinger and Mayorga, 2016; Beusen *et al*., 2015, 2016). Other sources of nutrients to water bodies are aquaculture facilities (FAO, 2017) and fertilizer use in tourism, especially on golf courses in coastal areas, which may be another substantial source of nutrients via run-off or groundwater infiltration, especially in Small Island Developing States (SIDS). Nutrients can also be introduced to coastal waters through submarine groundwater discharge, and it has been found that nitrate from agriculture is the most common chemical contaminant in the world's groundwater aquifers (WWAP, 2013). Marine sectors such as cruise tourism and commercial shipping likely contribute to nutrient pollution through the discharge of significant quantities of wastewater and food waste into the ocean, despite MARPOL Annex IV on the Prevention of Pollution by Sewage from Ships. Data on nutrient loads from marine-based sources is scarce but these are likely to be substantial considering the intensive use of the WCR marine area for economic activities.

Among all these sources, however, agriculture is currently the single most important anthropogenic source of nutrients to coastal areas in the WCR (UNEP CEP, 2019), as discussed in Chapter 2 of this report. Agriculture is an important economic sector in the WCR, contributing around 7 percent of the gross domestic product (GDP) at the regional level (UNEP CEP, 2019). However, for individual countries, this sector's contribution to GDP in 2011-2015 reaches up to 16 percent for Dominica in the insular Caribbean and 35 percent for Guyana among continental countries. Excessive and improper use of synthetic fertilizers in agriculture results in the loss of significant quantities of N and P. More than half of the N added to cropland is lost to the environment, wasting the resource, producing threats to air, water, soil, and biodiversity, and generating greenhouse gas emissions (Lassaletta *et al*., 2014). It has been estimated that the total nitrogen wasted globally amounts to around 200 million tonnes per year, which is equivalent to an economic loss of US$200 billion annually (Sutton *et al*., 2013). Sewage accounts for about 9 and 10 percent of N and P, respectively.

These results highlight the need for improved fertilizer use efficiency and effective, low-cost wastewater treatment technologies in the short and immediate term. Another source of nutrient inputs to the ocean is atmospheric deposition. Globally, nitrogen emission sources are dominated by combustion processes, which emit oxidized forms of nitrogen; and agricultural sources, which emit ammonia (Jickells *et al*., 2016). Deposition of nutrients in the ocean from dust clouds originating in the Sahara Desert is receiving increasing attention, especially in view of the recent *Sargassum* proliferation and influx in some parts of the wider Caribbean Sea. Many studies have shown that these clouds contain nutrients such as iron, N and P, which are deposited in the surface waters of the western Atlantic Ocean, stimulating primary production (e.g., Baker *et al*., 2010; Bristow *et al*., 2010; Yu *et al*., 2015; Chien *et al*., 2016; Barkley *et al*., 2019; Wang *et al*., 2019).

In the WCR and other regions, further nutrient enrichment of coastal waters are projected as human populations and their need for food and energy increase. With the WCR population projected to reach nearly 800 million by 2050 (UNEP CEP, 2019) and continuing unsustainable development patterns, the discharge of N and P into coastal waters is expected to continue to increase in the coming decades, unless appropriate action is taken.

In summary, coastal waters are strongly influenced by their watersheds, with increased loadings of nutrients and organic matter, primarily from agriculture, sewage, and the combustion of fossil fuels. Given that the major sources of nutrients are from watersheds, it is imperative that the management of nutrient pollution in the WCR is based on a ridge to reef (source to sea), watershed approach that also incorporates the major marine sources of nutrients.

1.2.3 Nutrient pollution ecological impacts and socio-economic consequences

The impacts of nutrient pollution on marine ecosystems are well documented. A discussion of nutrient pollution in the WCR is presented in the SOCAR report (UNEP CEP, 2019) and a detailed discussion of the environmental, ecological, and socio-economic impacts of nutrient pollution is also given in Chapter 3 of this report. Excessive loads of nutrients in coastal waters reduce water quality and trigger a cascade of changes that affect the health and productivity of marine ecosystems, with potentially severe socio-economic consequences (Chapter 3). Based on empirical data from the countries on DIN and DIP concentrations in coastal waters, the SOCAR assessment shows that many sites are in poor condition with respect to pollution from nutrients such as DIN (Figure 1.2). These sites are primarily associated with the discharge of domestic wastewater from urban areas and continental runoff from river basins with intense agricultural production such as the Magdalena River Basin of Colombia and the Mississippi-Atchafalaya River Basin of the USA. An assessment of nutrient pollution in transboundary river basins of the WCR, conducted under the Transboundary Waters Assessment Programme (TWAP), indicated that several of these rivers (Catatumbo, Massacre, Artibonite, Motaqua, Chamelecon and Rio Grande) had a moderate to high risk of nutrient pollution (UNEP-DHI and UNEP, 2016).

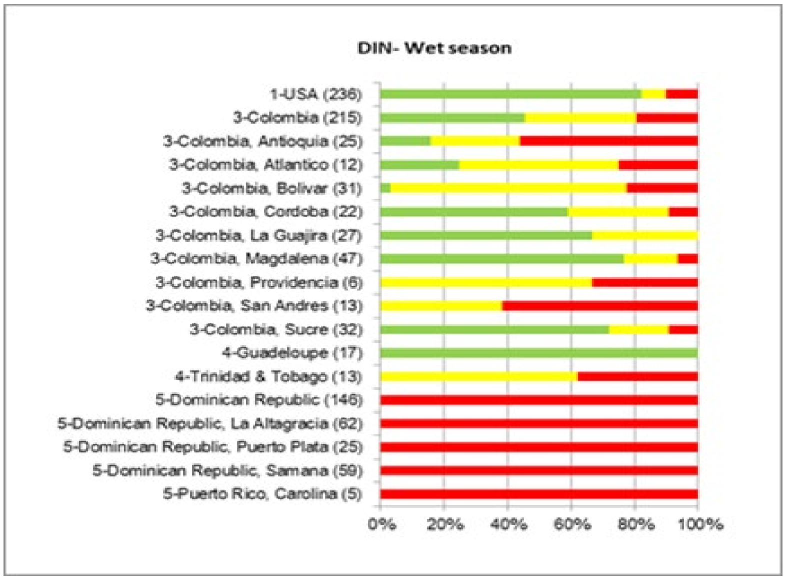


Figure 1.2 Proportion of sampling sites showing good, fair, and poor status in the wet season for dissolved inorganic nitrogen (DIN). The number preceding the country and 1st level administrative unit is the SOCAR sub-region; the number in brackets is the number of sampling sites. (Status: Green: good; yellow: fair; red: poor) (UNEP CEP, 2019).

Eutrophication can result in increased growth and abundance of phytoplankton (some of which can be toxic, as in harmful algal blooms) and macro-algae, and oxygen depletion at the sea floor as dead algal masses sink and decay (Breitburg *et al*., 2018). Additionally, low dissolved oxygen concentrations (hypoxia) can create “dead zones” (areas devoid of macrofauna), as seen, for example, in the northern Gulf of Mexico, which is the region’s most extensive hypoxic zone (UNEP CEP, 2019). Hypoxia is exacerbated by climate change impacts on the ocean (Breitburg *et al*., 2018). A recent and well-known phenomenon in the region that is thought to be linked to a combination of factors among which is nutrient enrichment of marine waters on both sides of the Atlantic Ocean is the proliferation and influx of *Sargassum* into the wider Caribbean Sea. While the exact cause of this phenomenon is yet to be confirmed, scientists believe that abnormal ocean currents and wind patterns linked to climate change, combined with increased nutrient inputs to the ocean likely contributed to the massive increase in biomass and movement of *Sargassum* around the Atlantic (e.g., Louime *et al*., 2017; Wang *et al*., 2019; Johns *et al*., 2020). Further research is required to conclusively identify the causes of the *Sargassum* proliferation in the WCR. See Chapter 2 for further details.

As a consequence of pollution including nutrient enrichment of marine waters of the WCR and other pressures such as warming waters and acidification of oceans due to climate change, the ability of the region’s marine ecosystems to provide essential ecosystem goods and services is being severely compromised. This has serious implications for human wellbeing and socio-economic development, and achievement of the SDGs and other aspirational goals as well as for development of the blue economy in the WCR. See Chapter 3 for discussion of the ecological impacts and socio-economic consequences of nutrient pollution.

1.3 THE NUTRIENT CHALLENGE AND THE GLOBAL DEVELOPMENT AGENDA

“Nutrient pollution is one of the most important problems facing aquatic systems globally. The problem qualifies as a wicked one[1], involving multiple pollutants from multiple sources interacting in complex ways over space and time along multiple pathways, with uncertainty present at each stage of the process—from pollutant generation to the final ecological and economic impacts.” Shortle and Horan 2017.

The accelerated use of nitrogen and phosphorus is at the centre of an intricate web of development benefits and environmental problems that threaten human health, climate, ecosystems and livelihoods. On the one hand, nitrogen and phosphorous are two key nutrients that together play a vital role in the global and local sustainable development agendas, with half of the world’s food security dependent on nitrogen and phosphorus fertilizer use. On the other hand, excess nutrients from fertilizers, fossil fuel burning and wastewater from human communities, livestock, aquaculture, and industry have profound impacts, from pollution of water supplies to the undermining of important ecosystems and the services and livelihoods they support. These problems will intensify, to the cost of countries, as the demand for food and energy increases, and growing urban populations produce more wastewater without adequate treatment infrastructure.

Producing more food and energy with less nutrient pollution and ecological degradation presents a dilemma, referred to as the ‘nutrient challenge’ (http://www.nutrientchallenge.org/). A new global effort is needed to address ‘The Nutrient Nexus’, where reduced nutrient losses and improved nutrient use efficiency across all sectors simultaneously provide the foundation for a greener economy to produce more food and energy while reducing environmental pollution (Figure 1.3). Sustainable nitrogen management provides a framework to add-up the multiple co-benefits of taking action (Sutton *et al*., 2013).

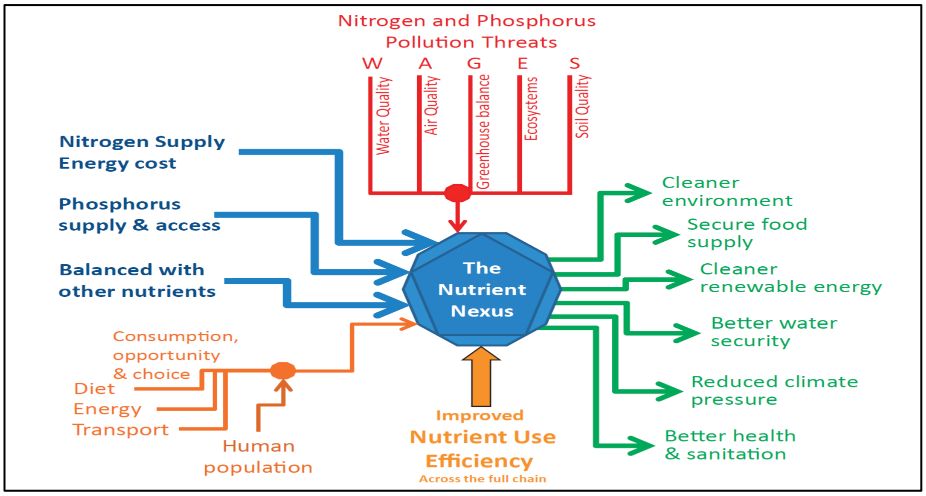


Figure 1.3 The ‘Nutrient Nexus’. Nutrient cycles represent a key nexus point between global economic, social and environmental challenges. Improving full-chain nutrient use efficiency becomes the shared key to delivering multiple benefits (Sutton et al., 2013).

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[1] The term “wicked problem” (first formalized by Rittel and Webber, 1973), describes problems that share several complicating features that make them difficult to solve. In environmental problems, these features include many complex, and often imperfectly understood, ecological and anthropogenic interactions; complex spatio-temporal interactions, operating at different scales that necessitate unique strategies over space and time; and economic, political, and institutional complexity affecting potential solutions (NRC, 2012).

Realization of the major implications of nutrient management and nutrient pollution on sustainable development has elevated nutrients, in particular nitrogen, on the global agenda, including the 2030 Sustainable Development Agenda. For example, as illustrated in Figure 1.4, nitrogen is relevant across all 17 SDGs. Note that in addition to N, which is the focus of Figure 1.4, pollution from excess P is also of concern and is addressed in the RNPRSAP.

Figure 1.4 Illustration of the multiple ways in which sustainable nitrogen management can contribute to meeting the SDGs, highlighting the potential of an ambitious aspiration to Halve Nitrogen Waste globally from all sources of nitrogen pollution by 2030 (Sutton et al., 2013).

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*) explicitly addresses nutrients, with the Index of Coastal Eutrophication (ICEP) the SDG indicator of nutrient pollution. The ICEP is based on the ratio of dissolved Si to N or P in the nutrient loads delivered to coastal areas and represents the potential for new production of harmful algal biomass in coastal waters, associated with enhanced nutrient inputs (see Chapters 2 and 3). Another global target that explicitly addresses nutrient pollution is Target 6 of the Convention on Biological Diversity (CBD) Post-2020 Global Biodiversity Framework (*By 2030, reduce pollution from all sources, including reducing excess nutrients, to levels that are not harmful to biodiversity and ecosystem functions and human health)*.

A Resolution that specifically addresses nitrogen management was adopted by the United Nations Environment Assembly (UNEA) on 15 March 2019: The Resolution on Sustainable Nitrogen Management (UNEP/EA.4/Res.14), which called on the Executive Director to mobilize a coherent, multi-sector, multi-impact approach to nitrogen. The United Nations Environment Programme (UNEP) has developed a Roadmap for Action on Sustainable Nitrogen Management 2020–2022. Further, in October 2019, the UN launched a Global Campaign on Sustainable Nitrogen Management, in Colombo, Sri Lanka, where a landmark declaration (Colombo Declaration on Sustainable Nitrogen Management) was made, setting an ambitious target to halve global nitrogen waste by 2030. This is expected to lead to immediate benefits in the fight against climate change, air pollution and biodiversity loss, and to result in US$100 billion in savings and foster innovation in sectors like farming, energy, and transport. Achieving this target will require improvement in the use of synthetic nitrogen fertilizers, increase in the use of organic fertilizers, boosting the recycling of nutrients from agriculture, among others (see Chapter 5).

Another major response to the 'nutrient challenge' is the establishment of the Global Partnership on Nutrient Management (GPNM) (Box 1.1) with its regional platforms. The GPNM was established under the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). The regional GPNM Platform for the Caribbean was launched in 2013 in Port-of-Spain, Trinidad and Tobago. Specifically, the purpose of the GPNM Caribbean regional nutrient platform is to extend the reach of UNEP and the GPNM to the country level to drive policy and encourage implementation of best practices in nutrient management to minimize adverse impacts on the marine environment. When fully operational, the GPNM Caribbean Platform along with the LBS Protocol will become the major regional platform for harmonized nutrient management in the region.

Box 1.1. Global Partnership on Nutrient Management (GPNM)

At the United Nations Commission on Sustainable Development in May 2009, it was agreed to establish a global mechanism to bring together and harmonize what was perceived to be fragmented efforts to address the nutrient challenge among the great number of stakeholders (government, research and academia, agricultural and fertilizer producer organizations in the private sector, regional and international IGOs and NGOs). The GPNM was formed as a result and became the multi-stakeholder partnership mechanism comprised of these diverse entities along with UN agencies committed to promoting effective nutrient management to achieve the twin goals of food security through increased productivity, and conservation of natural resources and the environment. It provides a platform for governments, UN agencies, scientists and the private sector to forge a common agenda, mainstreaming best practices and integrated assessments, so that policy-making and investments are effectively 'nutrient proofed'. The GPNM's activities are clustered into four key areas: (1) Development of policy and technical knowledge to inform decision making among policy makers, professionals, farmers, and private sector; (2) Provision of support for piloting and replication of appropriate solutions and BMPs for sustainable nutrient management and pollution reduction with focus on developing countries, sharing lessons from developed countries; (3) Generation of awareness resources and social marketing tools and facilitating dissemination to stakeholders to drive change in behaviors and practice; and (4) Contribution to continued strengthening of the GPNM to facilitate expanded global and regional partnerships, particularly through Regional-level Nutrient Management Platforms.
(http://www.nutrientchallenge.org/)

In addition to the above, the international community has embarked on several global projects and initiatives including:

- Global Environment Facility (GEF) project "Global foundations for reducing nutrient enrichment and oxygen depletion from land-based pollution, in support of the Global Nutrient Cycle" (GEF GNC Project), implemented by UNEP. The objective is to provide the foundations (including partnerships, information, tools and policy mechanisms) for governments and other stakeholders to initiate comprehensive, effective and sustained programmes addressing nutrient over-enrichment and oxygen depletion from land-based pollution of coastal waters in Large Marine Ecosystems. (http://www.nutrientchallenge.org/gef-global-nutrient-cycling-gnc-project).
- GEF project "Targeted Research for improving understanding of the global nitrogen cycle towards the establishment of an International Nitrogen Management System (INMS)", which is implemented by UNEP (https://www.inms.international/).

- The International Nitrogen Initiative (INI), which is an international programme established in 2003 under the sponsorship of the Scientific Committee on Problems of the Environment and the International Geosphere-Biosphere Programme. The INI Latin American Centre was established in 2001, tasked with assessing the nitrogen challenge in the region (https://initrogen.org/latin-america).

Under these initiatives, myriad projects and activities are being conducted around the world, including in Latin America and the Caribbean, and an immense volume of data, information, case studies, and lessons generated (see http://www.nutrientchallenge.org/).

An analysis of governance frameworks and activities at the regional and national levels in the WCR that are relevant to nutrient management is included in Chapter 4 of this report.

1.4 WCR REGIONAL NUTRIENT POLLUTION REDUCTION STRATEGY AND ACTION PLAN

In view of the multi-faceted nature of nutrient pollution and the increasing intensity of the drivers and pressures associated with nutrient pollution, a comprehensive regional nutrient pollution reduction strategy and action plan that adopts an integrated watershed approach incorporating all relevant sectors and stakeholders is an urgent imperative. In October 2019, the UNEP Caribbean Environment Programme (CEP) Regional Coordination Unit (CAR RCU)/Cartagena Convention Secretariat initiated the development of a Regional Nutrient Pollution Reduction Strategy and Action Plan (RNPRSAP) for the entire WCR (Gulf of Mexico, Caribbean, and North Brazil Shelf LMEs, as shown in Figure 1.1). The RNPRSAP will support global commitments related to the maintenance of the health of aquatic ecosystems, as discussed above. Its goal is to establish a collaborative framework for the progressive reduction of impacts from excess nutrient loads on priority coastal and marine ecosystems in the WCR. The RNPRSAP responds to and supports the Cartagena Convention and its LBS and SPAW Protocols, the CLME+ Strategic Action Programme (SAP), the CEP Regional Strategy for the Protection and Development of the Marine Environment of the Wider Caribbean Region, relevant multilateral environmental agreements (Convention on Biological Diversity- CBD, UN Convention to Combat Desertification- UNCCD, and the International Convention for the Prevention of Pollution from Ships- MARPOL), and the major global declarations and targets related to nutrient pollution mentioned above.

Financial support for preparation of the RNPRSAP was provided by the UNDP/GEF CLME+ Project “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." Several WCR institutions and regional actors collaborated with the CAR-RCU in the development of the RNPRSAP. Within the framework of this collaboration, the CAR-RCU engaged the following to prepare sub-regional studies on nutrient pollution, as contributions to the strategy: the Institute of Marine Affairs (IMA) of Trinidad and Tobago, in its capacity as Regional Activity Centre (RAC) for the LBS Protocol for the English speaking countries; the Cuban Center for Research and Environmental Management of Transport (CIMAB), in its capacity as the LBS RAC for the Spanish speaking countries; and the Federal University of Pará in Brazil for national studies on Brazil, Guyana, Suriname, and Venezuela. The CAR RCU obtained information from the French territories (Martinique and Guadeloupe), on behalf of the RAC IMA.

The RNPRSAP is elaborated in Chapter 5.

1.5 ORGANIZATION OF THIS REPORT

This chapter (Chapter 1) is succeeded by four chapters as follows:

Chapter 2: A detailed examination and quantification (where feasible) of nutrient sources at watershed scale. These include anthropogenic sources such as agriculture surface and groundwater runoff, domestic wastewater, industrial point sources including aquaculture, and atmospheric deposition; and natural sources such as floodplain vegetation and non-agriculture runoff. In addition, marine sources such as cruise and boating tourism, and commercial shipping were evaluated.

Chapter 3: A deep dive into the impacts of nutrient pollution. Ecological consequences analyzed include degrading water quality based on empirical data, eutrophication potential of coastal receiving basins using model outcomes; documented occurrence and aftermath of harmful algal blooms, formation of hypoxic zones, and documented impacts on ecosystem functioning including the spread of *Sargassum* nuisance blooms. In addition, the social and economic costs of nutrient pollution and its associated environmental impacts in the WCR are reviewed.

Chapter 4: An analysis of the current governance frameworks for addressing marine pollution in the WCR at the regional and national levels, including institutional, legislative and policy frameworks, existing technical and institutional capacity and other conditions that are relevant to the management of nutrient pollution in the WCR. Major gaps and barriers that need to be addressed for effective implementation of the RNPRSAP are also identified.

Chapter 5: Presents the WCR Regional Nutrient Pollution Reduction Strategy and Action Plan. It describes the RNPRSAP guiding principles and nine strategic Pillars with associated Objectives and Targets including necessary enabling conditions for implementation of the RNPRSAP; an institutional implementation framework; an action framework for implementation of the strategy at regional and national levels; a monitoring and evaluation framework; and a compendium of strategies and best management practices for addressing nutrient pollution. Chapter 5 also includes a summary of chapters 2 and 3 (nutrient sources and impacts) to facilitate the use of chapter 5 as a stand-alone document, should readers so desire. Hence, there is some unavoidable repetition in chapter 5 with previous chapters.

2 NUTRIENT INPUTS, SOURCES AND LOADS IN THE WIDER CARIBBEAN

2.1. DATA SOURCES AND METHODS

2.1.1 Watershed approach

This report uses a watershed approach in examining the sources, fluxes and coastal impacts of nutrient pollution. A watershed (also called a drainage basin or catchment) is defined as an area of land that drains all the streams and rainfall to a common outlet such as the mouth of a bay or any point along a stream channel (Figure 2.1). Every land extent on earth is part of a watershed unit. In all but a few cases, water exits to the coasts via rivers when these are exorheic watershed systems, such are majority of those in the Wider Caribbean Region (WCR). Endorheic watersheds are those which do not drain to the sea but to lakes or swamps such as the transboundary watersheds Cul-de-Sac Depression and Lago Enriquillo in Hispaniola. This report focuses on exorheic basins of the region.

The watershed scale of analysis is placed within a typological framework to allow for determining trends and patterns at the scale of continental/ insular types and the WCR sub-regions. The 40 countries and territories are classified into four types: a) **Big Continental States of Sub-regions I and III including North Brazil**.; b) **Small Continental States in Sub-region II**; c) **Small Islands in WCR Sub-regions III, IV and V**; and d) **Big Islands located in Sub-region V.** Each type has nuanced correlates in geographic attributes, land use and cover, demographic and economic features that drive nutrient consumption, flows and environmental impacts (Table 2.1).

The WCR-draining watersheds of 40 countries and territories make up the terrestrial component of the analysis in this report. The aquatic systems from the headwaters to the receiving coastal basins form the water continuum, and which serve as medium for conveying nutrients, sediments, wastewater and pollutants from land to sea. The watershed boundaries and the rivers coursing through these do not follow administrative boundaries. In the WCR, there are 26 transboundary river basins whose sub-basins are located in two or more countries. In the case of Brazil, all of its watersheds that drain to the North Brazil Shelf Large Marine Ecosystem, which extends from the Caribbean Sea to the Parnaiba Estuary, are included in this report. Amazon River Basins located outside of the WCR, such as those in Bolivia, Ecuador and Peru are included in the modeling of nutrient sources and loads only.

In keeping with a full assessment of the water continuum, this report includes marine-based sources of nutrient pollution as discussed in Chapter 2.10. While sea-based point sources such as oil-rig installations, shipping and boating discharges (merchant and cruise ships; yachts) remain as major data gaps, available information is presented to highlight the need for further research.

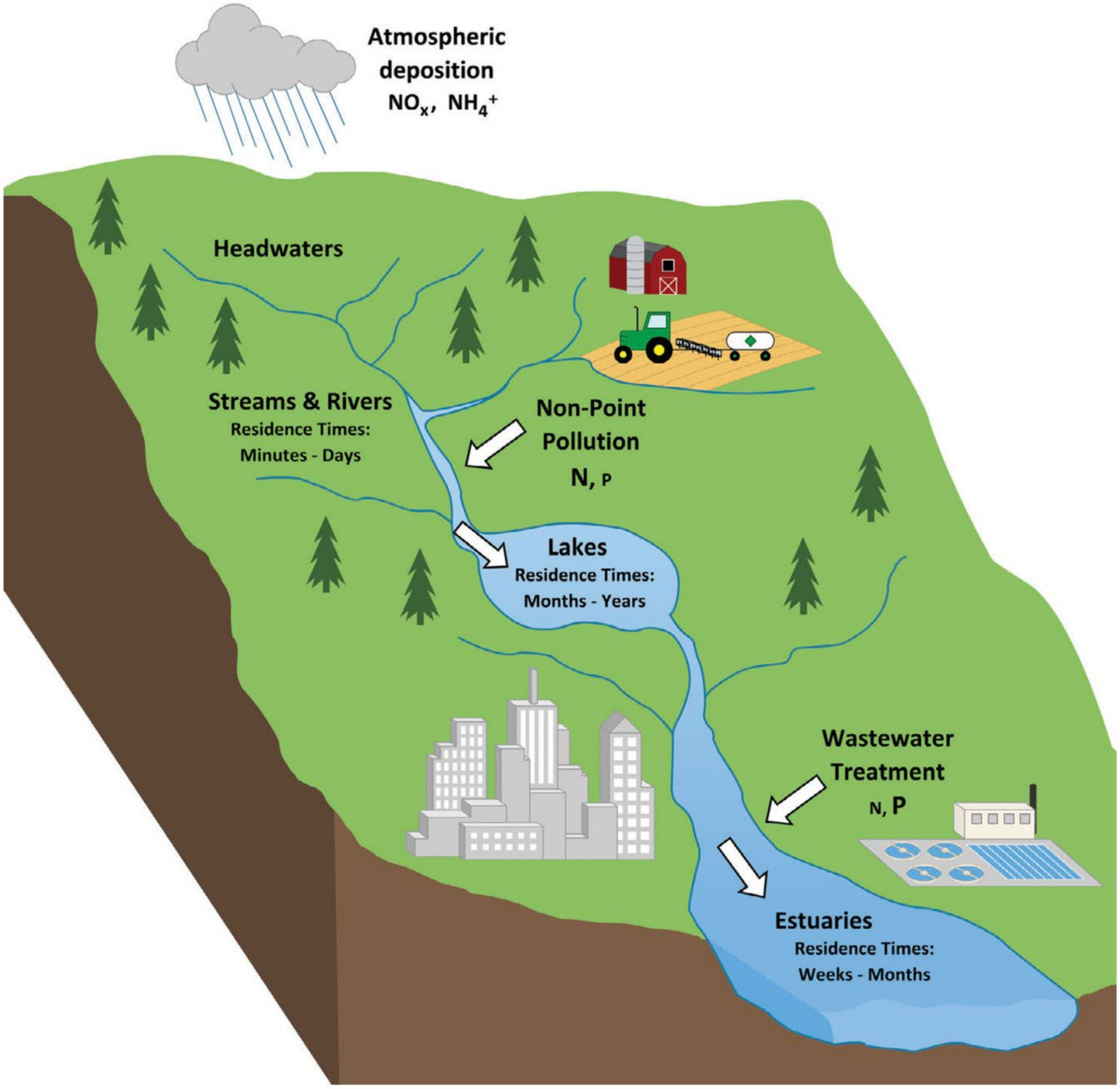


Figure 2.1 A watershed unit includes the land and the stream and riverine network it drains. It is delineated by a drainage divide which is land formation with the highest elevation from which headwaters originate. Included also are non-point and point sources of nutrients leading to estuaries and coastal waters. (Source: Wurtsbaugh et al. 2019)

2.1.2 Input data and analyses.

To characterize the watersheds and the fluxes and cycles of materials that make up nutrient flows, freely available global datasets were accessed and analyzed. These include:

- HydroATLAS v1.0 database, with two companion datasets: BasinATLAS and RiverATLAS by Linke et al 2019. Watershed features were derived from Level 12 dataset, which had the finest subdivisions of sub-basins for each watershed, chosen to provide the most accurate estimates of land-use areas, spatial Gross Domestic Product (GDP) and population. A total of 3,211 exorheic main basins draining into the WCR was analyzed at 15 arc seconds resolution. Temporal coverage for the watershed features are parameter-specific and generally cover the period from 2000 to 2015.
- Data set generated by the Integrated Model to Assess the Global Environment (IMAGE) – Global Nutrient Model (GNM) by Beusen et al. 2016. Using a soil budget method incorporating population, wastewater generation, and land use, this data set provides estimates of nutrient sources and loads in terms of total nitrogen (TN) and total phosphorus (TP) for the years 1900 to 2000. Data for Model year 2000 is presented. The model resolved a total of 470 WCR-draining basins at a resolution of 0.5° X 0.5° (2500 km^2 at the equator).
- Data set produced by the Global Nutrient Export from Watersheds 2 (Global NEWS 2) by Mayorga et al. 2010. Using a soil budget method, this data set provides estimates of loads of dissolved inorganic and organic forms of nitrogen (DIN, DON), phosphorus (DIP, DOP), particulate and dissolved organic carbon, and dissolved silica for model year 2000. Most importantly, these input parameters have enabled the authors to estimate the nutrient-specific Indices of Coastal Eutrophication Potential at watershed-scale. The data set provides data for 261 WCR-draining basins at a resolution of 0.5°.
- Country-scale data on Net Anthropogenic Nitrogen Inputs (NANI) from (1) atmospheric N deposition, (2) N fixation by planted forests and crops, (3) N fertilizer consumption, and (4) net of import minus export of N in agricultural products (Han et al. 2020). These were scaled to country-aggregated WCR watershed areas for model year 2000 to complement model years from the data sets above.
- FAO databases were accessed to obtain input parameters for:
    a. Land use at country scale for the period 1961 to 2018 at http://www.fao.org/faostat/en/#data/RL/visualize
    b. Pesticide use (FAOSTAT) at http://www.fao.org/faostat/en/#data/RP/visualize
    c. Wastewater (AQUASTAT) at http://www.fao.org/aquastat/en/
- National data analyzed in the preparation of the State of the Cartagena Convention Area Report (An Assessment of Marine Pollution from Land-based Sources and Activities in the Wider Caribbean Region) (UNEP CEP, 2019). These data sets although limited in their coverage of parameters in time and space, are critical in underscoring the need for local validation of model data, and in enhancing national capacities to implement strategic pollution monitoring programmes.
- Sub-regional reports presenting national data. Three subregional reports have been prepared as part of the process in preparing a Nutrient Reduction Strategy and data where appropriate are cited. The SOCAR dataset, which applies to English-, French- and Spanish-speaking countries, has been extensively used, especially for the continental and island countries and territories in WCR Sub-regions I, III, IV and V. For watersheds draining to the North Brazil Shelf LME (NBSLME), appropriate input data have been obtained from the global datasets cited above. The same was done for all continental countries of WCR Sub-region II, for which no national contribution to the SOCAR dataset was made . It should be noted that the Brazil Legal Amazonia data set (University

of Para, 2020) is a subset of the aggregate watershed areas that drain to the NBSLME, and that all computations are scaled to the NBSLME, which includes the Brazil Legal Amazon basin, and basins draining along the coast up to the Parnaiba estuary (Isaac and Ferrari, 2017). These also include the Amazon River watersheds in non-WCR countries such as Bolivia, Ecuador and Peru. Land use areas, and population sizes in these watersheds were used to calculate nutrient runoff and domestic sewage discharged to the environment. The integrated models included all watersheds of the Amazon River.

- Transboundary Waters Assessment Programme assessed transboundary river basins and indicators for nutrient pollution and for wastewater were accessed for WCR transboundary river basins (UNEP-DHI 2015; ILEC et al. 2016).

2.1.3 WCR Nutrient Pollution Reduction Strategy and Action Plan (WC RNPRSAP) Database V3

All of the core data comparable in methodology, across watersheds or countries, both input and derived, have been assembled as an WCR-NPRSAP Database that is integral to this RNPRSAP document. The scales reflect those of the original data sources, except for computations on domestic waste water inventories which were scaled to watershed-scale spatial population data from the HydroATLAS (Linke et al 2019) (Table 2.1). The database is meant to initiate the assembly of information that is needed to plan nutrient pollution reduction. Generation of empirical and model data to update and maintain this database is feasible when viable pollution monitoring programmes at national, subregional or regional scales are established in countries where these are currently absent, and strengthened where capacities exist as part of an overall strategy to reduce marine pollution in general, and nutrient pollution, in particular. For comparability across countries, and to allow for aggregation at WCR sub-regional scale, watershed data are aggregated to country scale. It must be noted that for key parameters in establishing ecological impacts of nutrient pollution, such as evaluating the tendency towards eutrophication, the watershed scale analysis is of utmost importance. Aggregating to a coarser scale than at main-basin level can mask the computation of positive indices of eutrophication potentials. Sub-basin scale analysis may become feasible as data for needed input parameters become available through fine-scale modeling or through sub-basin monitoring programmes. The database are spatially-explicit data, and each of the estimated parameters are referenced to a model year. None-spatial data such as those obtained from country-scale databases like FAOSTAT, are not included in the database as these are best accessed directly from the institutional data providers which usually updates country data on an annual basis.

Chapter 5 (section 5.3) provides a summary of the main trends and patterns of nutrient pollution including the associated watershed features, and are based mainly on the spatial datasets (HydroAtlas, IMAGE-GNM and Global NEWS) mentioned above. These are cross-referenced in this chapter, which aim to highlight contributing sources and loads for agro-chemical runoff, domestic wastewater including pathogens, and industrial nutrient point sources, among others. Country scale temporal trends and summaries such as those from FAOSTAT are provided in this chapter to complement these geo-referenced information .

Table 2.1 Organization of watershed-scale data in the RNPRSAP for the Wider Caribbean Region.

Watershed Features	**Land use and Demographic features (***resolution at 15 arc-seconds ~500 m at the equator)*	**Nutrient inputs and Soil-budget based Nutrient Sources** *(resolution at 0.5°~11 km at the equator)*	**Nutrient Loads** *(resolution at 0.5°~11 km at the equator)*	**Index of Coastal Eutrophication** *(resolution at 0.5°~11 km at the equator)*	**Coastal Water Quality (SOCAR National data related to nutrients)** *(point samples)*
Type					
Big Continental countries: Sub-regions I & III, North Brazil	✓	✓	✓	✓	• Colombia • Mexico • USA
Small Continental countries: Sub-region II	✓	✓	✓	✓	None available
Small islands: WCR Sub-regions III, IV and V	✓	✓	✓	Only Trinidad & Tobago with 2 basin cell counts	• Antigua & Barbuda • Barbados • Dominica • Grenada • Saint Lucia • Saint Vincent & The Grenadines • Trinidad & Tobago
Big islands: WCR Sub-regions V	✓	✓	✓	✓	• Dominican Republic • Jamaica • Puerto Rico
Data sources	Linke et al 2019 using Level 7 (for maps) and Level 12 basin datasets (for data computations)	Han et al. 2020; Beusen et al. 2015 for model year 2000	Beusen et al 2015: Model year 2000 for total nutrients; Mayorga et al. 2010: Model year 2000 for all forms of N and P	Mayorga et al. 2010	SOCAR Report: (UNEP CEP, 2019)

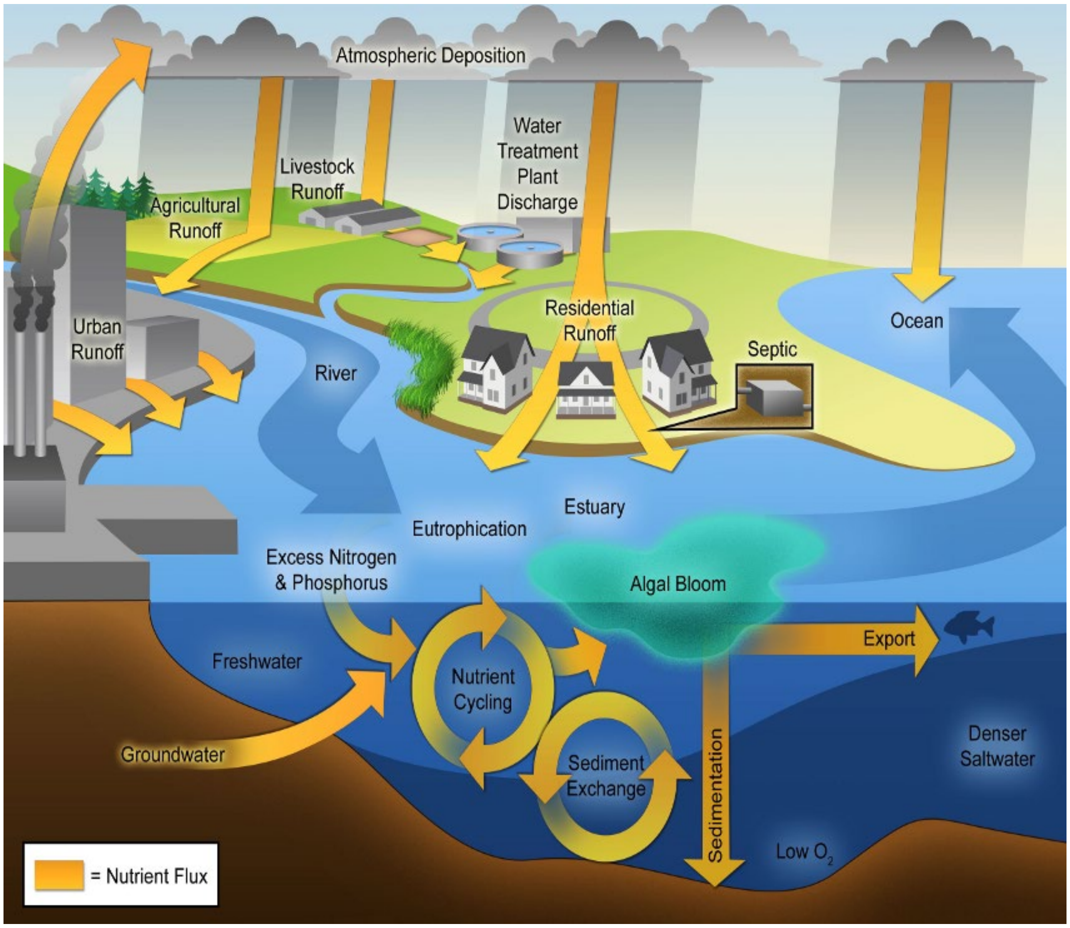


Figure 2.2 Land use in the catchment determines to a great extent the sources of nutrient and associated pollutants that adversely impact coastal waters. These include forest conversion to cropland and pastures for livestock, and urban extents paved with impervious surfaces. Agricultural surface and groundwater runoff and urban non-point flows contribute to excess nutrient loads to waterways down to the coast. (Source: Paerl http://www.coastalwiki.org/wiki/Portal:Eutrophication/Concept_drawing)

2.2 Land use in the watersheds of the WCR region.

Forest land conversion to grow crops and livestock, has been a singular driver of nutrient pollution since the production of synthetic nitrogen fertilizer reached commercial scale in the 1920s (Tilman et al. 2001) (Figure 2.2). Forest clearance and the expansion of cropland and pastures marked the advent of the Green Revolution (also known as the Third Agricultural Revolution) in the 1930s. High-yield seeds were developed and distributed, often displacing native varieties that were more resilient to pests and plant disease because of well-tuned evolutionary adaptations to local conditions (Rawlins et al. 1998). Yields increased with significant inputs of mineral fertilizer. During the first 35 years of the Green Revolution, global grain production, notably rice and wheat, doubled. As the case with environmental impacts, the adverse environmental consequences of modified terrestrial ecosystems and biogeochemistry, and the addition of fertilizers to boost food production began to become manifest with serious consequences (US National Science and Technology Council Committee on Environment and Natural Resources, 2000). The environmental impacts of chemicals to control unwanted growth of pests including weeds, insects and microbes, became evident relatively more quickly. Pesticides like DDT (dichloro-diphenyl-trichloroethane), now known to be highly carcinogenic and to be very persistent in the environment, was banned in the USA since 1972, with public awareness increasing after the publication of Rachel Carson's Silent Spring in 1962.

2.2.1 Agricultural land use.

Among WCR countries and territories, net changes in agricultural land showed a gradual increase from 1961 to 2018, the period for which harmonized data is available (Figure 2.3, Table 2.2, Annex 2.1). Pastures increased by 8% to over 4 million km^2 while cropland expanded by 10% with Brazil, Colombia, Cuba and Suriname doubling their respective cropland area; Belize increasing this three-fold and French Guyana expanding it five times over nearly six decades (Table 2.2). Across the WCR, cropland increased by 242,000 km^2 and pastures by 412,000 km^2.

In the case of forest land, data was systematized by FAO beginning 1990. Records spanning nearly 30 years from 1990 indicate a net loss of over a million km^2 of forest, 88% of which was cleared in Brazil. In the USA, Cuba and Puerto Rico, forest area showed a net increase of 73,000 (USA), 11,840 (Cuba), and 1,750 km^2, resp. It may be reasonable to think that the use of 1961 baselines would show an greater net decrease in forest land, across the WCR. Changes in forest extent had profound consequences on terrestrial biodiversity, and biogeochemical cycling of nutrients, which, has since become increasingly dominated by nitrogen and phosphorus inputs from sustained synthetic fertilizer application.

Because of the role of natural vegetation notably forests, in tightly cycling nutrients across the soil, water, air and biomass compartments and associated soil microbial communities, nutrients are maintained with minimal leakage to the stream network. Tropical forests, in particular, store large amounts of biomass in generally nutrient-deficient soil (Grau et al. 2017). Mechanisms for partial nutrient supplementation can be through organic nutrient relocation from older leaves before these fall (Foster and Bhatti 2006). As such forests can regulate nutrient demand to levels which can be significantly lower than that required by nutrient-hungry crops. The ecosystem services provided by trees in nutrient regulation and biodiversity maintenance are two compelling reasons for forest conservation. At the same time, these same functions keep nutrients in tight circulation, with no excess that can pollute. The relatively extensive forest cover in Sub-regions II and III should be conserved. In areas where forest is equal to or less than land areas devoted to crops and livestock, setting aside areas for vegetated buffers are among the most effective best practice in addition to fertilizer applications at levels that match optimal crop nutrient efficiency (Delkash et al. 2018).

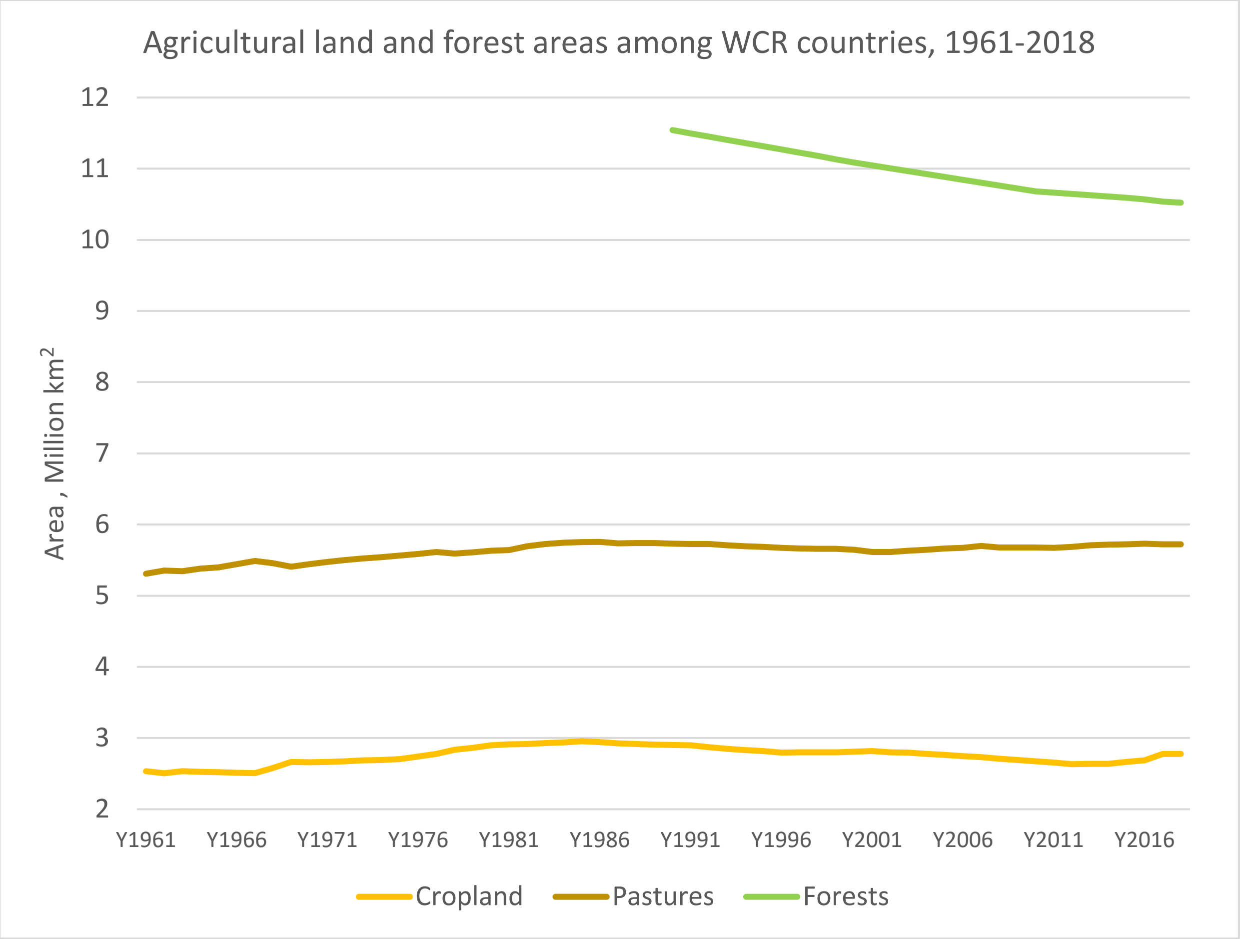


Figure 2.3 From 1961 to 2018, net changes in cropland and pastures in WCR countries and territories (million km2) show gradual net increase of 10% over nearly six decades following the Green Revolution. Pastures were nearly twice in area compared to cropland and increased by 8% over the same period. Forests over the recorded period from 1990 showed a steeper decrease with over a million km2 lost over almost three decades (not six decades) for which data has been systematized. (Input data source: FAOSTAT).

Table 2.2 Changes in agricultural and forest areas (km^2) among WCR countries and territories. Changes in cropland and pasture are tracked from 1961 to 2018; that for forest covers a shorter period from 1990 to 2019. (Input data: FAOSTAT). Values in red inside (parentheses) are losses.

WCR Sub-region	Area	UN Iso-Code	Cropland		Pasture		Forest	
			Change in Area (2018-1961) km^2	% change 1961 to 2018	Change in Area (2018-1961) km^2	% Change 1961 to 2018	Change in Area (2018-1990)	% Change 1990 to 2018
I	Mexico	MEX	57,950	28%	27,800	4%	(46,440)	-7%
I	United States of America	USA	(220,722)	-12%	(196,264)	-7%	73,450	2%
II	Belize	BLZ	800	190%	130	35%	(3,007)	-19%
II	Costa Rica	CRI	1,025	21%	2,850	31%	947	3%
II	Guatemala	GTM	5,090	33%	7,010	63%	(12,302)	-26%
II	Honduras	HND	1,160	8%	2,600	17%	(5,866)	-8%
II	Nicaragua	NIC	6,100	52%	10,250	46%	(27,918)	-44%
II	Panama	PAN	1,860	33%	4,490	42%	(3,707)	-8%
III	Brazil	BRA	320,740	102%	478,458	38%	(898,466)	-15%
III	Colombia	COL	49,220	99%	46,000	13%	(54,177)	-8%
III	French Guyana	GUF	158	527%	107	357%	(1,153)	-1%
III	Guyana	GUY	1,100	31%	(2,178)	-22%	(1,684)	-1%
III	Suriname	SUR	330	94%	100	167%	(1,568)	-1%
III	Venezuela (Bolivarian Republic of)	VEN	(1,820)	-5%	24,500	16%	(56,882)	-11%
IV	Antigua and Barbuda	ATG	(30)	-38%	20	100%	(19)	-18%
IV	Barbados	BRB	(90)	-53%	0	0%	0	0%
IV	British Virgin Islands	VGB	0	0%	10	25%	(1)	-2%
IV	Dominica	DMA	80	53%	0	0%	(24)	-5%
IV	Grenada	GRD	(120)	-63%	(20)	-67%	0	0%
IV	Guadeloupe	GLP	(183)	-42%	119	85%	(25)	-3%
IV	Martinique	MTQ	(53)	-25%	27	21%	41	8%
IV	Montserrat	MSR	(20)	-50%	0	0%	(10)	-29%
IV	Saint Kitts and Nevis	KNA	(109)	-68%	(31)	-78%	0	0%
IV	Saint Lucia	LCA	(40)	-29%	(24)	-80%	(5)	-2%
IV	Saint Vincent and the Grenadines	SVG	(40)	-44%	10	100%	10	4%
IV	Trinidad and Tobago	TTO	(450)	-49%	20	40%	(130)	-5%
IV	United States Virgin Islands	VIR	(30)	-60%	(50)	-71%	(49)	-20%
V	The Bahamas	BHS	30	33%	10	100%	0	0%
V	Cuba	CUB	19,116	116%	8,384	44%	11,840	58%
V	Dominican Republic	DOM	2,420	24%	(30)	0%	5,330	33%
V	Haiti	HTI	1,900	16%	(100)	-2%	(294)	-8%
V	Jamaica	JAM	(610)	-22%	(280)	-11%	678	13%
V	Puerto Rico	PRI	(2,378)	-78%	(2,093)	-67%	1,750	55%
	Net Change		242,324	10%	411,824	8%	(1,019,709)	-10%

2.2.2 Built-up surfaces.

Contemporaneously with the expansion of agriculture is population growth and increasing levels of urbanization for the WCR (Figure 2.4). Urbanization, the process through which a large number of people becomes permanently concentrated in relatively small areas, forming cities (UN 1997), is a key demographic indicator that has profound impacts on land cover and use, water utilization and biogeochemical cycling at local and regional scales (Talaue-McManus 2010, Seto et al 2010,). Despite a projected slow-down in population growth from 1950 to 2050, the WCR is urbanizing rapidly – Subregions 1, 3 and 5 will reach over 84-90%, and Subregions 2 and 4 will reach 73% and 67%, respectively by 2050. 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).

Both the rates of population increase and urbanization have significant implications on increasing demands for food and water supply, and sanitation and solid waste management, among others. For the small island territories and states of the region, the finiteness of land resources and facilities to support an increasing and urbanizing population, and proximity to coastal and marine ecosystems, pose serious sustainability challenges, including emissions of untreated or minimally treated domestic waste that contribute significantly to nutrient and pathogen pollution (see Section 2.4 on domestic waste).

Among the most serious biogeochemical impacts of urbanization is the increasing area of built-up surfaces that are impervious to water infiltration, leading to rapid flows of sediments and waste from both the upland and low-lying coastal areas. These result in episodic material pulses to wetlands, estuaries and marine ecosystems via runoff. Beginning in the late 1970s, studies have begun to chronicle the visible degradation of aquatic ecosystems as about 10% of land in the surrounding watershed becomes impervious (Klein 1979; Schueler and Holland 2000; Beach 2002). In the WCR, island states and territories are particularly vulnerable to losing natural landscapes as paved surfaces increase. Using spatial data from the RNPRSAP database V3.0, forest, agricultural land, and urban extents for each WCR country and territory, Table 2.3 shows that 17 of the 25 WCR islands have gone beyond the 10% threshold for built-up substrates, placing aquatic ecosystems including surrounding coastal waters at risk of degrading water quality resulting from diminished natural substrate filtering capacity and exacerbated by faster transport of water-borne pollutants as run-off across impervious surfaces.

The current century has been dubbed the Century of the City, as globally, urban dwellers exceeded rural residents beginning 2008 (Seto et al. 2010). Demographic and economic development changes in the Wider Caribbean have long crossed the rubicon of urbanization decades before the world at large did, and maybe reaping both positive and negative consequences of unplanned urban expansion. For the environment, a long-term forward-looking approach is needed to maintain ecological, social and economic well-being in urbanizing continental coastal and island settings, especially with regards the management of domestic waste, and the nutrients and pathogens released to the environment when these are mismanaged.

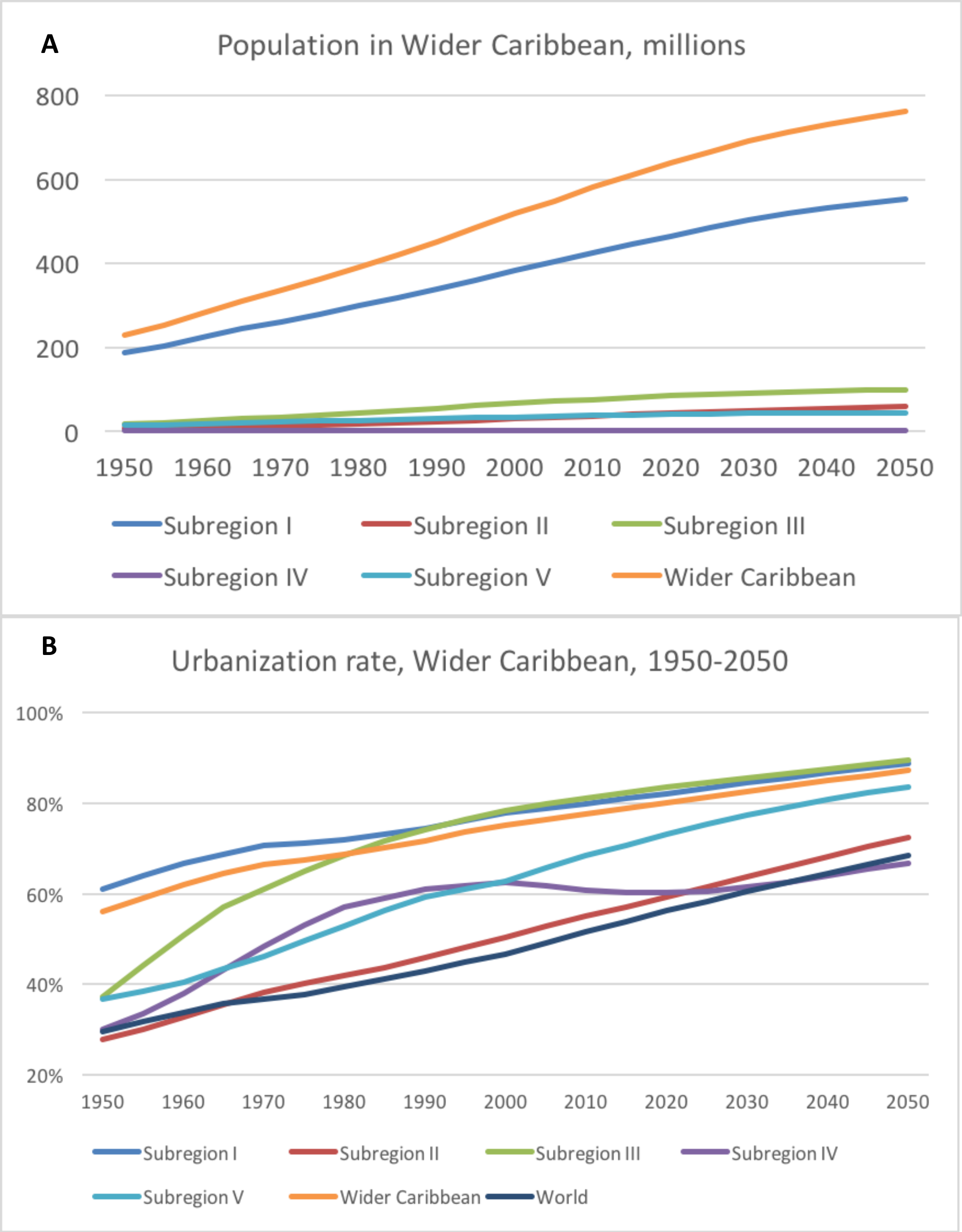


Figure 2.4 Population (A) and urbanization (B) trends in the WCR. (UNEP CEP, 2019; Input data source: UN World Urbanization Prospects 2018)

Table 2.3 Areas of forest, cropland, pasture and urban extents (RNPRSAP Database, Linke et al. 2019). Islands with orange highlight have impervious surfaces beyond the 10% threshold.

WCR Sub-region	Country/ Territory	Country Iso-Code	Percent WCR Watershed Area				WCR Watershed area (km2)
			Forest cover extent, (2000)	Cropland extent, (2000)	Pasture extent, (2000)	Urban extent, (2015)	
I	Mexico	MEX	30%	21%	35%	1.5%	1,055,320
I	USA	USA	28%	32%	31%	2.1%	4,385,834
II	Belize	BLZ	73%	5%	2%	0.5%	22,443
II	Costa Rica	CRI	79%	6%	41%	1.9%	24,435
II	Guatemala	GTM	62%	14%	24%	3.6%	85,186
II	Honduras	HND	65%	11%	12%	1.4%	93,686
II	Nicaragua	NIC	59%	18%	43%	1.0%	116,682
II	Panama	PAN	72%	2%	20%	1.0%	21,976
III	Colombia	COL	54%	4%	29%	1.1%	717,417
III	French Guiana	GUF	97%	0%	0%	0.1%	83,698
III	Guyana	GUY	90%	2%	6%	0.1%	210,097
III	Suriname	SUR	95%	0%	0%	0.2%	147,973
III	Venezuela	VEN	53%	4%	21%	0.9%	918,147
III	Brazil-LME17	BRA	75%	1%	10%	0.1%	4,897,474
III	Netherlands Antilles - Aruba	ABW	4%	0%	49%	44.0%	204
III	Netherlands Antilles - Bonaire	BES	33%	2%	31%	2.5%	379
III	Netherlands Antilles - Curacao	CUW	20%	1%	35%	23.0%	490

Table 2.3 (Continued)

WCR Sub-region	**Country/ Territory**	**Country Iso-Code**	Percent Watershed Area				**WCR Watershed area (km2)**
			Forect cover extent, (2000)	**Cropland extent, (2000)**	**Pasture extent, (2000)**	**Urban extent, (2015)**	
IV	Anguilla	AIA	0%	2%	23%	5.9%	112
IV	Antigua and Barbuda	ATG	49%	2%	23%	11.1%	512
IV	Barbados	BRB	5%	8%	2%	38.9%	463
IV	British Virgin Islands	VGB	18%	2%	23%	15.1%	463
IV	Dominica	DMA	5%	3%	1%	2.1%	798
IV	Grenada	GRD	39%	21%	4%	18.0%	355
IV	Guadeloupe	GLP	48%	2%	22%	13.7%	1,777
IV	Martinique	MTQ	19%	3%	1%	16.5%	1,219
IV	Montserrat	MSR	62%	2%	23%	0.0%	115
IV	Saint Kitts and Nevis	KNA	40%	2%	23%	15.4%	302
IV	Saint Lucia	LCA	36%	3%	1%	12.1%	662
IV	Saint Vincent and the Grenadines	SVG	30%	3%	1%	12.7%	535
IV	Trinidad and Tobago	TTO	67%	26%	2%	13.8%	5,365
IV	Virgin Islands (U.S.)	VIR	2%	2%	23%	19.0%	250
V	Cayman Is	CYM	74%	13%	13%	11.3%	335
V	Turks and Caicos	TCA	2%	9%	36%	1.6%	1,182
V	Bahamas	BHS	25%	5%	21%	1.0%	15,869
V	Cuba	CUB	23%	39%	24%	2.8%	114,757
V	Dominican Republic	DOM	29%	33%	43%	5.7%	48,407
V	Haiti	HTI	8%	42%	19%	11.9%	27,906
V	Jamaica	JAM	35%	26%	21%	13.8%	11,250
V	Puerto Rico	PRI	21%	10%	20%	28.9%	9,269

2.3 Agrochemical sources

The conversion of forests to agricultural land and unplanned construction of urban extents naturally alter the cycling of nutrients in the watersheds, and their fate and transport across land and via aquatic ecosystems including to downstream coastal waters. Exacerbating these modified land uses is the excessive application of agrochemicals, substances involved in the growth of farmed plants and animals, in natural or synthetic forms (https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/agricultural-chemicals). They may be broadly divided into two categories: chemicals that promote growth of plant or animal (e.g. plant fertilizers and animal food supplements including growth hormones); and those that presumably protect farmed organisms from other unwanted organisms (e.g. pesticides, herbicides, animal vaccines, and antibiotics). This report focuses on nutrient fertilizers and pesticides, which are mostly synthetic chemicals commonly used in cropland farming and that contribute the most to nutrient pollution.

The agricultural practice of fertilizer and pesticide applications at small farm holdings to industrial scales, has increased food supply to feed a growing and increasingly more affluent population. It has also created a toxic brew that diminishes the extent to which ecosystems, terrestrial and aquatic, can assimilate exotic chemicals without adverse impacts at physiological and biome scales. Unsustainable agricultural practices have pushed farming towards a false dichotomy of increasing food production at the inevitable expense of degrading ecosystems. A serious transformation of sustainable food production has to take place, and one that places front and center irreplaceable ecosystem services that keep the soil healthy, water available in quantities of high quality, and the nutrients bound in tight and efficient biogeochemical cycling.

2.3.1 Synthetic fertilizer and nutrient use efficiencies

Over a period of nearly six decades from 1961 to 2018, cropland among WCR countries increased from 2.5 million km^2 to nearly 2.8 million km^2, occupying just 12% of aggregate national land areas in the latest data year. Using the latest spatial data referenced to model year 2000, croplands make up 13% of aggregate WCR-draining watersheds (RNPRSAP Database V3.0). Currently, Latin American and Caribbean countries contribute 14% of the global food production, and 23% of agricultural and fish exports. These contributions are projected to increase to more than 5% by year 2028 (OECD-FAO, 2019). A major question is the extent of environmental tradeoffs these increases will exact, in addition to issues of food insecurity and poverty for many farming households in the region (Flachsbarth et al. 2015).

Fertilizers and pesticides are major inputs in farming with the explicit aim of boosting crop production. At the same time, they also cause major perturbations in the natural biogeochemical cycling of plant biomass given the massive amount of anthropogenic additions to the biosphere. Annex 2.2 details nitrogen (Panel A) and phosphorus fertilizer (Panel B) use among WCR countries from 1961 to 2018. For continental countries of Sub-regions I, II and III, there was an apparent increase in fertilizer application over this period. Among island states, application rates over time were more variable, but at times greatly exceeding the per unit area usage by their larger counterparts. In the case of Cuba, the collapse of the Soviet Federation in the beginning of the 1990s reduced usage drastically (Messina and Royce, 2019). For Puerto Rico, the erosion of farming with a series of policies that tilted the island's development towards manufacturing beginning the 1940s (Nagovitch 2020), greatly affected access and use of agrochemicals.

Sotomayor-Ramirez et al (2013) show a dramatic decrease in total mixed fertilizer consumption for Puerto Rico, best explained by the decrease in the area of agricultural land for the most part, and by the decrease in fertilizer rate application to a lesser extent. For model year 2000, total N and P fertilizer applied to 1,945,447 km^2 of croplands in WCR watersheds (excluding pastures) reached 10,450,000 tons and 3,830,000 tons, respectively. Of these tonnage, only 60% (average weighted by cropland area) is used up for synthesizing plant biomass, and the rest flows to surface and groundwater, fertilizing plants, big and small, floating and attached at levels that place these aquatic ecosystems and people at risk.

On aggregate for the WCR region, this report aims to estimate further the extent to which overall and cumulative nutrient fertilizer usage has contributed to the pollution load in terrestrial and aquatic ecosystems of the region.

A major indicator that has been designed to answer quantitatively the contribution of fertilizer application to increases in agricultural yield as well as to nutrient pollution is the use of indices called nutrient use efficiencies. Nutrient use efficiency is defined as the proportion of the nutrient applied from all sources that are taken up by the harvested crop (IFA et al 2016). By convention, nutrient use efficiencies are referenced to either nitrogen or phosphorus. For nitrogen use efficiency (NUE), the most comprehensive publication focuses on nitrogen flows in relation to the yield of crops for 105 countries from 1961 to 2009 (Lassaletta et al. 2014). Nitrogen Use Efficiency (NUE) is defined as the ratio of annual yield in crop production to the amount of annual nitrogen Inputs in kg N applied per ha cropland:

Nitrogen Use Efficiency, NUE = (annual harvested crop in Kg N ha^{-1} yr^{-1})/ annual Inputs [Synthetic N fertilizer + symbiotic N fixation, + manure application + atmospheric deposition] to cropland (Equation 1.0)

In the case of phosphorus, Lun et al. (2018) defined Phosphorus Use Efficiency (PUE) as follows:

Phosphorus Use Efficiency (PUE) of the agricultural system and of its subsystems = Total P harvested in economic outputs such as crops, meat, milk and eggs/ Total P inputs [P fertilizers for cropland, P from mined phosphate rock, atmospheric P deposition in cropland and pasture areas] (Equation 2.0)

These two major studies provide data to estimate nutrient runoff from cropland in the case of nitrogen, and from both cropland and pastures for phosphorus. Nitrogen use efficiency is underpinned by the response of crop yield to total nitrogen inputs, N fertilizer being just one of the inputs as defined in Equation 1.0 above. Thus, there is no N runoff estimated from pastures. Annex 2.3 provides a detailed analysis of nitrogen use efficiency at WCR country-scale using input data from Lassaletta et al. (2014). Use efficiency components such as inputs, crop yield, and surplus N (i.e. runoff) are shown at WCR (regional) scale in Figure 2.5.

Figure 2.5(A) shows the increasing trends in N- fertilizer and total N-inputs from 1961 to 2009. In response, crop yield increases but not in a proportional fashion. Because of such disproportionate yield, the croplands accrue excess or surplus nitrogen which is available as cropland N runoff. Plotting the ratio of yield to total N inputs, shows that this ratio, also known as nitrogen use efficiency, actually decreases exponentially over time, using unweighted use efficiency averages over time (Figure 2.5B). What crops do not assimilate of the N inputs in plant biomass synthesis, then becomes available as excess nutrient load (i.e. N runoff) and is transported to aquatic ecosystems and groundwater (Figure 2.5A – Surplus N (orange line)). Among N inputs, fertilizer dominates and drives the increasing trends of both total N inputs as well as excess nitrogen. Mathematically, the variance in fertilizer application rates accounts for 97% of the linear increase in total N inputs, and explains 96% of the linear increase in N-runoff (Figures 2.5C and 2.5D). Cropland N-runoff for model year 2000 was estimated to be 12,009 thousand tons region-wide with Sub-region I accounting for 83% of emissions, and is purely based on cropland use efficiencies, without accounting for other nitrogen losses.

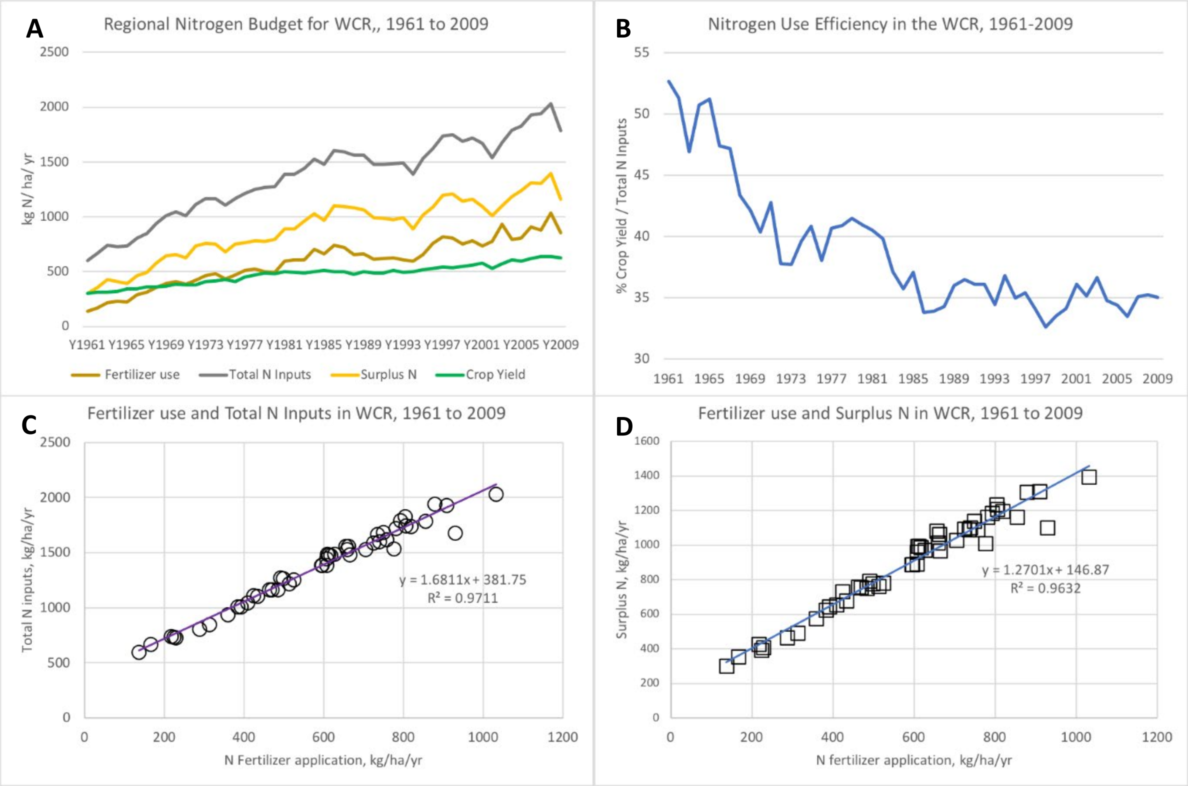


Figure 2.5 Role of nitrogen fertilizer in the regional N budget of the WCR and generation of surplus N as potential nutrient source load for the period 1961 to 2009. A. Major nutrient (total nitrogen inputs, fertilizer, and excess nitrogen) flows increase over the study period. Crop yield likewise increases, but not in a proportional manner. Nitrogen Use Efficiency (NUE) (B), which is N crop yield over Total N Inputs in fact shows a trend that decreases exponentially over time. This decreasing efficiency leads to increasing surplus N, which is the potential nutrient pollutant load.

In the case of phosphorus, Lun et al. (2018) estimated P use efficiencies separately for cropland, pastures and livestock, cognizant of the complex phosphorus flows and exchanges across these sub-domains of an agricultural system. In addition, their study provided P runoff estimates from cropland and pastures for WCR countries, which this report scaled to WCR-draining watersheds using spatial estimates of cropland and pasture areas in the RNPRSAP Database for model year 2000 (Linke et al 20190). Computed data are presented by country/territory in Annex 2.4, together with N runoff from croplands. Table 2.4 below summarizes the data by WCR Sub-region. In model year 2000, about 667 thousand tons of P was estimated to have been emitted by croplands and pastures region-wide. Cropland releases almost six times more phosphorus runoff than do pastures because of heavy fertilizer inputs to boost crop production.

The estimates above assume 100% application across the estimated acreage of cropland in the WCR watersheds which cover 1.94 million km^2 (Table 2, RNPRSAP Database). Further constraints on runoff estimates can be made by accounting for losses to gaseous forms in the case of nitrogen, and adsorption to nonagricultural sediments in the case of phosphorus. The unequivocal conclusion is that fertilizers are used with almost 40% wastage in the WCR, because application well exceed crop nutrient use efficiencies, generating excess nutrients that become pollutant loads. Weighted averages of cropland use efficiency in the WCR are at 57% for N and 58% for P for model year 2000. Cost-saving reductions in fertilize use **by 40%** would not only save money and labor, but also and more importantly conserve invaluable ecosystems. Nothing could be more compelling as this win-win situation if agriculture is to be sustainable for food and planet.

Table 2.4 P runoff from both cropland and pastures, and N runoff from cropland are estimated for WCR watershed aggregated to sub-regional scale. Surplus N estimates are based on crop yield so that N runoff from pastures are not addressed.

Model year 2000	Cropland, km^2	Pastures, km^2	Cropland P runoff, tons	Pasture P runoff, tons	Total Surplus P runoff, 10^3 tons	Surplus N runoff, 10^3 tons
Sub-region I	1,634,238	1,740,175	473,284	35,792	514	9,978
Sub-region II	46,466	95,529	8,873	6,031	15	305
Sub-region III	134,096	924,159	49,931	45,031	95	1,140
Amazon basins (Bolivia, Ecuador, Peru)	51,655	333,868	10	10	21	**264**
Sub-region IV	2,549	4,223	1,504	343	2	**No data**
Sub-region V	76,431	58,836	13,176	7,398	21	321
WCR Total	**1,945,435**	**3,156,790**	**546,779**	**94,605**	**667**	**12,009**

2.3.2 Pesticide inputs

Together with fertilizers, chemicals that kill unwanted organisms such as herbicides to remove unwanted weeds, fungicides and bactericides to kill unwanted microbes, and insecticides to rid crops of insect pests, have been formulated and applied in WCR croplands with a focused goal to provide nurturing fields where crops could be grown at maximum rates. A similar cocktail of chemicals are used for livestock in the form mostly of antibiotics to manage disease and infections. For this report, a conscious effort is made to examine pesticide use in WCR croplands for which exists a 30 year data support from FAOSTAT to date. Figure 2.6 shows usage of total pesticides (kg/ha/yr) by country from 1990 to 2018 (FAOSTAT) in kg per cropland ha. Across the five WCR Sub-regions, the high usage rates by countries in all except Sub-region I, stand out. The last graph of Figure 2.6 shows an almost 80% increase in total volume of pesticides for all 22 countries, reaching 940,000 tons of total pesticides in 2018.

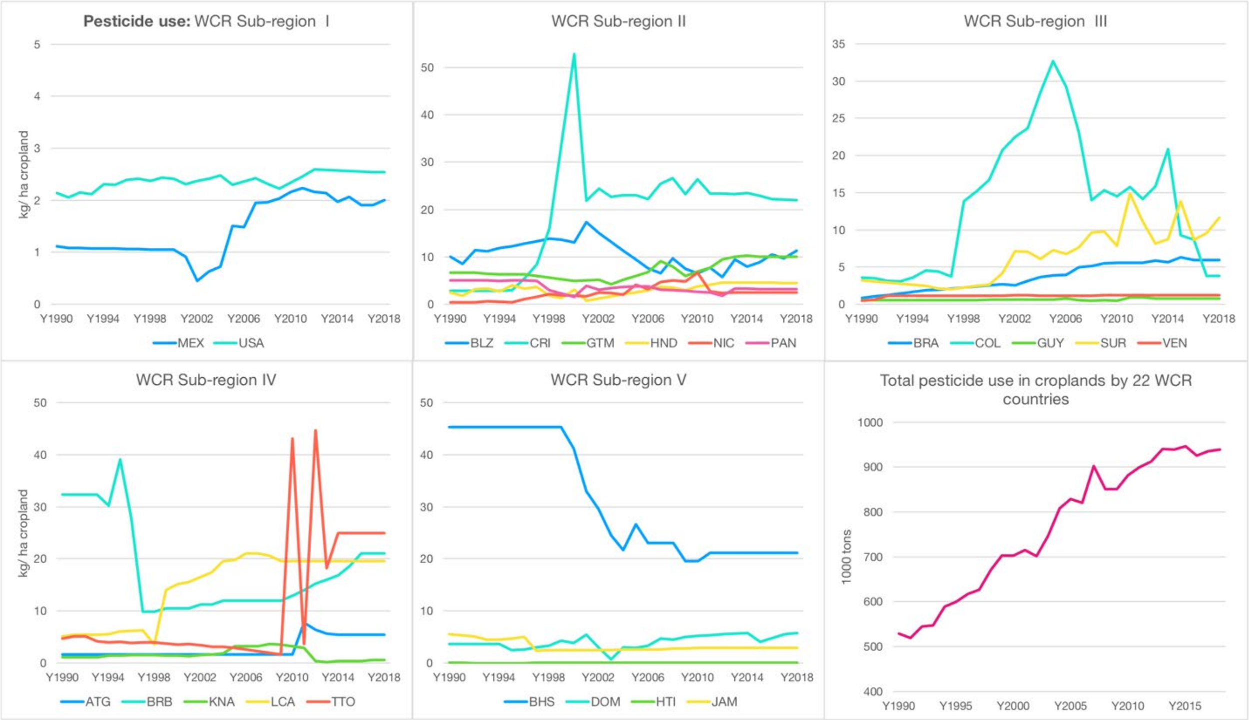


Figure 2.6 Total pesticide application rates (kg per ha cropland) for the period 1990 to 2018 are shown for 22 WCR continental and island states and territories with data in FAOSTAT (application rates at country scale). Last chart shows increasing usage over time across all croplands during reported period. Total pesticides are inclusive of herbicides, fungicides, bactericides, and insecticides.

The high per area usage rates among WCR countries especially small island states are further shown by Figure 2.7 which features the global top 10 country users, not for a single year, but averaged over the 28-year monitoring period. The top 10 pesticide users include the Bahamas (#1). Costa Rica (#2), Barbados (#3), Saint Lucia (#5), and Colombia (#7). In addition to high rates of application, FAO (2)19) reports that stockpiling of deteriorating and obsolete pesticide stocks occur. About 300 tons of these have been safely removed from eleven countries participating in Global Environment Facility (GEF) project on "The Disposal of Obsolete Pesticides including persistent organic pollutants (POPS), Promotion of Alternatives and Strengthening Pesticides Management in the Caribbean". This project which ran from 2016 to 2020 monitored discarded pesticide containers as serious threat in polluting food or water that are stored in these containers.

Table 2.5 shows the breakdown by country of use rates for 2000 and 2018 and total use in WCR-draining watershed croplands for model year 2000. A metric to allow a generic determination of pollutant loads based such as one based on pesticide input efficiency. This indicator is highly nuanced by hydrological and geophysical attributes of application sites, the life cycle of target species. To further complicate assessments for this indicator, legal requirements regarding dosage, manner of application, and environmental conditions during and after time of application, would need to be taken into account.

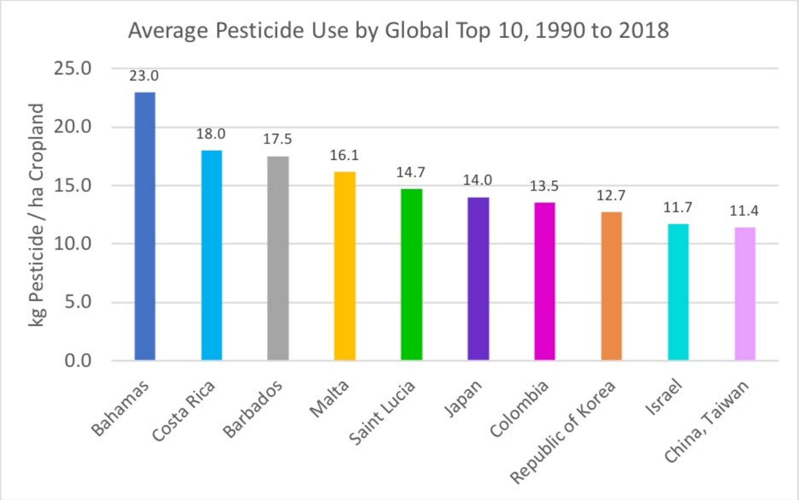


Figure 2.7 Top 10 countries with highest pesticide application rates averaged over the 28-year monitoring period from 1990. Five belong to the WCR region: The Bahamas (#1), Costa Rica (#2), Barbados (#3), Saint Lucia (#5), and Colombia (#7). Annual regional rate averages (as simple unweighted average across WCR countries each year) are plotted in Figure 2.5B. (Data: FAO ESS http://www.fao.org/faostat/en/#data/EP/visualize)

As such, for this report, the authors did not estimate pesticide flows to ecosystem compartments based on use efficiencies and pesticide inputs. Case studies below serve to show the transport and assimilation of pesticides in soil, atmosphere, water and sediments, and organisms, that underscore how insidious the consequences of pesticide use could be. It should be noted that existing public health standards usually regulate pesticide amounts relative to consumption of crops, but does not regulate pesticide impacts on ecosystem services such as impacts on soil health and farm workers' wellbeing.

Mendez et al (2018) documented the pathways for a herbicide (diuron), a nematicide (ethoprofos) and a fungicide (epoxiconazole), which are used in banana cultivation in Costa Rica. Diuron showed the highest transfer at 20% of annual emissions to downstream areas via runoff. All three pesticides occurred at similar or higher levels in soils and sediments than their concentrations in water. For all chemicals, their concentrations in the fruit were all below standards of the EU and US for Maximum Residue Limits (MRL). These standards protect banana consumers but do not provide any ecosystem protection of areas where bananas are grown, or for the farmers themselves who are at risk of chemical exposure.

The case of Guadaloupe shows the persistent nature of organochlorine (OC) pesticides in long-term contamination of terrestrial and aquatic ecosystems. OC pesticide use, Chlordecone in particular, was introduced in the island in the 1970s to control the banana weevil in monocrop banana farms in Guadeloupe. The chemical was banned in 1993, about 25 years to date. Coat et al (2011) examined trophic guilds to determine the contamination level of stream biota in relation to their trophic interactions. The study found a heavily contaminated food web including herbivores, detritivores, omnivores and carnivores, with OC levels among the highest so far detected for freshwater ecosystems – concentrations averaged 51 μg kg^{-1} wet weight for molluscs to 219 μg kg^{-1} for fish. River mouth plankton was found to be the most contaminated prey component in the stream and marine samples showed slightly lower chlordecone concentrations. Crabit et al. (2016) found that soil-to-river transport via groundwater was a major transfer pathway for chlordecone accounting for 2% of soil pesticide stocks. This study estimated that it would take at least 50 years to flush out the chemical accumulated in soils.

Table 2.5 Pesticide application rates among WCR continental and island states. Highlighted are among the highest reported rates of pesticides in the world with five countries in the region remaining among the top 10 pesticide users per ha of cropland in 2018 (FAO Statistics on Pesticides Use in Agriculture, 1990-2018). Last column of this table provides estimates of total pesticides in tons for croplands in the WCR draining watersheds of the region for Year 2000.

WCR Sub-region	Country/ Territory (Isocode-3-alpha)	Country/ Territory	Pesticide Application Rate (kg per ha cropland) (Y2000)	Pesticide application Rate (kg per ha cropland) (Y2018)	Cropland area in WCR watersheds (Y2000)	Total pesticides in WCR draining watersheds (tons, 2000)
I	MEX	Mexico	1.05	2.00	224,409	23,563
I	USA	United States	2.41	2.54	1,409,823	339,767
II	BLZ	Belize	13.09	11.34	1,218	1,594
II	CRI	Costa Rica	52.79	21.99	1,352	7,136
II	GTM	Guatemala	4.93	10.02	11,834	5,834
II	HND	Honduras	3.07	4.51	10,471	3,215
II	NIC	Nicaragua	1.83	2.47	21,080	3,858
II	PAN	Panama	1.58	3.20	512	81
III	BRA	Brazil	2.56	5.94	67,858	17,372
III	COL	Colombia	16.69	3.82	25,991	43,378
III	GUY	Guyana	0.61	0.76	5,120	312
III	SUR	Suriname	2.63	11.60	641	169
III	VEN	Venezuela	1.16	1.19	34,392	3,989
IV	ATG	Antigua & Barbuda	1.60	5.40	10	2
IV	BRB	Barbados	10.50	21.00	37	39
IV	KNA	Saint Kitts and Nevis	1.47	0.59	6	1
IV	LCA	Saint Lucia	15.19	19.60	20	30
IV	TTO	Trinidad and Tobago	3.50	24.91	1,416	496
V	BHS	Bahamas	41.18	21.17	861	3,544
V	DOM	Dominican Republic	3.86	5.74	16,166	6,240
V	HTI	Haiti	0.02	0.02	11,705	23
V	JAM	Jamaica	2.48	2.89	2,931	727

A systematic and comprehensive review of literature for pesticides in Central America and the Caribbean was published by UNEP in 2002. A more quantitative regional assessment is needed to determine strategic ways to establish ecological standards to guide the use of pesticides moving forward. Colin et al (2020) argue that insecticide use could be reduced by shifting the focus on how much is needed to kill an insect pest, to a mindset that asks how much is required to protect a crop and the ecosystems that allow it to grow in the first place. Banning is no longer effective as more novel insecticides are formulated that replace the banned chemicals. Low dose prophylactic applications can be sufficient in eliminating insect damage to crops while preventing build up that triggers resistant forms to evolve, all within an Integrated Pest Management approach including crop rotation and alternating treatment approaches. Lechenet et al (2017) showed that for commercial farms in France, low pesticide application and high crop productivity and high farm profitability were compatible among 77% of farms they studied. Reductions of 37, 47 and 60% of herbicide, fungicide and insecticide use, resp., were established as economically viable scenarios. Ramakrishnan et al (2019) underscore the solid science behind the impacts of pesticides on soil health, and the diversity and functioning of the soil microbiome that ultimately underpins the productivity of croplands. A failure to safeguard these ecosystem services, and a continuing disregard of the economic benefits of greatly reducing pesticide inputs, would put agriculture on a really untenable path of epic proportion.

2.4 Domestic wastewater and sewage

Wastewater is defined as used water that has been utilized for domestic (i.e. municipal), industrial and commercial purposes (Tuser 2020). Sewage is wastewater that goes through a sewer to deliver it to a wastewater treatment facility or to receiving water bodies. Wastewater also includes storm runoff that washes through built-up surfaces such as roads, parking lots and rooftops.

Wastewater consists of 99.9% water and 0.1% waste, which can contain organic matter, microorganisms and inorganic substances. Wastewater is further classified by source. Domestic wastewater is produced from restroom use, bathing, food preparation and laundry. Commercial wastewater is produced by businesses such as beauty salons, auto repair shops. Industrial wastewater is produced by industrial or commercial manufacturing processes, including agriculture.

In this report, watershed-scale parameters were used to estimate nutrient fluxes from untreated domestic wastewater. Unlike the SOCAR inventory which delimited a 100 km swath of coastal fringe for calculating wastewater, this study subsumes the entire watershed regardless of distance from shore. This means a higher population count for entire watersheds than residents living within 100-km coastal margins for similar model years. Thus, an aggregate watershed-scale population of 372,180,000 most likely released untreated sewage in the order of about 15 km^3 (1 $km^3 = 10^9 m^3$), containing 890,000 tons of N and 155,000 tons of P for model year 2010 (RNPRSAP Database, Linke et al. 2019) (Table 2.6). These values are conservative in that they exclude contributions from partially treated sewage when these are discharged at point sources such as sewage outfalls.

Unfortunately, untreated domestic wastewater and sewage are not just about adding to the nutrient load polluting surface and groundwater systems. Sewage contain disease vectors or pathogens. Figure 2.8 (upper panel) shows the increasing role of environmental factors (unsafe water, sanitation and handwashing) in causing diarrheal diseases in the region for the period 1990 to 2016. The lower panel indicates the rise of diseases such as Cholera, Rotaviral enteritis, and Enterotoxigenic E. coli infection as among the leading causes of death among children and persons of all ages (Global Burden of Disease Risk Factors collaborators, 2016). Vectors for these diseases are sewage pathogens.

Ramirez-Morales et al (2020) highlights another category of effluents contained in domestic wastewater. This study documented the occurrence of 70 pharmaceutical active compounds in wastewater treatment plants discharging to freshwater in Costa Rica and examined their ecotoxicity levels to aquatic test organisms and their phytotoxicity on plant and soil functions such as seed germination. Chemicals detected included antibiotics (36%), analgesics (21%), psychiatric drugs (15%), stimulants (6%), and lipid lowering drugs (6%). Twenty one of the detected pharmaceutically active compounds showed medium or high hazard levels in treatment plant effluents. Compounds considered most critical include risperidone, lovastatin, diphenhydramine, trimethoprim and fluoxetine in terms of environmental risk.

Table 2.6 Domestic wastewater estimates at watersheds aggregated to WCR sub-regions. Data coverage is at 99% of total watershed population. [Note: data for North Brazil has been corrected to include all watersheds draining to the North Brazil Shelf Large Marine Ecosystem (NBS LME), inclusive of Brazil's Legal Amazonia].

WCR Sub-region	Population in watershed area draining to WCR, 10^3 (2010)	2010 Untreated Wastewater released to environment 10^9 m^3/yr	10^3 tons TN in Untreated Wastewater (2010) (N = 60 g m^{-3})	10^3 tons TP in Untreated Wastewater (2010) (P = 10 g m^{-3})
Sub-region I	198,428	5.68	341	57
Sub-region II	20,262	0.81	48	8
Sub-region III	70,018	4.70	282	47
North Brazil Shelf LME	22,634	0.79	39	13
Amazon watersheds in BOL-ECU-PER[1]	19,298	0.34	20	3
Sub-region III Islands	102	0.004	0	0.04
Sub-region IV	3,014	0.18	11	2
Sub-region V	38,017	2.45	147	25
TOTAL	**372,180**	**15**	**890**	**155**

[1] Watersheds in Bolivia, Ecuador and Peru that are part of the Amazon River Basin.

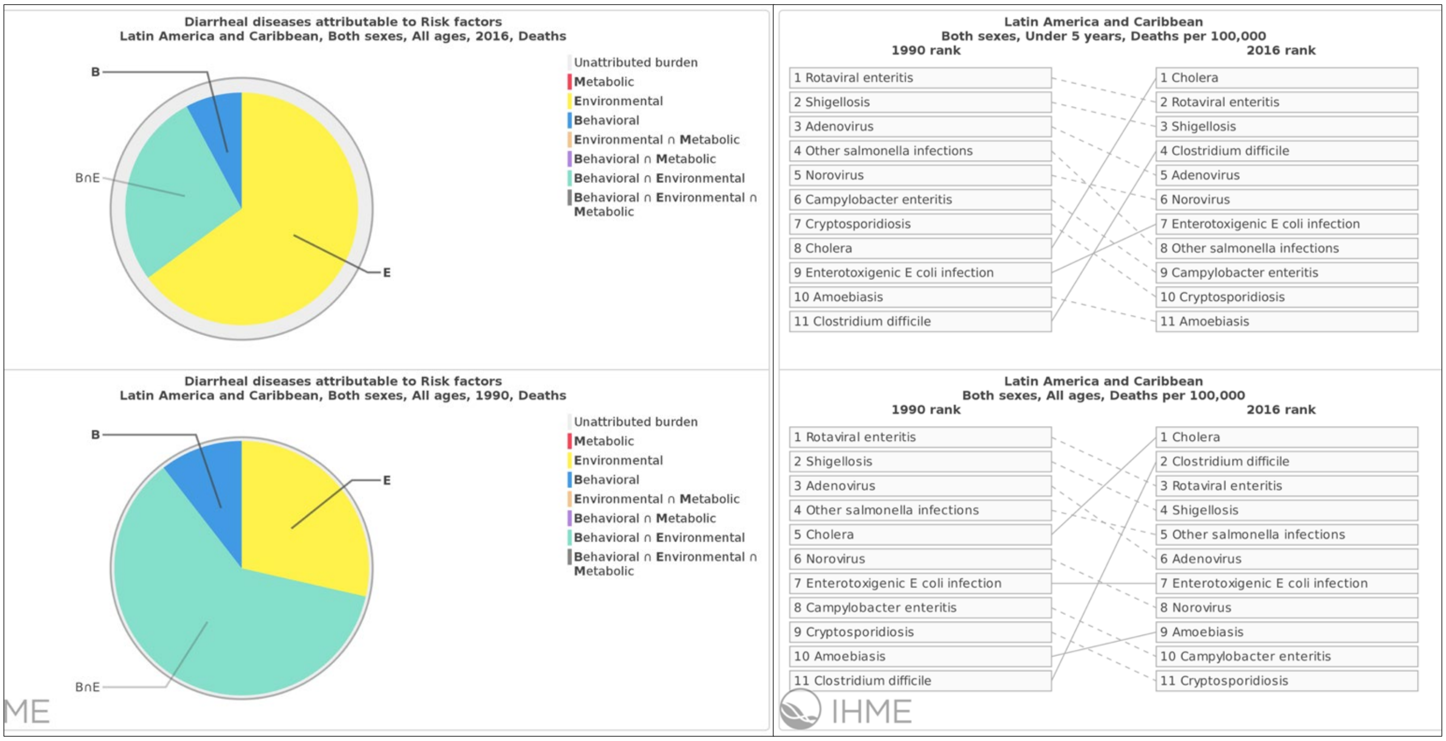


Figure 2.8 Left panel shows an increasing percentage of diarrheal diseases attributed to environmental risk factors (unsafe water, sanitation and handwashing) for the period 1990 to 2016 in Latin America and the Caribbean. Right panel shows that diseases caused by sewage pathogens such as Cholera, Rotaviral enteritis and Enterotoxigenic E. coli infection have risen in ranks as mortality factors over the same period. (Data source: https://vizhub.healthdata.org/gbd-compare/; GBD 2016 Risk factors collaborators, 2017)

An increasingly urbanizing population necessitates the provision of appropriate sewage and domestic wastewater treatment technology and infrastructure, which can remove nutrients and pathogens. Fuhrmeister et al. (2015) examined 108 low and middle income economies and analyzed scenarios of optimal improvement of sanitation to reduce nutrient and microbial pollution. They found that under the best technology scenario, there would still be 20-40% of pollutants remaining to be treated. A transformative approach to wastewater and sewage treatment needs to take place. Such would target household level needs not just for sewage connection but for innovative toilet technology that separates solid from liquid waste. It is worth noting that regulating nutrient compositions of household products such as phosphate content of detergents can help reduce wastewater pollution. Jamaica, as an example, adopted an environmental standard in 2012, allowing only up to a maximum of 5% phosphate content by weight for detergents (Chemical Watch 2012). At the treatment plant scale, the removal of pathogens must be maximized and nutrient and water recovery integrated in an overall circular nutrient and water economy, with complementary ecological and public health standards that guide the re-use of recovered material.

2.5 Urban (stormwater) runoff

To date, there is no systematic assessment of urban runoff for the WCR. The integrated models by Beusen et al (2015) and Mayorga et al. (2010) excluded urban runoff in the global modeling because urban surfaces in general have very limited spatial extent that could not be resolved with acceptable confidence levels using the standard 0.5° X 0.5° scale. Given the small spatial extents or urban surfaces, the appropriate hydrodynamic modeling scale would be at individual urbanized watersheds such as that used in the Stormwater Management Model (SWMM) (Choi and Ball, 2002). Recently, urban runoff models at the scale of 40 ha and that can quantify benefits of runoff reduction have been developed and are helping storm runoff managers to analyze the efficacy of mitigation actions so these can be widely applied (Beck et al 2017). Despite their small spatial extents, the high concentration of human population in urban extents, along with the increase in impervious substrates, can serve to amplify fluxes of nutrients and associated pollutants to coastal waters, and which can be detrimental to the blue economies of insular states and territories. National urban development agencies should provide periodic estimates of urban extents and explore materials that can be used for pavers that allow infiltration including the use of rain gardens and constructed wetlands to catch runoff.

2.6 Industrial point sources

2.6.1 Systematic Inventory for the period 1997 to 2008

A systematic inventory of industrial point sources of nutrient pollution covering the period 1997 to 2008 was implemented and published as the Caribbean Environment Programme Technical Report No. 52 (2010), a milestone document in examining land-based sources of marine pollution in the WCR. A country-scale tabulation of industrial point sources is included in this report as Annex 2.5, a sub-regional condensed form for which is shown in Table 2.7. Notable in this brief tabulation is the heavy oxygen demand of the effluents, and the high amount of total suspended solids. The levels of nitrogen and phosphorus are similar to estimated sewage discharge for NBS LME in 2000. As point sources, concentrated waste discharged persistently can create small areas of dead zones which may be colonized by microbes, essentially altering trophic relationships in these zones. A mechanism for updating industrial point sources every ten years just like population censuses needs to be in place to allow for both science and policy guidance to inform pollution management towards timely and effective nutrient pollution reduction. Further, the meaningful participation of industry is requisite to effectively reduce point sources.

Table 2.7 A sub-regional scale summary of industrial pollutant load in the WCR for the period 1997 to 2008 (CEP 2010).

Countries and territories	**Industrial pollutant load discharged in WCR (t / yr)**				
	BOD	**COD**	**TSS**	**TN**	**TP**
Sub-region I	196249	374072	504462	13410	2444
Sub-region II	9, 954	21807	5983	659	263
Sub-region III	34,288	69,498	86,647	10,768	674
Sub-region IV	197,062	353, 883	42,382	1,326	631
Sub-region V	52, 117	109, 328	8,525	1, 915	1,287
Total	**489,000**	**928,000**	**648,000**	**28,000**	**5,000**

2.6.2 Industrial and agricultural point sources of ammonia (NH_3)

In 2018, Van Damme et al. reported industrial and agricultural ammonia point sources using a high-resolution mapping of atmospheric ammonia measured daily over a nine-year period by a satellite-based Infrared Atmospheric Sounding Interferometer (IASI). This global data set of NH_3-emitting hotspots and regions was examined for relevant inventory for the WCR. Table 2.8 summarizes the combined ammonia emissions by country from identified hotspots in tons NH_3 per year. A full listing of hotspots are provided in Annex 2.6. Deposition of ammonia, through dry or wet deposition, has been shown to contribute to nitrogen loads leading to eutrophic aquatic systems (Sutton and Fowler, 2002; Erisman et al., 2008).

In the WCR, the emitting hotspots were classified as being agricultural (i.e. feed lots for intensive livestock farms), industrial (NH_3-based fertilizer plants, nickel-cobalt mines as in Cuba); or non-determinate (e.g. Mexico City). Ammonia emission fluxes in ton/yr from hotspots located in WCR watersheds for the period 2008-2016 are aggregated by country and provided in Table 2.8. The flux emissions were calculated by the authors based on a baseline NH_3 lifetime of 12 hours. Analyses of hourly and monthly changes in gaseous signatures underpinned the annual flux estimates. Aggregated over WCR country for spots that are located in WCR-draining watersheds, the total annual ammonia flux of almost 123,400 tons are of the same magnitude as domestic waste load for Sub-region III in 2000. Ammonia can also be deposited in the form of particulate aerosols, which can combine with acidic components turning it into airborne irritants before deposition.

Ammonia-emitting regions are included in the analyses of Van Damme et al. (2018). Because of the larger areas involved, a modelling approach of fate and transport of gaseous nitrogen rather than a simple inventory should be done in the future to better constraint estimates. None of the integrated models such as those by Beusen et al (2015, 2016) and Mayorga et al (2010) have included industrial point sources in the estimation of nutrient fluxes unlike domestic waste and sewage. The variable life spans of industrial facilities and the nuances in operation and technology are currently difficult to parameterize in models. Incorporating periodic inventories will help fill this gap so hybrid flux assessment approaches may need to be designed to integrate these critical sources of pollutants. Details on regions can be accessed directly from the accompanying supplemental material of the publication.

Table 2.8 Ammonia fluxes from point sources in the WCR for the period 2008 to 2018. (Input data: Van Damme et al. 2018).

Country	Ammonia Emission flux tons/yr						
	Hotspots	Agriculture	Hotspots	Industrial	Hotspots	Not classified	Total
Colombia	1	1,750	1	4,257			6,008
Cuba			2	4,176			
Mexico	10	42,511	3	5,406	1	6,388	54,305
USA	18	52,927	3	4,363			57,290
Trinidad and Tobago			1	1,009			1,009
Venezuela	1	2,304	2	4,668			6,972
Total	**30**	**99,492**	**12**	**23,879**	**1**	**6,388**	**123,371**

2.7 Sahara dust

Transport of dust over the Caribbean was first reported in the scientific literature in 1970 with dust collected in Barbados in 1967, and which was traced to an African dust storm (Prospero et al. 1970).

Interest on long-range transport of dust has been sustained since then because of its potential role in global biogeochemical cycles under the modulation of climate changes. In this report, information on the contribution of Sahara dust in nutrient dynamics and transport of associated microbes and chemicals is briefly synthesized.

Dust transport from North Africa to the Caribbean is an annual event with peaks in June-July. An estimated 210 Tg Fe reaches the Atlantic Ocean via dust transport (Jickells et al. 2005). Soluble iron is essential as a micronutrient that plays a critical role in controlling oceanic phytoplankton production, and which is insoluble in the presence of oxygen and at pH levels above 4 (Jickells et al. 2005). While Saharan aerosols contain less soluble iron than other aerosols, the sheer volume of transport makes Saharan dust the major source for oceanic production (Baker et al. 2006). The presence of acid pollutants mixed with Saharan dust may help explain the low amounts of soluble iron because of acid processing while dust is over the Sahara before its transport to the Atlantic (Ravelo-Perez et al. 2016). Saharan dust over the Amazon has been found to contribute soluble iron to the Amazon, boosting bioavailable concentrations to plant roots and leaves of the forest canopy (Rizzolo et al. 2017).

In addition to soluble iron, Sahara dust transports persistent organic contaminants including pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) (Garrison et al. 2014). Seven of 13 banned and currently used pesticides were found in the study including chlordanes, chlorpyrifos, dacthal, dieldrin, endosulfans, hexachlorobenzene and trifluralin.

There is great interest in examining microbiomes associated with Sahara dust. Among the bacterial taxa isolated were: Rhizobiales, Sphingomonadales, Geodermatophilaceae and Bacillaceae (Gonzalez-Toril et al, 2020).. Earlier investigations wanted to find *Aspergillus sydowii*, the fungal pathogen responsible for infections among sea fans known as aspergillosis in the Caribbean (Smith et al. 1996, Garrison et al. 2006). In 2008, identification of microbial colonies from dust samples to species level showed the presence of 7 species of *Aspergillu*s and the total absence of *A. sydowii (Rypien 2008)*. The unequivocal results called for identification of microbes to species level as generic identification would be highly insufficient to establish pathology of coral diseases.

2.8 Nutrient sources using integrated models

Inventories of nutrient sources have been presented in previous sections of this report. These include nutrient-use efficiency based calculations of agricultural nutrient runoff, domestic waste water and sewage contributions and emission fluxes from ammonia hot spots. In this section, the authors use the outputs of the Integrated Model to Assess the Global Environment – Global Nutrient Model (Image-GNM by Beusen et al. 2016); and the data set derived from the Global Nutrient Export from Watersheds 2 (NEWS 2) by Mayorga et al. (2010) to provide estimates of nutrient fluxes. The IMAGE GNM dataset provides hindcasting from 2000 to 1900, affording a century long view of changes in total nitrogen and total phosphorus loads and their sources from watersheds to the river mouths. Note that the parameters used individually in inventories, are also used in the IMAGE-Global Nutrient Model, as integrated components of biogeochemical processes (Figure 2.9). The interactions among these parameters are captured by the modelling framework, and are essential in constraining nutrient load estimates as net of retention, removals, and chemical species transformation, all taking place during transport. Often, the model estimates are lesser in absolute value but of similar order of magnitude to inventory-based estimates. To complement the IMAGE-GNM dataset, the Nutrient Export from Watersheds Model 2 (NEWS 2) data outputs provide a contemporaneous view of nutrients by chemical species (dissolved

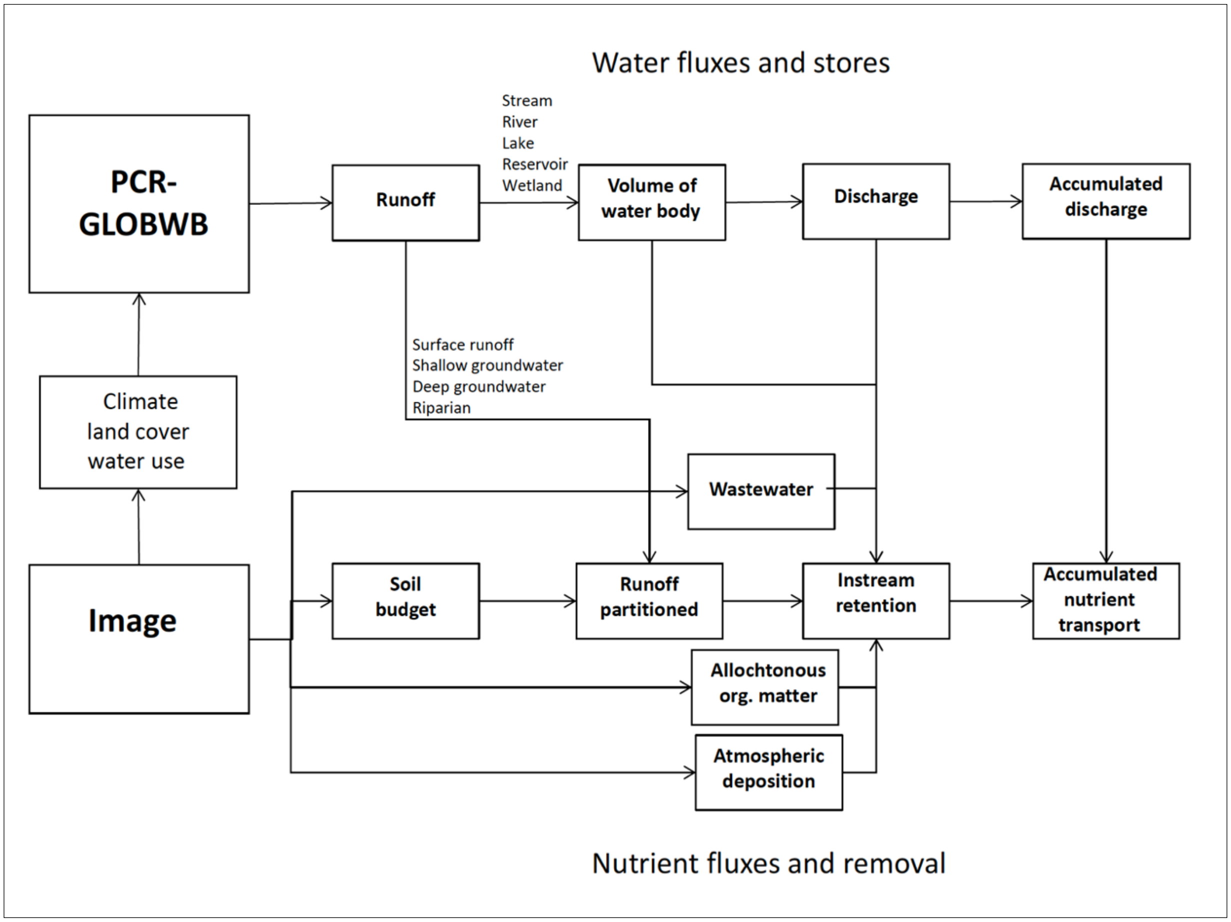


Figure 2.9 Model framework for estimating nutrient loads by source, net of retention and removal processes, and their accumulation to points of eventual discharge to coastal waters. Note the process-based parameters used in transporting nutrients via water. (Source: Beusen et al. 2015). PCR-GLOBWB (PCRaster Global Water Balance); IMAGE (Integrated Model to Assess the Global Environment).

inorganic and organic nutrients, and their particulate forms) and allows the computation of a nutrient index of eutrophication potential based on dissolved nutrient flows and their ratios. The IMAGE GNM data set resolved a total of 470 WCR basins and the NEWS model provided data for 261 WCR basins. Both datasets are contained in the RNPRSAP Database V3.0, and salient results are summarized here.

Model results from the IMAGE-GNM Model have been reported in the SOCAR report (UNEP CEP, 2019). These are featured in this report to complement the changes in land use and cover attributes discussed in the previous sections, and to round up a coherent body of evidence that nutrient flows at contemporaneous magnitudes pose a serious threat to ecosystems in the WCR. As previously indicated, this report expands the spatial domain of the WCR to include the watersheds that drain to the North Brazil Shelf Large Marine Ecosystem (NBS LME). It should be noted that global models cover all resolvable space at standard global grid size of 0.5°, and which empirical monitoring will never match. As such, they can be used to identify potential hot spots which can become the focus of targeted empirical monitoring programmes and subsequent mitigation measures.

Sources of nitrogen in a watershed can be anthropogenic in origin such as: atmospheric deposition of gaseous N forms such as N_2O from fossil fuels, and NH_3 from industrial or intensive agricultural activity (Van Damme et al. 2018), fertilizer runoff via surface waters and through groundwater; domestic wastewater and sewage point sources, and aquaculture facilities. Natural sources include vegetation in floodplains, natural surface runoff (i.e. non-agricultural), and flows from non-agricultural groundwater systems. In model year 2000, a total of 5.5 Tg (1 Tg = 1 million tons) of nitrogen were received by watersheds in Sub-regions I to V, in addition to 8.4 Tg N received in NBS LME catchments (Table 2.9). Sixty percent of N fluxes to the WCR sub-regions came from agricultural sources (40% from groundwater in agricultural lands, 20% from farmland surface runoff (Figure 2.10A), with another 9% coming from sewage. In stark contrast, the forested watersheds of the NBS LME show the dominance of natural N sources including floodplain vegetation contributing 65%, and natural groundwater, 28% (Figure 2.10C). Across all five subregions , agricultural sources, both surface and groundwater, dominate (Figure 2.10B). In Sub-region V, the influence of sewage as N source is significant at 24%. Figure 2.10D shows the nitrogen loads discharged at river mouths: offloaded nitrogen in NBSLME increased by a mere 4% over a century given the tight biogeochemical cycling that forests and associated soil microbiomes perform. In contrast the aggregate discharged N load for the sub-regions increased by 70% over the same time frame.

For phosphorus, the highly modified state of watersheds with farms and pastures in sub-regions I to V, occupying 50% of watershed area on aggregate, explains why surface runoff from agricultural lands account for 56% of total P sources amounting to 0.6 Tg in model year 2000 (Figure 2.11A, Table 2.10). The same trend is evident at sub-regional scale except in the case of Sub-region IV where weathering contributes the most (Figure 2.11B). In NBS LME watersheds, the dominant source of phosphorus is floodplain vegetation at 63% (Figure 2.11C). Discharged P loads among urbanized watersheds of sub-regions I to V increased by 42% over a 100-year period; those emptying to the NBS LME increased in load by 11%.

Figure 2.12 gives a spatially explicit view of how nutrient sources changed in influence over time. Groundwater in agricultural lands is a contemporaneous major source of nitrogen pollution along with domestic waste point sources as populations increase. In the case of phosphorus, agricultural surface runoff contributes the most along with sewage. It should be noted that discharged loads of both nitrogen and phosphorus are less than the corresponding estimated sums of nutrient sources because of retention along banks and river mouths. Retention mechanisms for nitrogen include denitrification, deposition and plant uptake, all of which contribute to maintain water quality for downstream systems including coastal waters. When retention mechanisms are exceeded by increasingly heavier fluxes, then a cascade of ecosystem responses are triggered that lead to consequential changes in ecosystem health. It is important to note that continued deposition creates a pool known as **legacy nutrients** which can prolong and sustain periods of eutrophication and pose serious challenges to medium-term mitigation (Chen et al, 2018). Legacy nitrogen, in particular, needs to be well defined in terms of age and partitioned by source, such as soil or groundwater, to appropriately set mitigation targets. In the case of the Mississippi River Basin (MRB), Van Meter et al (2016), established that significant N loading above baseline levels was underway before the widespread use of N fertilizers, and driven by forest and grassland conversion to agricultural row croplands in the mid-19th century. About 85% of present-day annual N loads in the MRB are contributed by soil legacies, older than 1 year of age (from time of deposition/application in the catchment to loading at catchment outlet), of which more than half come from man-made sources since 1960. These findings have serious implications on mitigation. Short-term targets for the MRB should couple the increased utility of constructed wetlands to filter agricultural surface runoff on the short-term, with medium- to long-term reduction of N fertilizers, and a redesign of tile drainage networks to impede transport of surface runoff. The impacts of increasing nutrient load are discussed in Chapter 3.

Table 2.9 Sources of Nitrogen loads (in 1000 tons N) for WCR Sub-regions I to V excluding North Brazil LME, and which is separately shown. Values and percentages refer to regions in Column 1. (Input data: Beusen et al. 2016.)

Nitrogen Sources (Model Year 2000)	**Atmospheric deposition**	**Vegetation in floodplains**	**Surface runoff (agriculture)**	**Surface runoff (natural)**	**Groundwater (agriculture)**	**Groundwater (natural)**	**Sewage**	**Aquaculture**	**All sources**
SR I-V (1000 tons)	58	749	1,083	64	2,195	799	509	10	5,468
SR I-V (%)	1%	14%	20%	1%	40%	15%	9%	0%	100%
NBS LME	22	5494	180	95	211	2384	23	0	8,411
NBS LME (%)	0%	65%	2%	1%	3%	28%	0%	0%	100%

Table 2.10 Sources of Phosphorus loads (1000 tons in model year 2000 for WCR sub-regions I to V, excluding the North Brazil Shelf (NBS) LME which is separately shown. (Input data: Beusen et al. 2016.)

Phosphorus Sources (Model Year 2000)	**Weathering**	**Vegetation in floodplain**	**Surface runoff agriculture**	**Surface runoff natural**	**Sewage**	**Aquaculture**	**All sources**
SR I-V (1000 tons)	120	62	339	20	66	1	608
SR I-V (%)	20%	10%	56%	3%	11%	0%	100%
NBS LME (1000 tons)	180	458	23	59	3	0	723
NBS LME (%)	25%	63%	8%	3%	0%	0%	100%

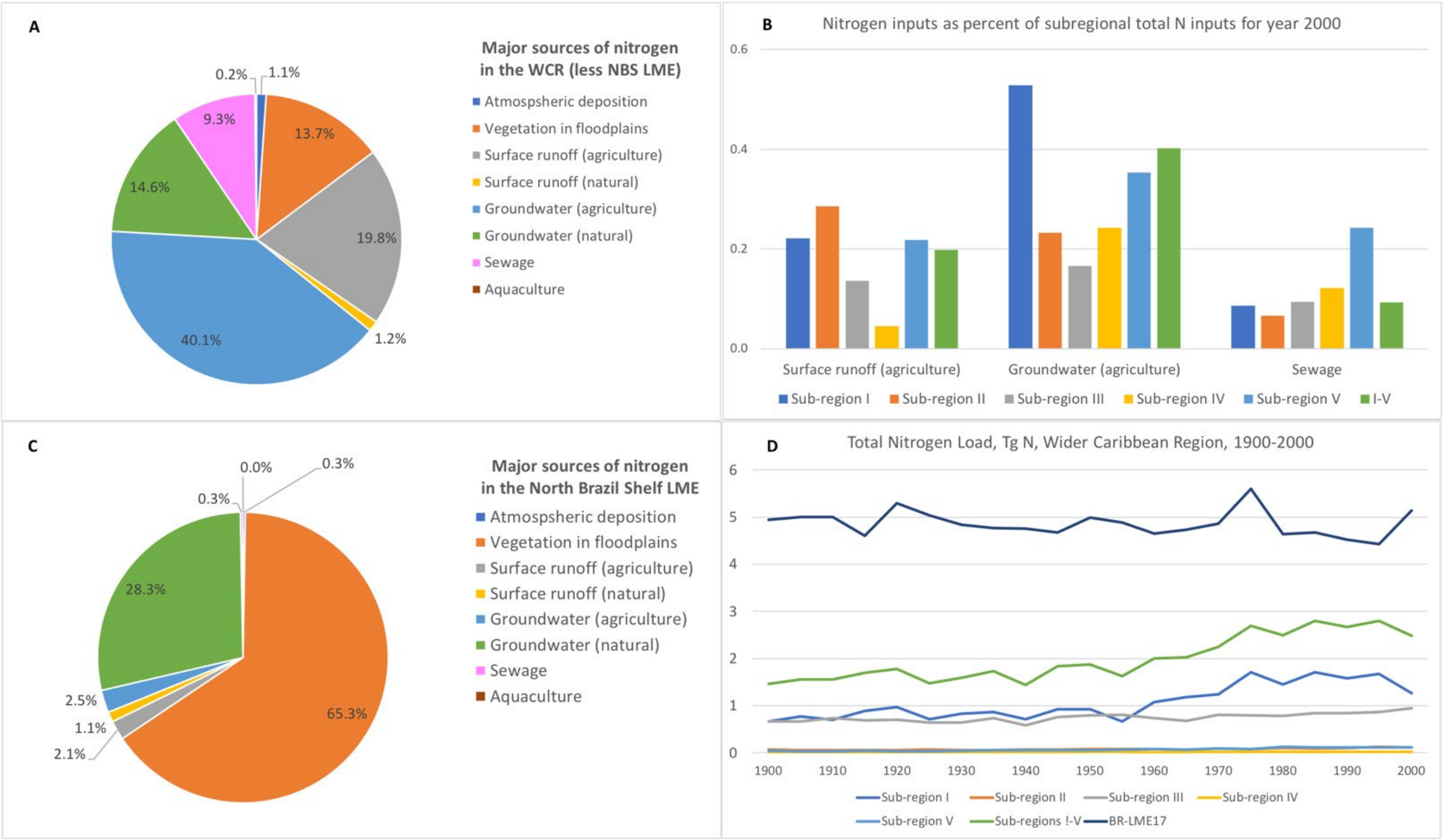


Figure 2.10 (A) Nitrogen sources for aggregated sub-regions I to V (excluding NBS LME.; (B) Nitrogen loads by source by WCR sub-region for model year 2000 as percent of sub-regional total N loads; (C) Nitrogen load by source in the North Brazil Shelf (NBS)LME; Items A-C are for model year 2000; and (D) Total nitrogen load discharged at river mouths in the WCR from 1900 to 2000.

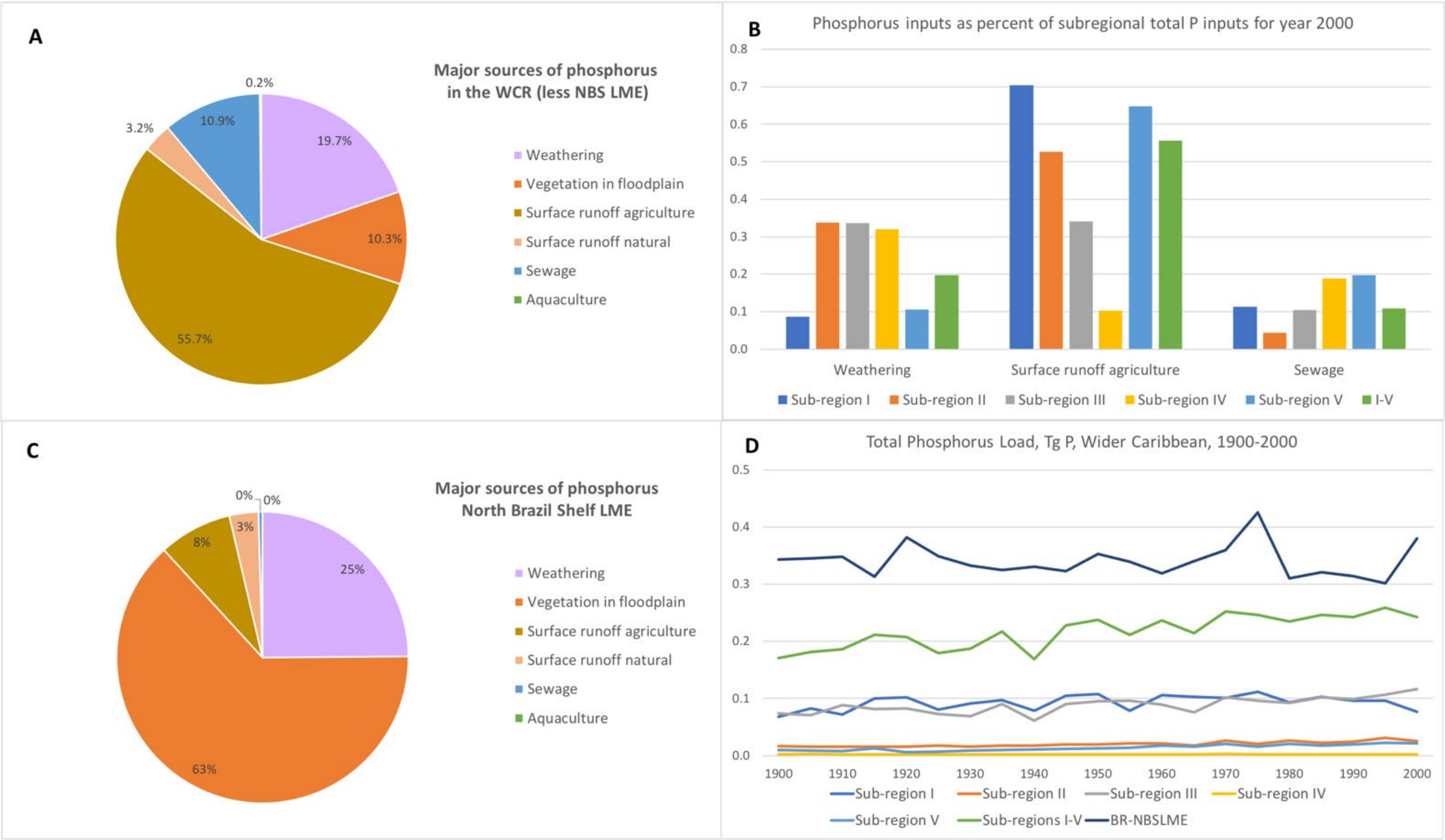


Figure 2.11 (A). P loads by source for aggregated total load for Sub-regions I to V (less NBS LME.; (B) P loads by source as percent of sub-regional total P loads; (C). P loads by source in the NBS LME; Items A - C are for model year 2000. (D). Total phosphorus load (Tg N) discharged at river mouths in the WCR from 1900 to 2000. (Input data: Beusen et al. 2016).

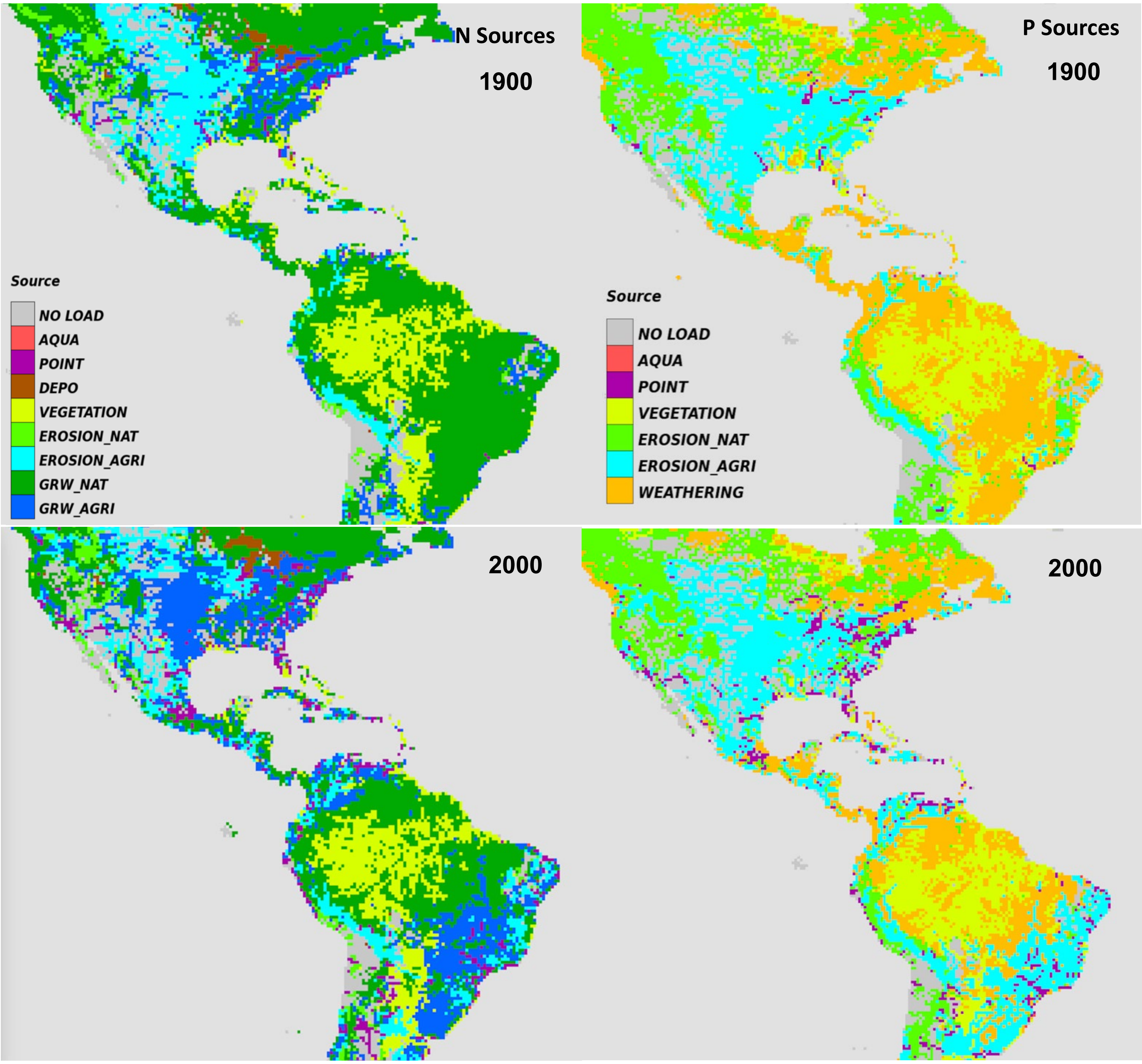


Figure 2.12 Nutrient loads from sources in 1900 and 2000. Nitrogen loads from groundwater in agricultural areas (dark blue) and from domestic wastewater point sources (purple) increased dramatically over a century. In the case of phosphorus, increases in agricultural runoff (aqua) along with domestic point sources (purple) are evident. (Source: Beusen et al. 2016)

2.9 Total Suspended Solids (TSS)

In addition to nutrients and pathogens, a third major component of material deliveries from the watershed are total suspended solids (TSS), both organic and inorganic forms, and are larger than 2 microns in size. They consist of floating particles derived from sediment, silt, sand, plankton and algae. Their presence determine the visual water clarity of water, and influences the extent to which light can penetrate and fuel photosynthesis in coastal receiving basins. Equally important, they also indicate the degree of erosivity of land areas in the watershed, a process which needs to be managed to minimize soil loss and nutrient deficiency and promote better water clarity for coastal waters. TSS standards are difficult to establish as TSS mass-based measurements are highly nuanced by watershed and stream network and riverine features and processes.

The Global NEWS data set provides estimates of TSS for 262 WCR basins that were resolved at 0.5° X 0.5° resolution. Twenty three catchments had yields of or more than 1000 tons km^{-2} yr^{-1} (Figure 2.13). These included catchments in Central America, in the islands of Hispaniola (Haiti and Dominican Republic) and Jamaica, and in Colombia and Mexico. TSS yield values in tons km^{-2} yr^{-1} for 262 basins are shown in Annex 2.7. A first point to highlight is that basins with significantly moderate to wide forest extents have medium to low TSS yield. TSS yields are highest where deforestation rates and conversion to agricultural land are high. As such, TSS mobilization as an erosion indicator is bad for both ends of the pipe and may be best addressed at source by implementing soil management practices including cover crops, and non-tillage farming. The best of these would be the total protection of forest lands and riparian buffer zones.

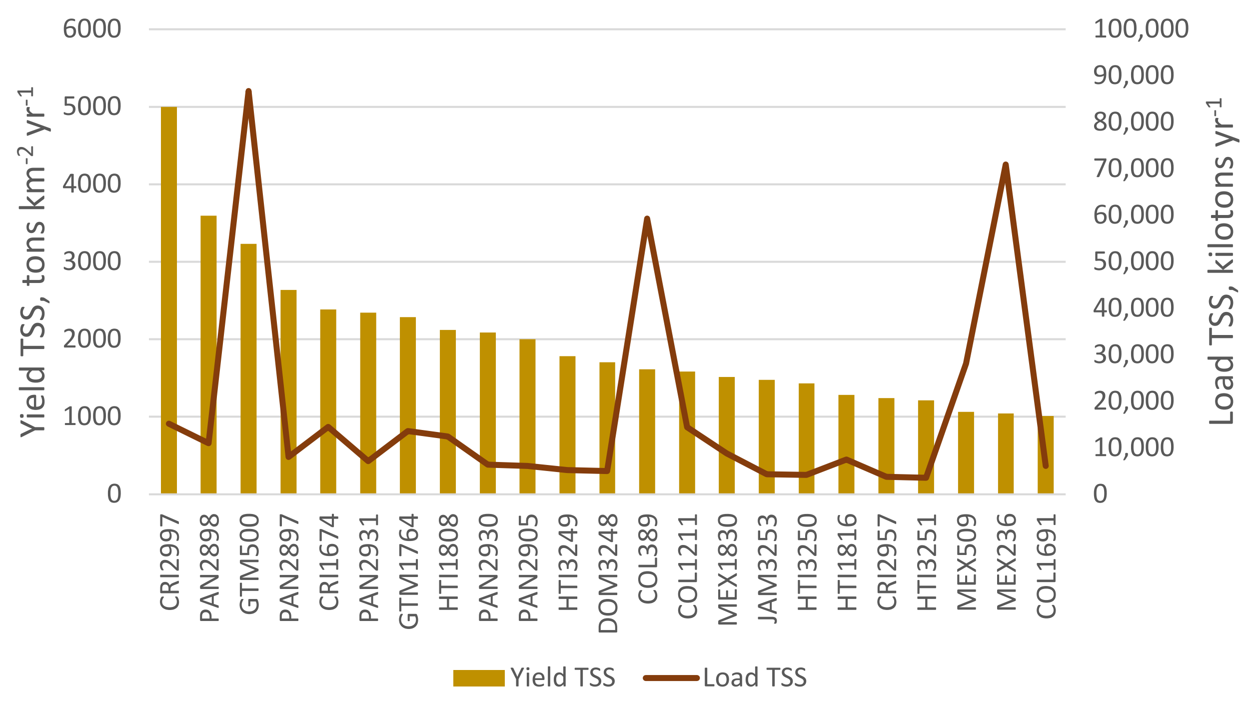


Figure 2.13 WCR Catchments with the highest yields of TSS. Basin names are Country ISO Code followed by Basin Number in the Global NEWS data set. CRI Costa Rica, PAN Panama, GTM Guatemala, HTI Haiti, DOM Dominican Republic, COL Colombia, MEX Mexico, JAM Jamaica. Included in the top 23 are 7 insular catchments (5 in Haiti, 1 each in Jamaica and Dominican Republic); 10 catchments in Central America, 3 in Colombia and 3 in Mexico.

2.10 Marine sources of nutrient pollution

While agriculture is the singular human activity that has altered ecosystems and nutrient regimes in terrestrial, freshwater and coastal environments, activities at sea including marine tourism and shipping have the potential to add significant nutrient loads. Periodic and comprehensive assessments of these sources are needed to better inform the development of appropriate regulations on nutrient pollution reduction, as well as those relevant to other waste streams (solid and plastic waste, air pollutants, among others). at national and regional scales. It is worth noting that the MARPOL Convention declared the Wider

Caribbean Region as a Special Area under MARPOL Annex V (Prevention of Pollution by Garbage from Ships) in 1991, and to take into effect on May 1, 2011, but not for MARPOL Annex IV (Prevention of Pollution by Sewage from Ships). A consideration of the MARPOL Special Area Status of the WCR should be considered in light of the extent of stressors from marine sources of nutrient pollution. The Baltic Sea was adopted by MARPOL as the first Annex IV Special Area in 2013, and a similar status for the WCR should be considered by MARPOL member states of the WCR.

2.10.1 Cruise tourism

The Wider Caribbean Region accounts for a third of global cruise tourism which by far, is the most lucrative form of tourism sub-sector to date with revenues amounting to US$ 40 billion in 2016 (Honey 2016, 2019). Cruise passengers to the WCR numbered 24 million in 2016, while stay over visitors reached 29 million (Honey 2019). Over 30 Caribbean island nations are cruise destinations to mega-ships, each averaging 3000 passengers and 500 crew, hence the term “floating cities” (Figure 2.14).

The cruise industry utilizes a business model that is underpinned by a legal loophole – the flag of convenience. Registered in countries under whose flags the cruise ships sail but with hardly any clout to enforce labor, financial or environmental regulations, cruise liners have almost total wherewithal to establish business practices which maximize profit above all. Cruise lines contain onshore spending onboard the ship or in company owned private islands, keep labor costs low by paying sub-minimum wages, avoid taxes, and skirt environmental and safety regulations. Economic impact studies have shown that stay-over tourism generates up to 7X the revenues a host country earns from being a cruise destination (Honey 2016).

In 2008, the US Environmental Protection Agency released its findings on cruise ship- generated waste streams including sewage, graywater, oily bilge water, solid waste and hazardous waste; including a thorough analysis of mitigating technology and existing international and US laws that regulate discharges in US territorial waters or their transport to US ports.

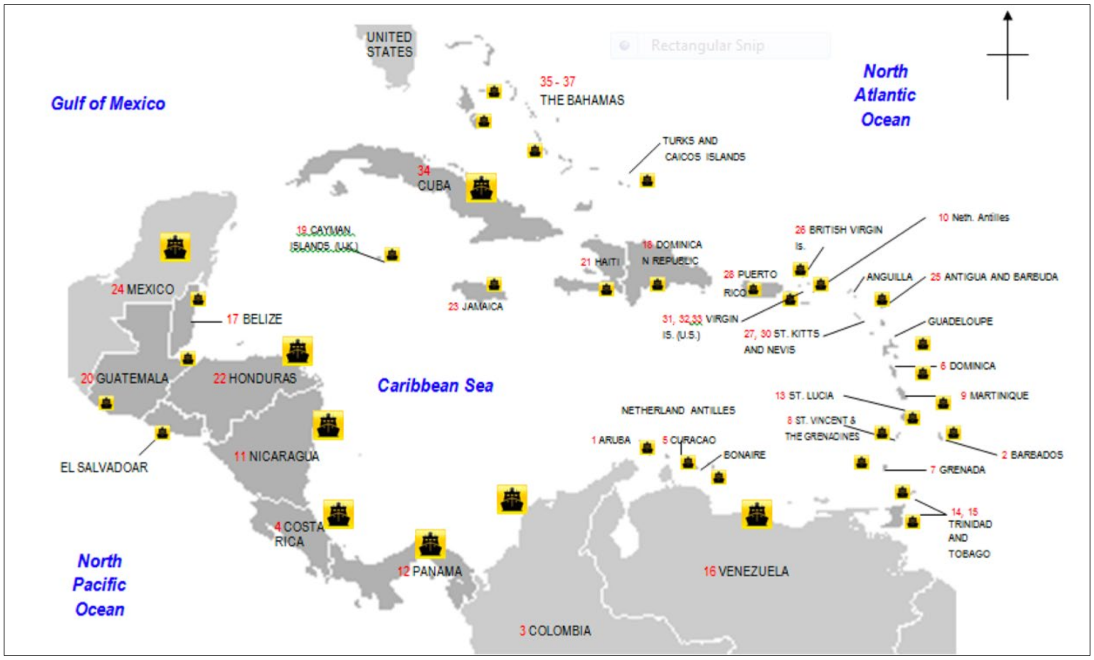


Figure 2.14 Cruise ports in the Wider Caribbean. Ports in the US and Brazil are not included (ACS Directorate for Sustainable Tourism, 2016). [draft]

Table 2.11 Waste streams generated by cruise ships (US EPA 2008)

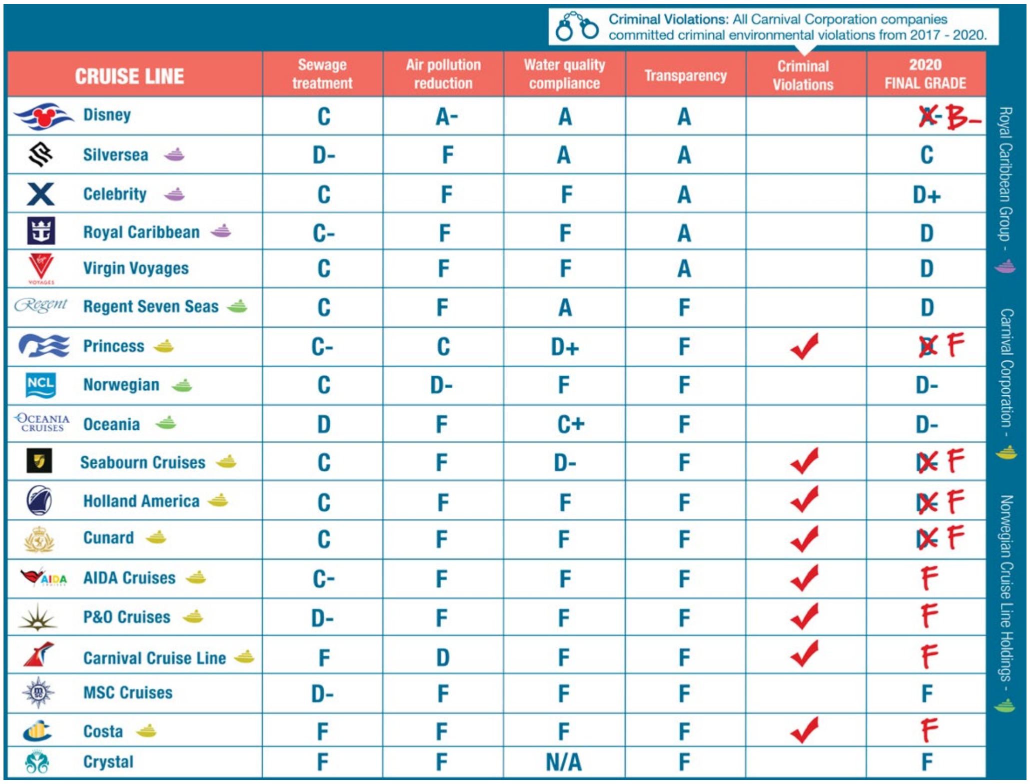
Waste Stream	Average Waste Production rate per cruise ship per day	Average Production rate per person per day	MARPOL (International Convention for the Prevention of Pollution from Ships)
Sewage (black water)	21,000 gallons	8.4 gallons	Discharge prohibited unless is discharging comminuted and disinfected sewage of more than 3 nm from nearest land; or is discharging sewage which is not comminuted or disinfected at a distance of more than 12 nm from the nearest land
Graywater (wastewater from sinks, baths, showers, laundry and galleys)	170,000 gallons	67 gallons	MARPOL Annex 4
Oily Bilge Water	2640 gallons (max for 2700-3200 passenger capacity		MARPOL Annex I, Regulations for the Prevention of Pollution by Oil
Solid waste	(Royal Caribbean Cruises, per vessel per week): 60 cubic meters of dunnage 5 cubic meters of glass 2.5 cubic meters of cans 12 cubic meters of food waste	7.7 lbs/person/day	MARPOL Annex V; also requires governments to ensure the provision of port reception facilities for solid waste
Hazardous Waste (solid waste with hazardous constituents)	(Royal Caribbean Cruises, 17 vessels): - Photo waste: 1300 gallons/week - medical waste: 80 lbs/ week - batteries: 580 lbs/ week -spent paint and thinners: 225 gallons/week		Hazardous if its appears on 4 hazardous waste lists (F-List, K-List, P-List, or U-List) or has one of four hazardous features (ignitability, corrosivity, reactivity, or toxicity); Hazardous substances are stored on board and should be disposed of in port reception facilities following port country AND MARPOL standards.

In the WCR, no systematic assessment of cruise vessel waste generation has been done. Neither is a periodic reporting of waste generated, discharge or held for disposal in receiving port facilities being practiced as part of a cruise line's permit to operate in international waters or in a nation's respective exclusive economic zone. The Friends of the Earth (FOE), a non-governmental environmental organization produces a periodic report card on cruise ships. In 2020, the FOE evaluated 18 major cruise lines with 112 cruise ships plying with Caribbean itineraries (FOE 2020) (Figure 2.15). The ships and companies were rated with letter grades based on:

1) Sewage treatment: Rating checks If a cruise line has installed the most advanced sewage and graywater treatment systems available instead of discharging minimally treated sewage directly at sea.
2) Air pollution reduction: Rating determines if a cruise line has retrofitted its ships to "plug in" to available shoreside electrical grids instead of running polluting engines when docked. Or uses the lowest sulfur fuel worldwide or both.

3) Water quality compliance. Evaluation is referenced to water pollution standards aimed at protecting the Alaskan coastal waters. Ships get an “F” if they use scrubber system since these generate toxic water effluent.

4) Transparency. Cruise lines and vessels get high marks if they respond to FOE’s requests for information on environmental practices.



Criminal Violations: All Carnival Corporation companies committed criminal environmental violations from 2017 - 2020.

CRUISE LINE	Sewage treatment	Air pollution reduction	Water quality compliance	Transparency	Criminal Violations	2020 FINAL GRADE
Disney	C	A-	A	A		~~A-~~ B-
Silversea	D-	F	A	A		C
Celebrity	C	F	F	A		D+
Royal Caribbean	C-	F	F	A		D
Virgin Voyages	C	F	F	A		D
Regent Seven Seas	C	F	A	F		D
Princess	C-	C	D+	F	✓	~~D~~ F
Norwegian	C	D-	F	F		D-
Oceania	D	F	C+	F		D-
Seabourn Cruises	C	F	D-	F	✓	~~D-~~ F
Holland America	C	F	F	F	✓	~~D-~~ F
Cunard	C	F	F	F	✓	~~D-~~ F
AIDA Cruises	C-	F	F	F	✓	F
P&O Cruises	D-	F	F	F	✓	F
Carnival Cruise Line	F	D	F	F	✓	F
MSC Cruises	D-	F	F	F		F
Costa	F	F	F	F	✓	F
Crystal	F	F	N/A	F		F

Royal Caribbean Group -
Carnival Corporation -
Norwegian Cruise Line Holdings -

Figure 2.15 Year 2020 Report Card for 18 Cruise lines evaluated by the Friends of the Earth accompanied by details available at the FOE website. (Source: *https://foe.org/projects/cruise-ships/?issue=335*)

The average passenger capacity of cruise vessels in the WCR is 3890, a median of 3660 and a range of 260 to 9000. A systematic assessment of the nutrient, pathogen, heavy metal effluents (among others) of both black- and graywater waste streams can be assessed with core information on the functionality of on-board waste treatment technology, disposal rates at reception facilities at ports-of-call along each cruise itinerary; onboard storage capacity volumes, georeferenced locations of disposal sites, and composition by volume of discharged waste. The assessment should include an examination of all waste streams and ecosystem impacts, not just those that contribute to nutrient pollution.

On the issue of nutrient wastes, both sewage and graywater, the US EPA analyzed existing technology alternatives which cruise lines can employ to treat these waste streams:

1) In traditional Type II Marine Sanitation Devices (MSDs), sewage is treated using biological treatment and chlorination, or maceration and chlorination. The biological-treatment-

chlorination MSDs combination work in similar fashion as land-based biological treatment of municipal waste (Figure 2.16). Cruise ships install up to four systems, to allow for off-line maintenance at given period of operation.

US EPA (2008) examined the efficacy of this technology in treating sewage and in meeting effluent standards. The results indicate that:

a) 43% of samples examined for fecal coliform met the MSD standard of 200 fecal coliform per 100 ml;
b) 32% of samples evaluated for total suspended solids (TSS) were compliant with the MSD standard of 150 mg/ liter
c) Only 1 sewage sample out of 70 met both the fecal coliform and TSS standards
d) Average ammonia concentration in effluent was 145 mg Ammonia Nitrogen/ liter in 100% of samples, and was an order magnitude greater than average values for untreated domestic wastewater at 12-50 mg Ammonia-N/ liter.

As such, the efficacy of Type II MSDs in treating cruise ship sewage and graywater effluents is non-compliant with existing standards as they contain significant amounts of fecal pathogens and nutrients above standard limits.

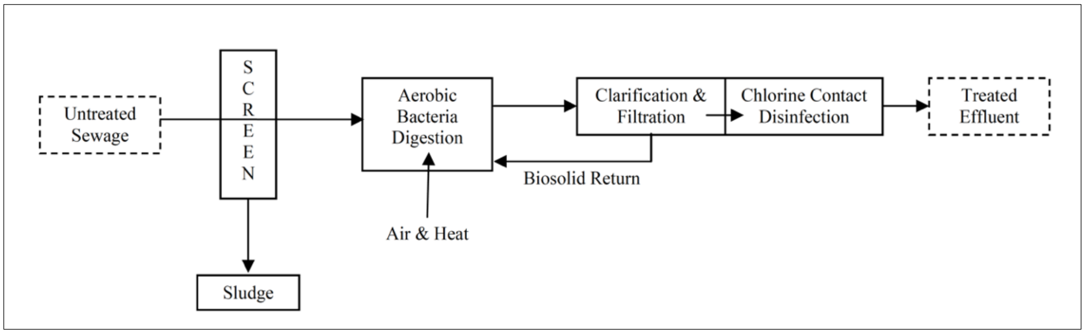


Figure 2.16 Ship effluent treatment using Type II Marine Sanitation Device using biological treatment and chlorination disinfection. (Source: US EPA, 2008)

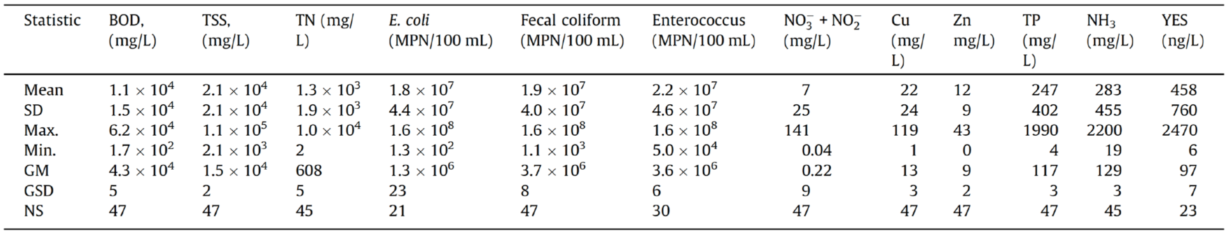
2) An alternate treatment technology is called Advanced Wastewater Treatment Systems (AWTs). This include improved screening, biological treatment, solid separation through filtration or floatation, and UV disinfection. Technology advancements in each step of the sewage treatment can improve efficacy and compliance. The US EPA analysis (2008) from cruise ships operating in Alaska showed that AWTs are effective in removing pathogens, substances that require oxygen to metabolize, suspended solids, oil and grease and particulate metals. AWTs achieve moderate nutrient removals, largely as a result of uptake by microbes in the bioreactors (US EPA 2008). Ammonia was not removed by nitrification as indicated by the unchanged levels in nitrate and nitrite concentrations. As such, even with the use of AWTs, nutrients specifically ammonia-nitrogen remained in excess, in both ionized (NH_4^+) and unionized (NH_3) forms. Unionized ammonia is the more toxic form, depending on abiotic factors (pH, temperature and salinity) that strongly influence the toxicity level for impacted organisms.

3) The US EPA reported on additional technologies that AWT's can combine to address the treatment of nutrients can only be removed by tertiary level treatment plants on land. At the time of the report, the technologies examined have not been tested on cruise ships for efficacy in treating nutrient waste. The use of these technologies would require testing of appropriate infrastructure and material design under specified operating conditions, including training and certification of technical personnel. These nutrient- reducing technologies include: a) ammonia removal by biological nitrification; b) total nitrogen removal by ion exchange; and c) phosphorus removal by chemical precipitation.

In a seminal paper, Avellaneda et al (2011) examined the relative risk attendant to several alternatives for the disposal of biosolids by cruise ships. Biosolids are sedimented residuals formed by onboard treatment of wastewaters, and which includes sewage and graywater. The study included a sampling programme through which 47 samples from 32 different cruise ships equipped with AWT system were obtained, and which were sent for analysis to laboratories certified in testing solid waste like biosolids following EPA protocols. Components include: biological oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN), *Escherichia coli,* fecal coliform (Fecal C.), enterococci (Entero.), nitrite/nitrate (NO_2/NO_3) copper (CU), zinc (Zn), total phosphorus (TP), ammonia (NH_3), Yeast Estrogen Screen (YES) and *Cryptosporirium parvum* (a microbial pathogen). Table 2.12 shows the component concentrations of the biosolid samples ever measured and published. This empirical data set on concentrations by component underpinned the modeling of waste loads and of disposal scenarios in the study. Estimated ocean loading as model outcomes assuming continuous discharges by all operational cruise ships over a 3 month model period with 61 discharge sites in the model domain, is shown in Figure 2.17. The model results visualized the spread and extent of discharges with dilution during transport, with an assumption of no decay of the diluted biosolids.

Avellaneda et al (2011) evaluated four loading scenarios: (1) discharge of biosolids in potentially shallow/ sensitive waters; (2) discharge in deep waters; (3) onboard incineration, and (4) land disposal. For each disposal scenario, public health and ecological risks were evaluated (Table 2.13). The model outcomes indicate that deep water disposal and incineration present the two best options with lower risks both for public health and ecosystems. These would require subsequent research to establish the carbon footprint of these options, and the operational guidelines in the case of deep-water disposal to ensure its implementation will not create adverse deep sea ecological impacts and that such will be covered by appropriate regulations through environmental monitoring and compliance by appropriate bodies.

Table 2.12 Measured concentrations of components found in biosolids generated by cruise ships and associated statistics (mean, standard deviation (SD), maximum value (MAX), minimum value (MIN), geometric mean (GM), geometric standard deviation (GSD), and number of samples (NS). (Source: Avellaneda et al. 2011)



Statistic	BOD, (mg/L)	TSS, (mg/L)	TN (mg/L)	*E. coli* (MPN/100 mL)	Fecal coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	$NO_3^- + NO_2^-$ (mg/L)	Cu (mg/L)	Zn mg/L)	TP (mg/L)	NH_3 (mg/L)	YES (ng/L)
Mean	1.1×10^4	2.1×10^4	1.3×10^3	1.8×10^7	1.9×10^7	2.2×10^7	7	22	12	247	283	458
SD	1.5×10^4	2.1×10^4	1.9×10^3	4.4×10^7	4.0×10^7	4.6×10^7	25	24	9	402	455	760
Max.	6.2×10^4	1.1×10^5	1.0×10^4	1.6×10^8	1.6×10^8	1.6×10^8	141	119	43	1990	2200	2470
Min.	1.7×10^2	2.1×10^3	2	1.3×10^2	1.1×10^3	5.0×10^4	0.04	1	0	4	19	6
GM	4.3×10^4	1.5×10^4	608	1.3×10^6	3.7×10^6	3.6×10^6	0.22	13	9	117	129	97
GSD	5	2	5	23	8	6	9	3	2	3	3	7
NS	47	47	45	21	47	30	47	47	47	47	45	23

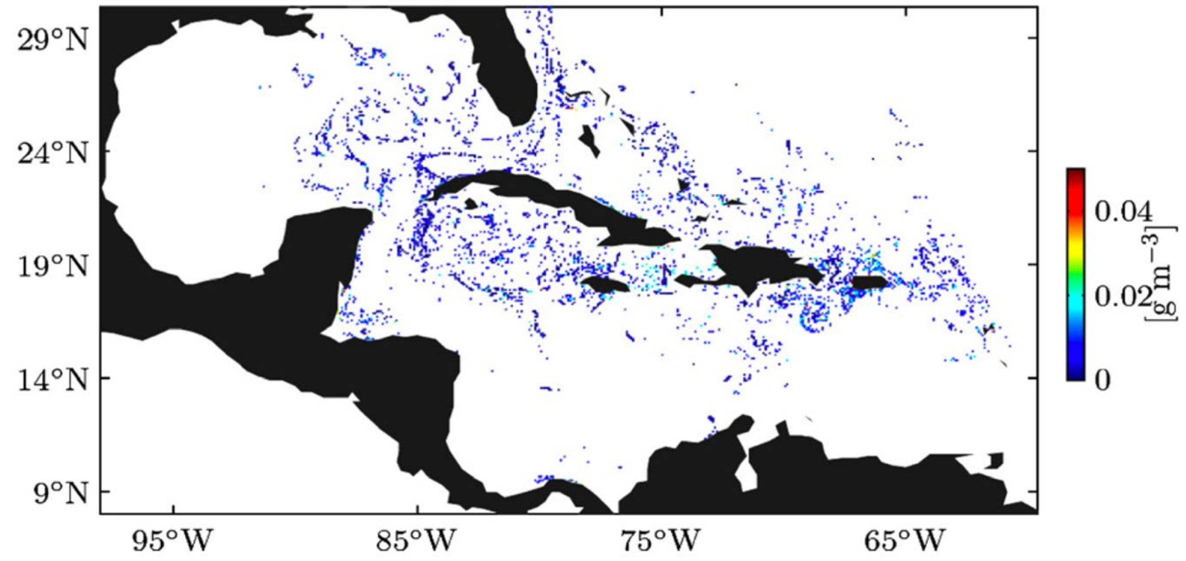
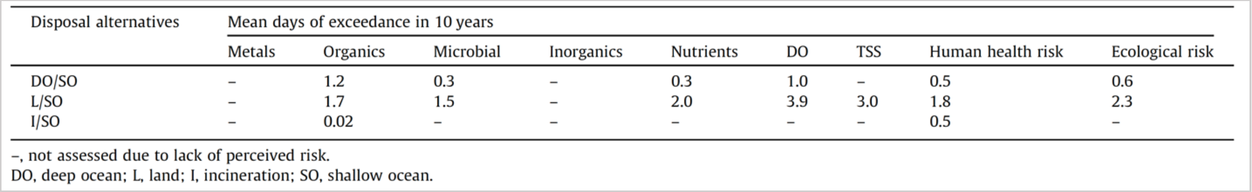


Figure 2.17 Estimated dry biosolids concentrations resulting from an assumed 3-month period of continuous discharges from all cruise lines in operation at the time of study, assuming no decay. Model conditions: 50 kg/m^3 day, or 5% of wet biosolids. (Source: Avellaneda et al. 2011).

Table 2.13 Relative risk indicators for the different disposal alternatives (Source: Avellaneda et al. 2011).



Disposal alternatives	Mean days of exceedance in 10 years								
	Metals	Organics	Microbial	Inorganics	Nutrients	DO	TSS	Human health risk	Ecological risk
DO/SO	–	1.2	0.3	–	0.3	1.0	–	0.5	0.6
L/SO	–	1.7	1.5	–	2.0	3.9	3.0	1.8	2.3
I/SO	–	0.02	–	–	–	–	–	0.5	–

–, not assessed due to lack of perceived risk.
DO, deep ocean; L, land; I, incineration; SO, shallow ocean.

Notwithstanding progress in terms of onboard wastewater treatment technology, a strategic change in changing the cruise tourism business model is critical. The most disruptive transformation that can happen to open the way for a clean and just cruising, if at all possible, is one that closes the flag of convenience loophole, an anomaly that has enabled cruise line companies in the last 50 years to externalize environmental, economic and social costs so that profit is maximized and enabled by countries that act as flags of convenience, including some in the Caribbean region. The MARPOL regulatory framework, like most environmental standards, must internalize the protection of ecosystem functioning, including the connectivity in space and time of physical and biological processes that determine the fate and transport of materials and biota. At the supranational and national levels, environmental standards at their core must ensure the conservation of water and benthic quality, and biodiversity and food webs, in order to sustain ecosystem services that underpin a blue economy, for the long-term. Regulations must, in addition, also address the social and economic asymmetries that the cruise industry has long practiced. Small island nations in particular, must proactively participate in cruise tourism only if this helps them safeguard their ocean ecosystems which comprise the base of their ocean economies.

2.10.2 Yachting tourism

Unlike stay-over or cruise tourism, the yachting sector is less studied because of the more individualized sailing activities and support requirements of yachters (also called cruisers or boaters). The yachting sector can be further disaggregated into a number of segments: charters, short-term visitors (day cruises to 6-month long stays), long-term visitors (live aboards and second-home owners) and luxury yachts (Honey 2016b). The sector's development in the last 30 years is driven by two factors: the US economy and hurricanes (Honey 2016b). Yachting depends largely on the presence of marinas and boatyards to provide the support services (berth rental, boat charters, utility services, sale of fuel, food and restaurant services, chandlery, storage, and repairs) and coastal infrastructure that yachting requires (Phillips 2014, Honey 2016). By year 2015, the number of marinas in insular Caribbean has grown to 140 facilities with a total berth capacity of 9300, and which enjoys 70 to 100% occupancy during the peak sailing season from July to December (Table 2.14).

For eight island member states of the Eastern Caribbean Currency Union (ECCU) (*Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines*), data on tourism visitor types including yacht passengers are made freely available and accessible at the website of the Eastern Caribbean Central Bank (https://www.eccb-centralbank.org/statistics/tourisms/comparative-report). Over a 20-year period, yacht passengers took a downturn during the recession in the late 2000, and has steadily increased from 115,000 in 2000 to at 192,000 in 2019, a gain of 66% (Figure 2.18). In comparison, over the same period, cruise tourism more than doubled (121% increase), accounting for 68% of the tourist population in the ECCU region. From 2000 to 2019, yacht passengers consistently accounted for 4% of total tourists in the Eastern Caribbean.

Honey (2016b) compared the daily and total expenditures of tourist types using year 1999 data for Antigua and Barbuda (Table 2.15). Yachters contributed US$ 13.43 million compared to $9.17 million by cruise ship tourists with the boating population being a tenth of the cruise ship visitor population size. Stay-over visitors who stayed in hotels and ate in restaurants contributed over 90% of tourism revenues in Antigua and Barbuda for the study year.

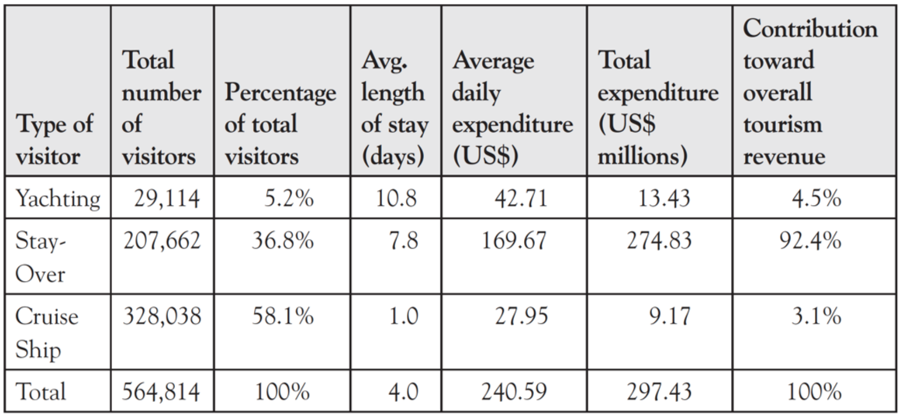
Talaue-McManus et al (2008) examined the winter (n=140) and summer (n=78) boaters in the Bahamas in 2004, including their perceptions on marine protected areas, spending patterns, nutrient waste generation and disposal, and potential ways to mitigate nutrient pollution. Twenty percent of all boater offloaded their liquid waste at marinas, 46% kept this in holding tanks before discharging to the sea, and 36% directly disposed at sea. Boaters contributed 56 tons TN or 4% of estimated tonnage of TN discharged in Bahamian waters in 2004, including those from residents and land-based tourists (Figure 2.19). Considering that over 80% of boaters directly discharged their liquid waste to coastal waters, resulting concentrations of diluted but untreated liquid waste ranging from 1 to 20 µM of nitrogen-ammonia, could prove deleterious to coral reef health (LaPointe 1992, 1993; Sealy 2004, Collins 2006, Talaue-McManus et al. 2008). To mitigate this practice, a simple model was used to determine the cost and feasibility of installing pump-out facilities along boating routes, on the assumption that the pumped out liquid waste could eventually be treated in a land-based wastewater treatment plant to produce less deleterious nutrient effluent (Brooks 2004, Talaue-McManus et al. 2008) (Figure 2.20).

Table 2.14 Distribution of marinas and berth capacity in insular Caribbean for year 2015. (Source: Birkhoff, 2015)

Country	Country 3-letter ISO Code	Number of Marinas	Number of Berths
Anguilla	AIA	11	113
Antigua and Barbuda	ATG	9	340
Aruba	ABW	3	125
Bahamas	BHS	10	845
Barbados	BRB	2	100
Bonaire	BES	3	100

British Virgin Islands	VGB	5	462
Cayman Islands	CYM	2	85
Cuba	CUB	9	786
Curacao	CUW	1	128
Dominica	DMA	2	0
Dominican Republic	DOM	7	878
Grenada	GRD	11	407
Guadeloupe	GLP	2	200
Jamaica	JAM	7	182
Martinique	MTQ	6	1,178
Puerto Rico	PRI	4	458
Saint Barthelemy	BLM	1	152
Saint Eustatius	BES	1	0
Saint Kitts and Nevis	KNA	1	36
Saint Lucia	LUC	2	293
Saint Martin/ Sint Maarten	MAF/SXM	13	1,020
Saint Vincent and the Grenadines	VCT	7	30
Suriname	SUR	1	15
Trinidad and Tobago	TTO	2	108
Turks and Caicos Islands	TCA	2	0
US Virgin Islands	VIR	11	842
TOTAL		**140**	**9,303**

Table 2.15 A comparison of economic contribution by tourism sector (Honey 2016).



Type of visitor	Total number of visitors	Percentage of total visitors	Avg. length of stay (days)	Average daily expenditure (US$)	Total expenditure (US$ millions)	Contribution toward overall tourism revenue
Yachting	29,114	5.2%	10.8	42.71	13.43	4.5%
Stay-Over	207,662	36.8%	7.8	169.67	274.83	92.4%
Cruise Ship	328,038	58.1%	1.0	27.95	9.17	3.1%
Total	564,814	100%	4.0	240.59	297.43	100%

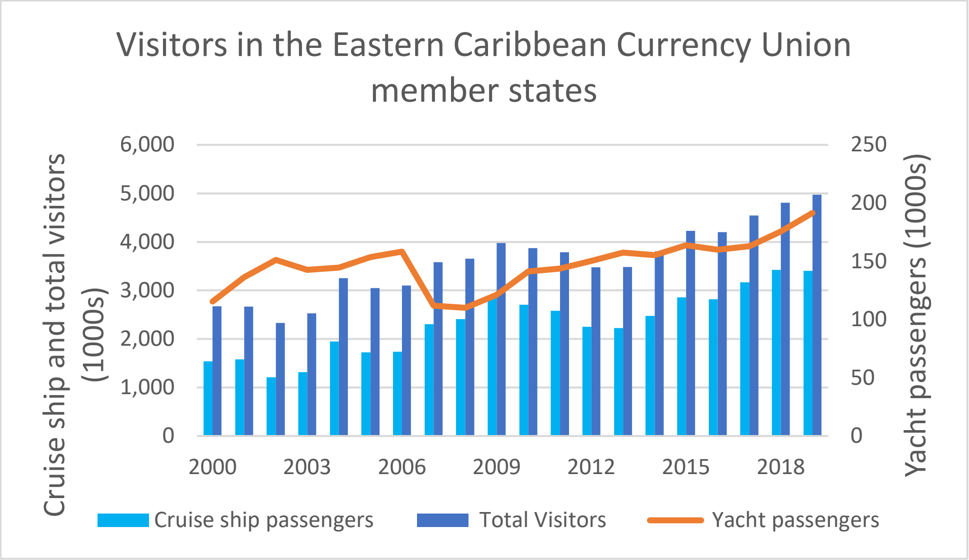
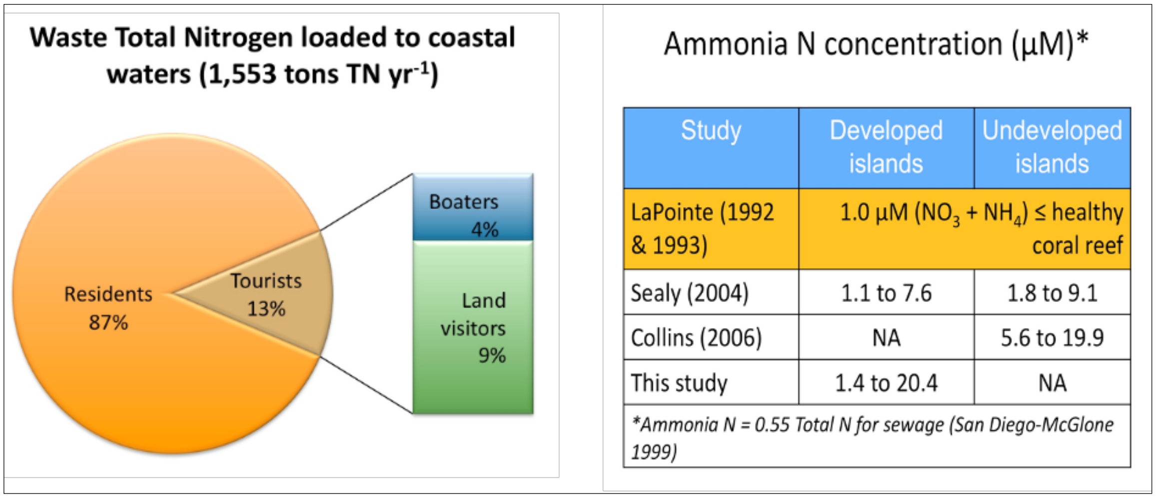


Figure 2.18 Yacht passengers, cruise ship and total visitors summed across Eastern Caribbean Currency Union member states: Anguilla, Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines. (Source of input data: https://www.eccb-centralbank.org)



Ammonia N concentration (µM)*

Study	Developed islands	Undeveloped islands
LaPointe (1992 & 1993)	1.0 µM (NO_3 + NH_4) ≤ healthy coral reef	
Sealy (2004)	1.1 to 7.6	1.8 to 9.1
Collins (2006)	NA	5.6 to 19.9
This study	1.4 to 20.4	NA

**Ammonia N = 0.55 Total N for sewage (San Diego-McGlone 1999)*

Figure 2.19 Estimated waste total nitrogen loaded by tourists and residents in the Bahamas for model year 2004. Yachters, both winter and summer boaters, discharged 4% of waste total N loading, equivalent to o 56 tons TN per year (Talaue-McManus et al. 2008).

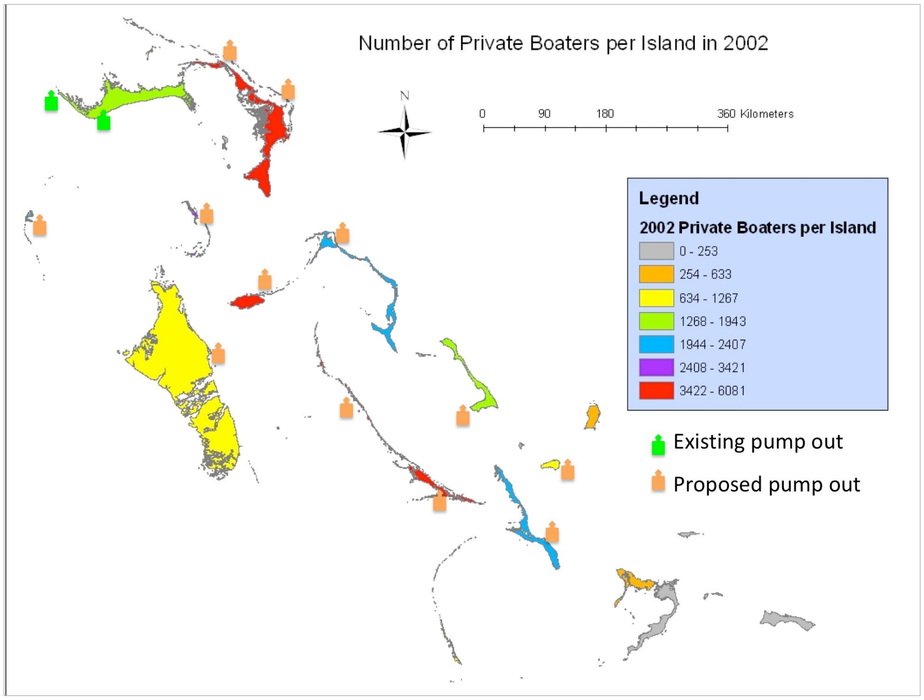


Figure 2.20 Modeled distribution of pump out stations to meet the liquid waste disposal needs of the yachting population in the Bahamas in 2002 and in the near-term (Brooks 2004; Talaue-McManus et al. 2008).

Making yachting more environmentally compliant can best be achieved by willful collaboration among boaters, marinas and government. Boaters can align their behavior toward the conservation of the natural assets they enjoy. Greening one's boating experience through the use of wind and/or solar power, installing gadgets such as portable or composting toilets, or Marine Sanitation Devices (MSD) (Types I or III), and mapping out appropriate sites for discharge while cognizant of no-discharge zones, are individual steps boaters can take. Port states need to channel boating and broader tourism revenues into proper siting and design of marinas, and providing port waste reception facilities including having functional wastewater treatment plants to deal with resident and tourist waste. In insular Caribbean, the latter remains a major challenge because of expensive capital outlay and maintenance, and which may best be addressed by innovative public-private partnerships. Though the environmental footprint of boaters remain small compared to large cruise vessels, their access to shallow seascapes for discharging wastewater can impact coastal waters significantly if these effluents, on aggregate, become chronic and unmitigated, despite dilution effects.

2.10.3 Cargo and oil shipping

Shipping dominates the measured ocean economy of the Wider Caribbean Region, contributing 76%, with parameters mostly assessed for island states and territories in 2012 (Patil 2016). About US$311 billion worth of container goods passed through the region in 2012, accounting for 8% of the global container ship volume (Figure 2.21). The exchange of shipped cargo and growing use of containers is facilitated by hub ports that specialize in transshipment or ship-to-ship transfers (Rodrigue and Ashar 2016). These hubs are located within a transshipment "triangle", "funnel", "corridor" . In anticipation of the deployment of post-Panamax cargo ships, it is projected that the transshipment services in the Caribbean may grow though the details as to what the increased container throughput would entail for mainline, feeder and transshipment port operations, is nuanced by every port's capacity to play the efficiency card with agility (Sanchez and Wilmsmeier 2009).

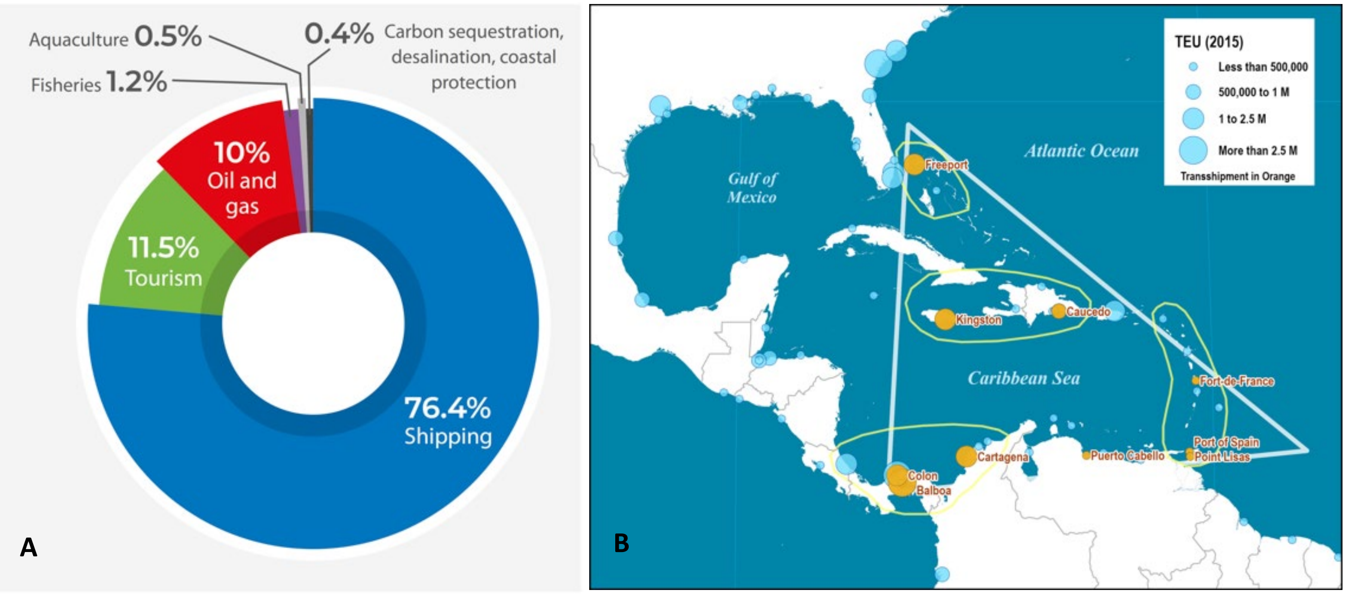


Figure 2.21 A. Ocean economy of mainly insular Caribbean dominated by shipping. B. The Caribbean transshipment triangle with hub ports define the entry of goods to the Caribbean basin. The main hub (transshipment) ports are shown as orange circles. (Sources: Heileman and Talaue-McManus (2019); https://porteconomicsmanagement.org/pemp/contents/part1/ports-and-container-shipping/container-port-traffic-transshipment-traffic-caribbean-basin/

Pinnock and Ajaguna (2012) classify Caribbean ports based on the roles they perform in a globalized shipping network. How these roles will evolve in response to the post-Panama Canal Expansion will determine the economic growth and the corresponding environmental footprint of shipping in the Caribbean.

Figure 2.22 shows the 16-year trends in growth of the container throughput in terms of the twenty foot equivalent units (TEU, a standard cargo volume) for the (A) Wider Caribbean Region (less the USA), and (B) Insular Caribbean. The regional volume is driven by expansion in Mexico and the transshipment hubs, posting a 70% growth from 2000 to 2016 (Figure 2.19). Over the same period, insular Caribbean which accounts for 1/7 of the regional volume, grew by 50%, largely reflecting the growth of insular transshipment hub ports in Jamaica, Bahamas, Dominican Republic and in Trinidad and Tobago. However, indications of saturation among island state ports because of the state of port infrastructure and lack of equipment including cranes, and integrated information technology systems have strongly limited growth in the post-economic recession in the first decade of the 21st century (Caribbean Development Bank, 2016).

Even with the challenges small island ports face for space and modernization, shipping in the WCR for cargo and oil transport are predicted to increase, both in average vessel size for those that will call in global hubs, and in overall vessel traffic to deal with increase in traded goods arriving through containers.

Table 2.16 Classification of Caribbean ports based on the roles they perform within the global shipping network (Pinnock and Ajagunna 2012).

Port	Countries	Global Hub	Sub-Regional Hub	Service/Feeder
Kingston Container Terminal	Jamaica	●		
Freeport	Bahamas	●		
Manzanillo	Panama	●		
Colon	Panama	●		
Caucedo	Dominican Republic	●		
Cartagena	Colombia	●		
Port of Spain	Trinidad		✳	
Point Lisas	Trinidad		✳	
Kingston Wharves	Jamaica		✳	
Bridgetown	Barbados			⊕
Rio Haina	Dominican Republic			⊕
Puerto Plata	Dominican Republic			⊕
La Romana	Dominican Republic			⊕
Boca Chica	Dominican Republic			⊕
Georgetown	Cayman Islands			⊕
St. John	Antigua and Barbuda			⊕
Castries	Saint Lucia			⊕
Vieux Fort	Saint Lucia			⊕
George Town	Guyana			⊕
Havana	Cuba			⊕
Willemstad	Curacao			⊕
Point-A-Pitre	Guadeloupe			⊕

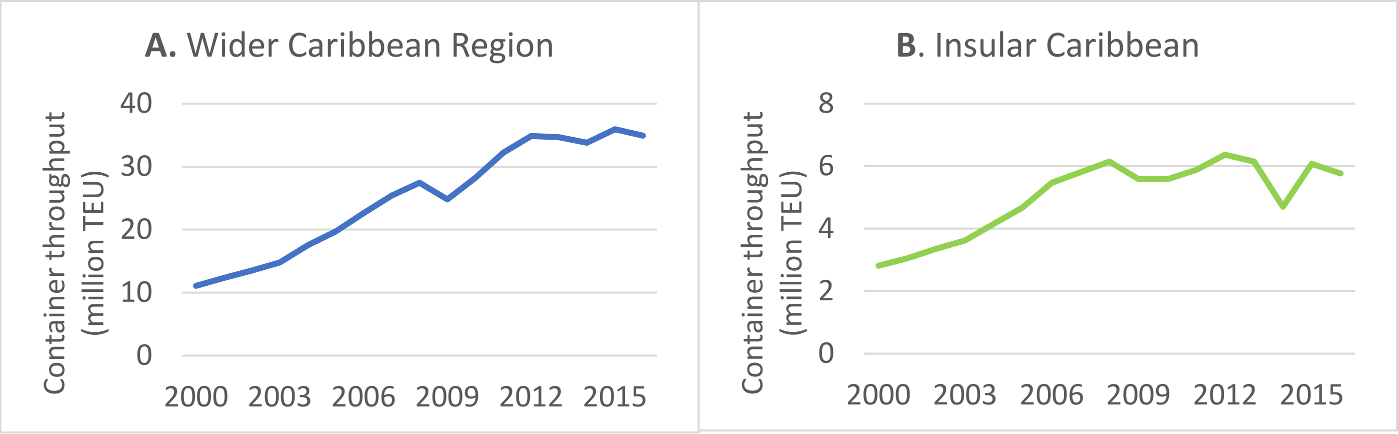
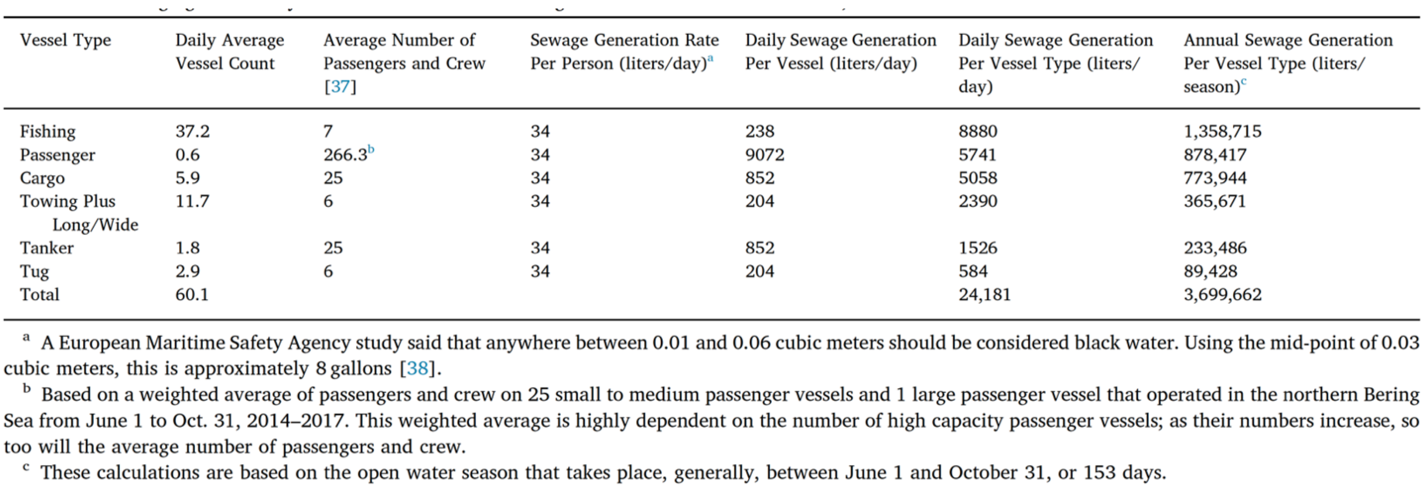


Figure 2.22 Trends in container throughput growth for the (A) the Wider Caribbean Region and (B) Insular Caribbean. (Source of input data: ECLAC).

Given the above context, and despite the lack of assessments of the environmental footprint of shipping in general, and in the Wider Caribbean Region in particular, published studies on nutrient wastes of container vessels operating in other parts of the world or on other forms of shipping wastes emitted in the WCR can serve as proxies in providing preliminary insights on how transport vessels contribute to nutrient pollution.

Parks et al. (2019) examined oil, sewage and gray water produced by vessels in the northern Bering sea. Their study provides empirical data that can be used to inform models to estimate similar waste streams in other locations such as in the WCR (Tables 2.17 and 2.18)

Table 2.17 Estimated sewage generated by vessels in the Northern Bering Sea from June 1-October 31, 2014-2017 (Parks et al. 2019)



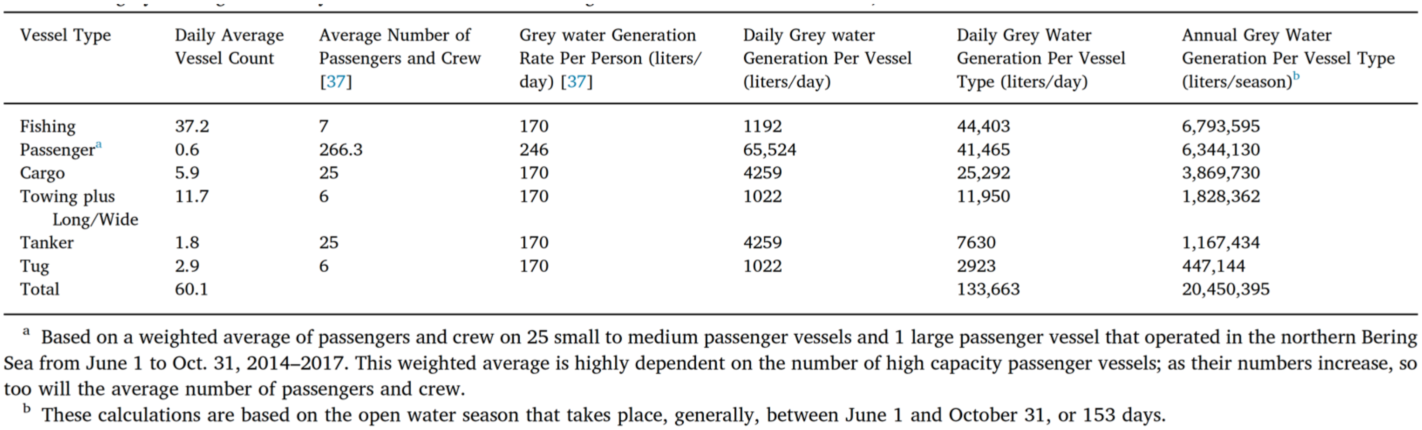
Vessel Type	Daily Average Vessel Count	Average Number of Passengers and Crew [37]	Sewage Generation Rate Per Person (liters/day)[a]	Daily Sewage Generation Per Vessel (liters/day)	Daily Sewage Generation Per Vessel Type (liters/day)	Annual Sewage Generation Per Vessel Type (liters/season)[c]
Fishing	37.2	7	34	238	8880	1,358,715
Passenger	0.6	266.3[b]	34	9072	5741	878,417
Cargo	5.9	25	34	852	5058	773,944
Towing Plus Long/Wide	11.7	6	34	204	2390	365,671
Tanker	1.8	25	34	852	1526	233,486
Tug	2.9	6	34	204	584	89,428
Total	60.1				24,181	3,699,662

[a] A European Maritime Safety Agency study said that anywhere between 0.01 and 0.06 cubic meters should be considered black water. Using the mid-point of 0.03 cubic meters, this is approximately 8 gallons [38].

[b] Based on a weighted average of passengers and crew on 25 small to medium passenger vessels and 1 large passenger vessel that operated in the northern Bering Sea from June 1 to Oct. 31, 2014–2017. This weighted average is highly dependent on the number of high capacity passenger vessels; as their numbers increase, so too will the average number of passengers and crew.

[c] These calculations are based on the open water season that takes place, generally, between June 1 and October 31, or 153 days.

Table 2.18 Estimates of grey water generated by vessels in the northern Bering sea from June 1 to October 31 (2014-2017) (Parks et al. 2019



Vessel Type	Daily Average Vessel Count	Average Number of Passengers and Crew [37]	Grey water Generation Rate Per Person (liters/day) [37]	Daily Grey water Generation Per Vessel (liters/day)	Daily Grey Water Generation Per Vessel Type (liters/day)	Annual Grey Water Generation Per Vessel Type (liters/season)[b]
Fishing	37.2	7	170	1192	44,403	6,793,595
Passenger[a]	0.6	266.3	246	65,524	41,465	6,344,130
Cargo	5.9	25	170	4259	25,292	3,869,730
Towing plus Long/Wide	11.7	6	170	1022	11,950	1,828,362
Tanker	1.8	25	170	4259	7630	1,167,434
Tug	2.9	6	170	1022	2923	447,144
Total	60.1				133,663	20,450,395

[a] Based on a weighted average of passengers and crew on 25 small to medium passenger vessels and 1 large passenger vessel that operated in the northern Bering Sea from June 1 to Oct. 31, 2014–2017. This weighted average is highly dependent on the number of high capacity passenger vessels; as their numbers increase, so too will the average number of passengers and crew.

[b] These calculations are based on the open water season that takes place, generally, between June 1 and October 31, or 153 days.

A component of grey water among vessels is food waste. Bien et al (2016) found that food waste among passenger ships in the Baltic Sea, which is a MARPOL (Annex IV-Sewage) Special Area, contributed 52% of nitrogen load from ship-generated sewage. Management of sewage is sensitive areas such as the Baltic would miss the mark by as much if food waste loading is not factored in. Tables 2.19 and 2.20 provide theoretical nitrogen and phosphorus loads based on empirical measures of food waste, and in comparison with sewage loads.

Table 2.19 Estimated annual nitrogen and phosphorus loads from discharged high-nutrient food waste generated onboard cargo ships in the Baltic Sea (Bien et al. 2016).

Ship type	N [tonnes/year]	P [tonnes/year]
Ferry ships	29.6	5.5
Cruise ships	118.23	21.99
Cargo ships	34.58	6.43
Sum	182.41	33.94

Table 2.20 Estimated annual nitrogen and phosphorus loads from discharged sewage generated onboard cargo ships in the Baltic Sea (Bien et al. 2016). Assumptions: 15 gN/person-day and 5 gP/ person-day excretion (Hänninen and Sassi, 2009).

Ship type	N [tonnes/year]	P [tonnes/year]
Ferry ships	112.5	37.5
Cruise ships	107.25	35.75
Cargo ships	131.4	43.8
Sum	351.15	117.05

To automate the estimation of sewage generation by large vessels, Chen et al (2018) outlines a method, essentially creating a Sewage Pollutant Discharging Inventory. The methodology builds on the requirement of the International Convention for the Safety of Life at Sea (SOLAS) for ocean-going ships greater than or equal to 300 gross tons, built on or after 1 July 2002, and all passenger ships, to be fitted with a Ship Automatic Identification System (AIS) equipment. Such Global Positioning System (GPS)-enabled equipment assembles all the technical specifications of the vessel, including the dynamic data associated with the Degree of Ship Activity (DSA) in real space and time. Specific to the calculation of sewage production, the number of crew on board, the DSA, the sewage treatment device efficiency, are among the input parameters to populate formulas for calculating sewage production and the concentrations of pollutants in the raw sewage and in the treated effluent. For this data to be useful for monitoring and assessing ship-based sewage, there has to be regulations that safeguard the integrity and use of the data, including its utility for compliance monitoring.

In the case of oil spills, Singh et al (2015) assessed oil spill risk from shipping activities in the Caribbean Sea, including those by oil tankers, oil products tankers, container ships and cruise ships. While national plans can respond to an island state or territory’s respective risks from each of the assessed shipping activity (Figure 2.23), the authors call for a coordinated policy, and which can be appropriately coordinate with the Cartagena Convention Protocols on Oil Spills, and Specially Protected Areas and Wildlife (SPAW).

2.11 Nutrient sources: final remarks

At the core of nutrient pollution are consumption patterns, driven by agriculture, demographic increases and urbanization, and by shipping for leisure or trade. As such, meaningful reductions in nutrient flows may be achieved by transforming consumption of food and materials within the rubric of a circular economy.

For domestic waste, innovation in collection (e.g. separating liquid and solid waste and composting beginning at household source), and recycling of both components, can save water and minimize nutrient and pathogen discharges.

In agriculture, broadening the targets of environmental regulation from mere product consumption to ecosystem protection can shift the current trajectory towards a more sustainable pathway. For one, fertilizers can be applied based on the nitrogen and phosphorus use efficiencies of target crops. For pesticides, the minimum amount for prophylaxis to safeguard crops, soil biomes and farm workers, not just consumers, should be used. The consequent reductions in both fertilizer and pesticide applications would reduce economic and environmental costs of farming, enhancing both human and ecosystem well-being.

In shipping (cruise tourism, yachting, and cargo shipping), unregulated discharge of waste in shelf waters in proximity to shallow coastal ecosystems such as coral reefs and seagrass meadows, will undermine the blue economies of insular and continental states and territories. The regulation of sewage dumping in a special sensitive area such as the Wider Caribbean Region should be reexamined so that the region can apply for designation as a MARPOL Annex IV-Sewage Special Area just like the Baltic Sea. Such designation would enable stricter regulation of vessel wastewater dumping practices under the existing regulatory framework of the MARPOL, and adding to its designation as a MARPOL Annex V-Garbage Special Area, which took effect since May 1, 2011.

The challenge of reducing nutrient sources is heavy. The risks of unabated nutrient pollution to ecosystems and economies are real (Chapter 3). A scenario of business as usual can no longer be a tenable option. With a functional and proactive Cartagena Convention Secretariat, regional mechanisms to mobilize countries and territories can be established, building on existing national capacities (Chapter 4), and to foster collaboration and partnerships in implementing a nutrient pollution reduction strategy (Chapter 5).

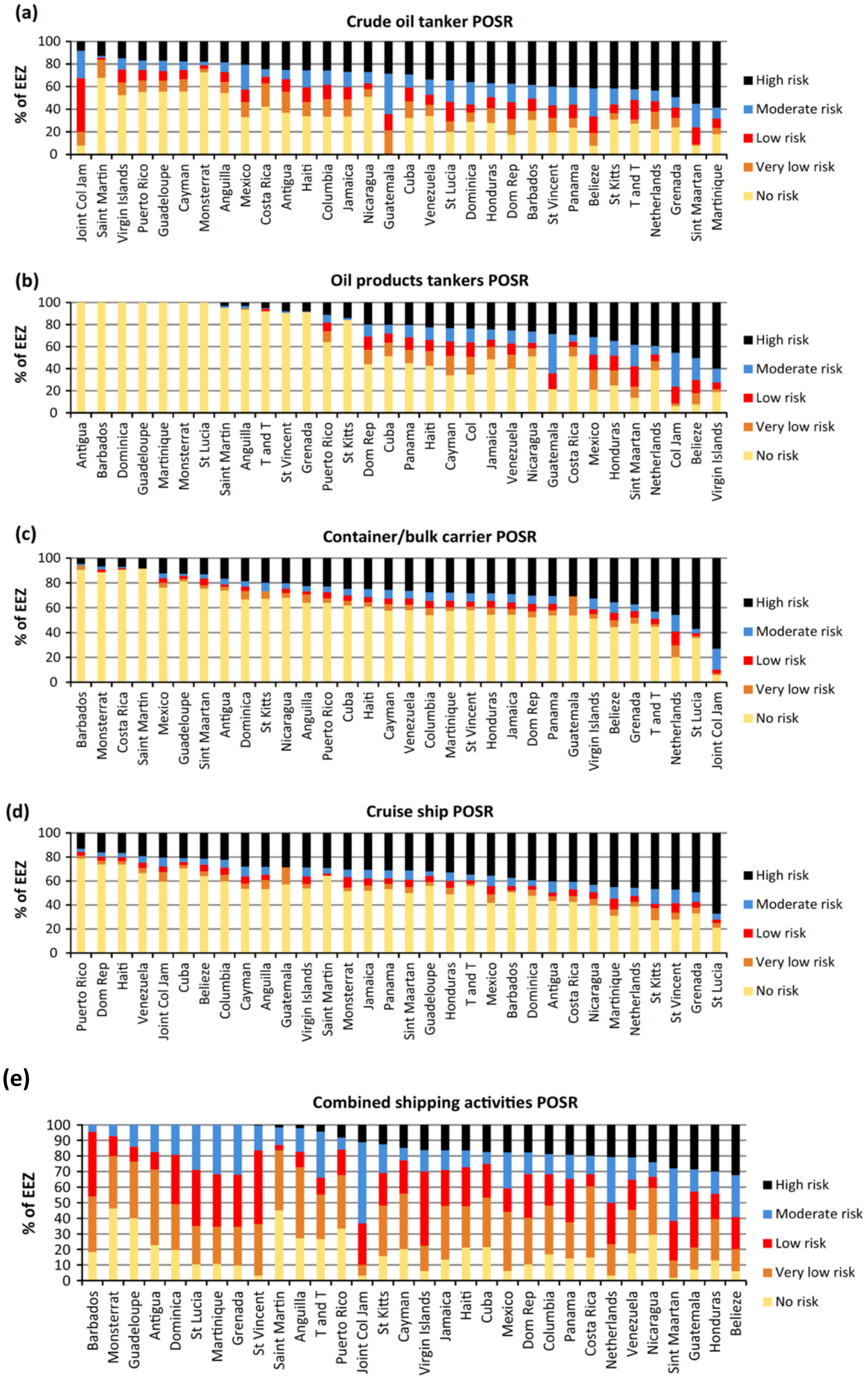


Figure 2.23 Assessments of Potential Oil Spill Risk by shipping activity: (a) Crude oil tanker; (b) Oil products tanker, (c) container ships, (d) cruise ship, and (e) combined activities. (Source: Singh et al., 2015).

3 IMPACTS OF NUTRIENT POLLUTION IN THE WIDER CARIBBEAN REGION

The coastal and marine waters of the Wider Caribbean Region are subject to multiple stressors including nutrient pollution. In assessing impacts of nutrient pollution, the first order responses in terms of physical and ecological changes (water quality, organismic, population, and ecosystem changes) are discussed. The overlay of climate warming, and interactions of modified nutrient regimes with climate-related phenomena such as deoxygenation and acidification, along with changes in ocean circulation, can amplify or dampen these first-order impacts in varying degrees. Anthropogenic stressors such as overfishing and coastal development tend to increase nutrient-induced consequences.

The impacts of nutrient pollution on society, both socially and economically can be direct or indirect, and often are in consonance with other stressors. This chapter aims to highlight where the science is unequivocal in attributing impacts to excess nutrients as the dominant agent of change. It also underscores hypothesized interactions excessive nutrient loads can have with other stressors including changing ocean circulation, which can exacerbate localized nutrient loads with lateral or vertical transport of nutrient-enriched waters, together resulting in potentially greatly magnified impacts. Very often, while attribution by impact helps to identify strategic actions, the framing of these to address ecosystem-scale properties is most crucial and which often address interactions rather than individual causative agents.

3.1 ECOLOGICAL IMPACTS

3.1.1 Nutrient pollution degrades water quality

A key exercise in the assessment of the State of the Cartagena Convention Area Report (SOCAR) for land-based sources of pollution completed in 2019 was the solicitation of national data sets on coastal water quality by the Convention Secretariat from WCR countries (UNEP CEP, 2019). Data on about 70 water quality parameters were provided by 16 countries/territories, 9 of which were Parties to the Land-Based Sources (LBS) Protocol and which are located in WCR Sub-regions I, III, IV and V (Figure 3.1). There was no submission from Sub-region II countries (Central America), and which must be addressed in subsequent SOCAR reporting. Data coverage among these data sets was uneven and non-uniform across parameters or time (2009-2016). The SOCAR main authors processed and analyzed the national data sets by site and by seasons (wet season: May to December; dry season: January to April), and by geography up to the 1st level administrative division. Seasonal averages of individual parameters at site level were assessed using standards adapted by the LBS Working Group. The resulting ratings of sites grouped at the first administrative level and by country are shown in the following sections below.

Parameters pertinent to nutrients are highlighted in this report as they represent quantitative indicator-based assessment of water quality in some coastal waters of the WCR. These include dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), chlorophyll a, enteric pathogens *Escherichia coli* and *Enterococcus sp*, total suspended solids (TSS), bottom dissolved oxygen, and pH. The SOCAR assessment used standards referenced in the US National Coastal Condition Report IV (US EPA, 2012) and Annex III of the Convention Land-based Sources (LBS) Protocol.

For certain countries that followed a statistically designed monitoring programme, the site- specific results can be generalized to national coastal waters. This is not the case for all data submissions. As a result, the results presented here cannot be generalized to the coastal waters of the WCR. A vision of the periodic SOCAR reporting is to provide a truly regional state of the Cartagena Convention Area which can only be achieved when majority of the countries/territories are able to implement a national pollution monitoring programme.

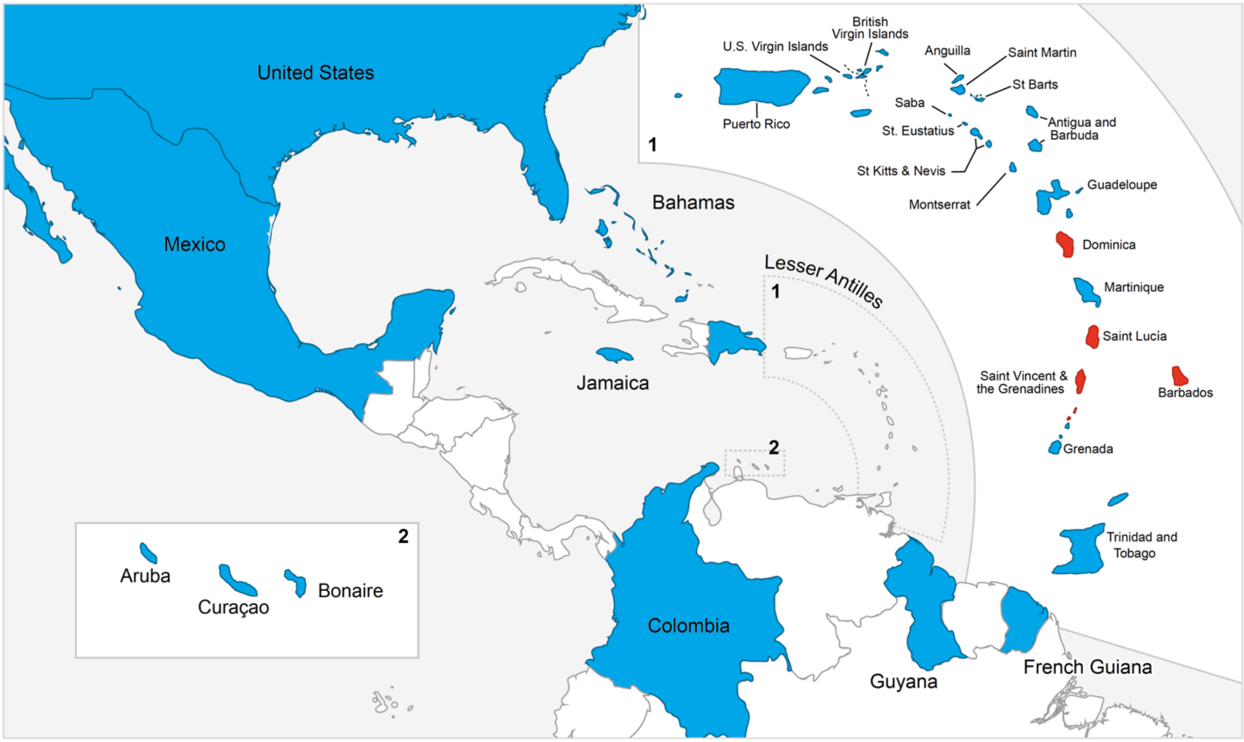


Figure 3.1 Countries and territories that submitted national data sets on water quality (shaded in blue). Data for insular countries highlighted in red were obtained from the Caribbean Public Health Agency (CARPHA).

Empirical concentrations of DIN and DIP. Once offloaded into coastal receiving basins, nutrients and other water-borne materials from the watershed are diluted by coastal waters at concentrations that are net of river mouth retention and local transport and circulation. Between particulate, dissolved organic and dissolved inorganic forms of nutrients nitrogen N and phosphorus P, the dissolved inorganic forms are most readily taken up in the process of photosynthesis. Inorganic N in aquatic systems are biologically available, but inorganic P can be adsorbed to suspended and sediment particles (Howarth et al 2021). Available dissolved nutrients fuel immediate plant growth and algal populations increase in sizes as a result. Monitoring sites assessed for DIN and DIP using WCR-wide standards are shown in Figure 3.2. Wet season DIN values in all reported sampling sites around Trinidad and Tobago and the Dominican Republic appear to have exceeded standards and are rated as Poor for this indicator (Figure 3.2A). For DIP, almost all insular sampling sites and a third of coastal sites for continental countries failed to meet the Good or Fair standards (Figure 3.2B). While these patterns cannot be generalized to the national scale because of limited spatial coverage or to ascertain that these states are persistent across seasons or years, the initial data releases do indicate that poor water quality because of increase dissolved nutrient concentrations occur among certain sampled sites during the wet season when nutrient deliveries are presumed to be greater. These sites should be regularly monitored especially because of proximity to and/ or influence by river basins that have been assessed to have high eutrophication potential (see Section 3.1.2).

Chlorophyll a. As a major plant pigment, the concentration of chlorophyll a tracks the growth of green pigment-bearing microalgae in response to water column nutrient regimes. Among tropical insular sites that are not influenced by major rivers, waters are usually oligotrophic, and chlorophyll a concentrations are low as indicated by the assessment range for islands. For islands with data, no site was rated poor but all 17 sites in Guadeloupe were in Fair condition (Figure 3.3). Among sites in continental countries, Mexico, USA and Colombia showed exceedances to merit Poor rating in some of their monitoring sites. Coincidences in space with river mouths assessed as having high eutrophication potential indices should be subject to periodic assessment by national monitoring teams to determine whether these initial states are persistent. In the case of islands, runoff and critical point sources in tandem with local circulation can help explain current pigment concentrations. Persistent states of high chlorophyll concentrations should be addressed within broader programmes on nutrient pollution reduction.

Enteric pathogens. The presence of sewage pathogens in coastal waters indicate the release of untreated or partially treated domestic waste water, including pastoral runoff containing livestock fecal material. Reductions in fecal pathogens reduce diarrheal disease transmission risks, which comprise a major health concern in Latin America and the Caribbean (Fuhrmeister et al. 2015; GBD 2016 Risk Factors Collaborators, 2017) (see section 3.x on social impacts). Using a binary Good-Poor standards for *Enterococcus* and *Escherichia coli* (Figure 3.4A), all assessed countries had sites with exceedances in acceptable pathogen counts (Figure 3.4B and C). The wastewater inventory estimates, model outcomes from Integrated Model to Assess the Global Environment – Global Nutrient Model (IMAGE-GNM) modelling, and these empirical observations present an unequivocal set of evidence that sewage/ animal fecal matter are present in coastal waters of assessed countries in sufficiently high numbers to fail water quality standards. The public health implications as well as potential losses of tourism revenues that dominate island economies cannot underscore enough the acute need to address sewage pollution as an integral component of a circular nutrient economy. Sewage treatment technology at level 3 can remove nutrients and pathogens, but costs of technology and maintenance are exorbitantly high for developing states, insular or continental. Simpler technologies such as composting toilets is a potential alternative, but must have a support infrastructure at local level to make it viable at watershed scale (US EPA 1999). Other relatively low cost technologies that catch urban runoff such as rain gardens, vegetated swales, and constructed wetlands, among others, can help ameliorate runoff sources but not point sources. Better still, a more comprehensive plan to recover nutrients from composted waste material for potential use as organic farm inputs under strict health and environmental safety standards may provide much needed incentives and point a way forward towards a more circular and holistic approach to waste nutrient recovery, reuse and nutrient pollution reduction.

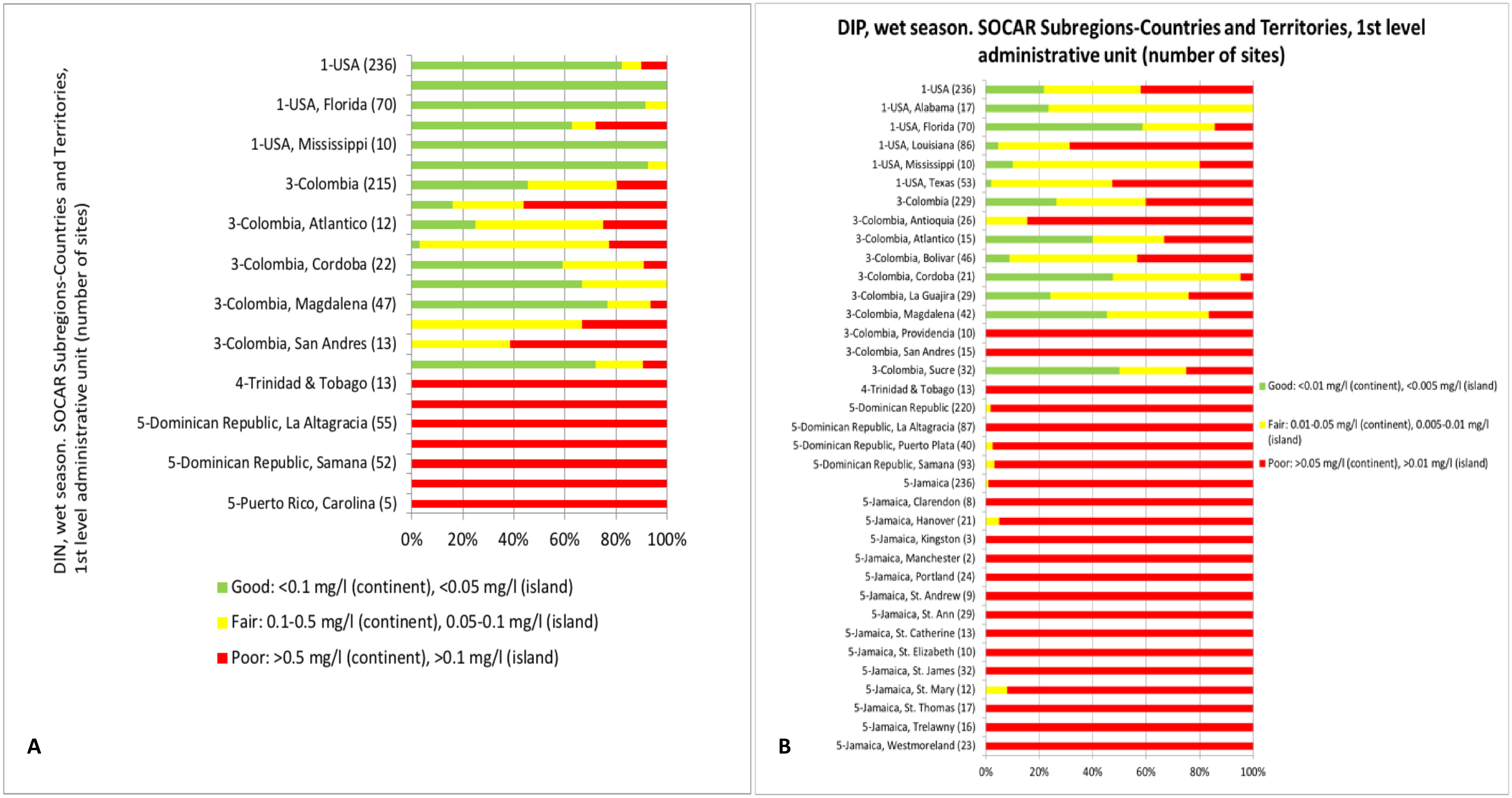
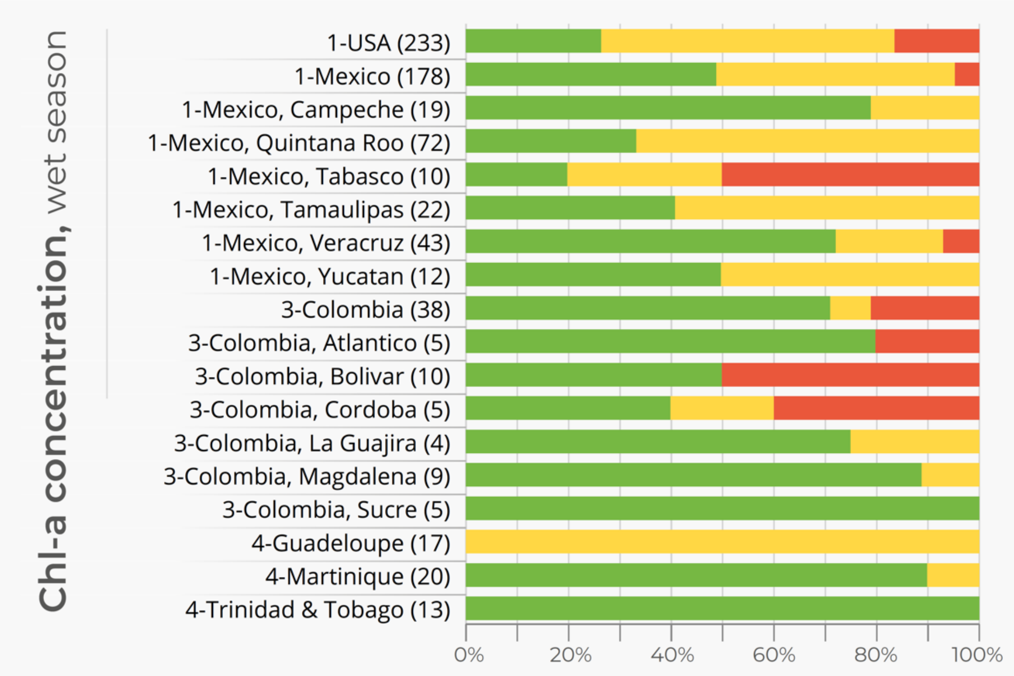


Figure 3.2 Monitoring sites during wet season showing Good-Fair-Poor sites for: A. Dissolved Inorganic Nitrogen (DIN), B. Dissolved Inorganic Phosphorus (DIP). Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). (UNEP CEP, 2019).



Status	Continental µg l⁻¹	Island µg l⁻¹
Good	<5.0	<0.5
Fair	5.0 to 20.0	0.5 to 1.0
Poor	>20.0	>1.0

Figure 3.3 Monitoring sites for Chlorophyll a in the wet season. Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). (UNEP CEP, 2019)

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 pp.
E. coli	0-126 MPN/100ml	>126 MPN/100ml	

A

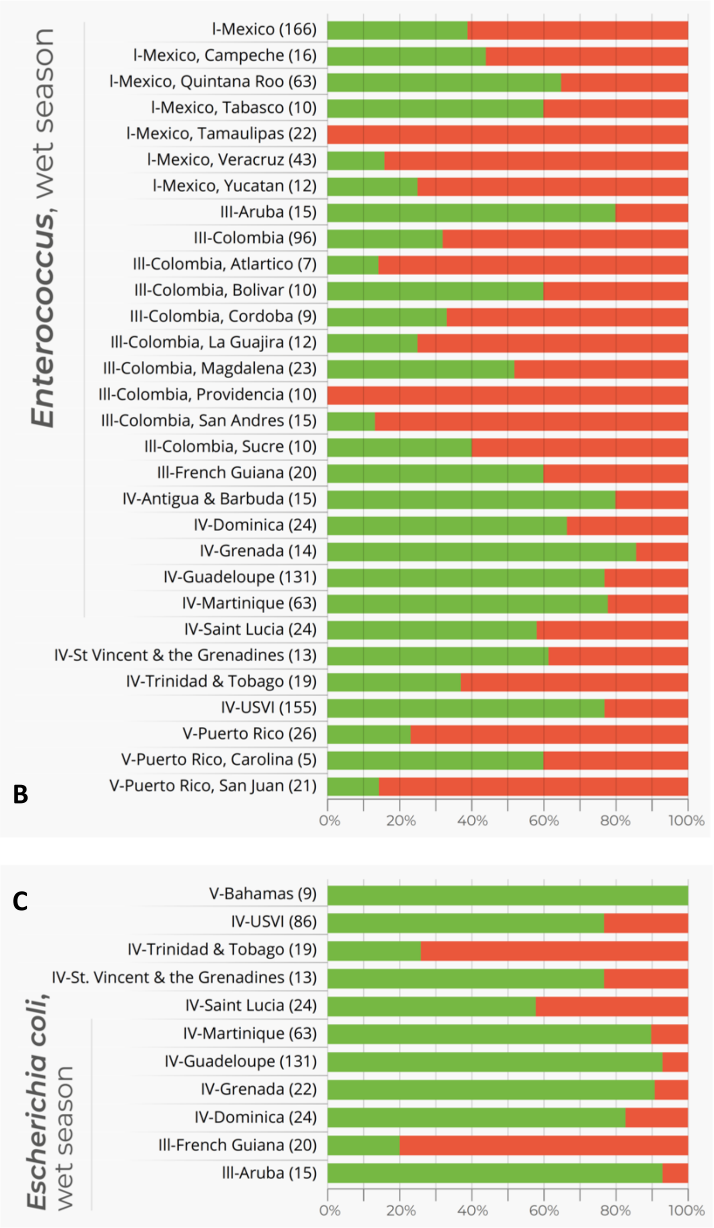


Figure 3.4 Assessment of monitoring sites for enteric pathogens using binary standards (Panel A)during the wet season. Panel B shows status of sites for Enterococcus, and Panel C for E. coli. Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). (UNEP CEP, 2019)

Turbidity. Turbidity is an optical property of liquids determined by the amount of material, dissolved or suspended, that scatters light shined through the water sample. Measures of turbidity can include the concentrations of total suspended and dissolved solids, or the amount of light that penetrates at depth using a light meter, or a Secchi disk. For monitoring sites that are naturally turbid because of riverine influence, TSS standards are not applicable. In waters where coral reefs are naturally found and which depend on good light penetration in waters that tend to be low in nutrients and chlorophyll, TSS standards are used to assess water quality along with other indicators. In the SOCAR assessment, the acceptable range for turbidity was 0 – 1.5 NTU (Nephelometric Turbidity Units), and was not applied in areas that are naturally turbid. These areas include Trinidad and Tobago (Gulf of Paria), entire coast of French Guiana, Colombia, and all the coastal states of Mexico except Campeche, Quintana Roo, and Yucatan coasts.

The assessment results using wet season data indicate exceedances in all sites except Guadeloupe (Figure 3.5). For Dominican Republic and Jamaica, high TSS yields from land erosion as shown by the Global Nutrient Export from Watersheds (NEWS) Model outcomes (Section 2.8), can explain high TSS concentrations in the water column, especially during periods of rainfall. In areas where land erosion is not significant, turbidity may be explained by high amounts of dissolved matter or significant plant growth from rich nutrient regimes in the water column. Resuspension and tidal currents can add to lateral flows.

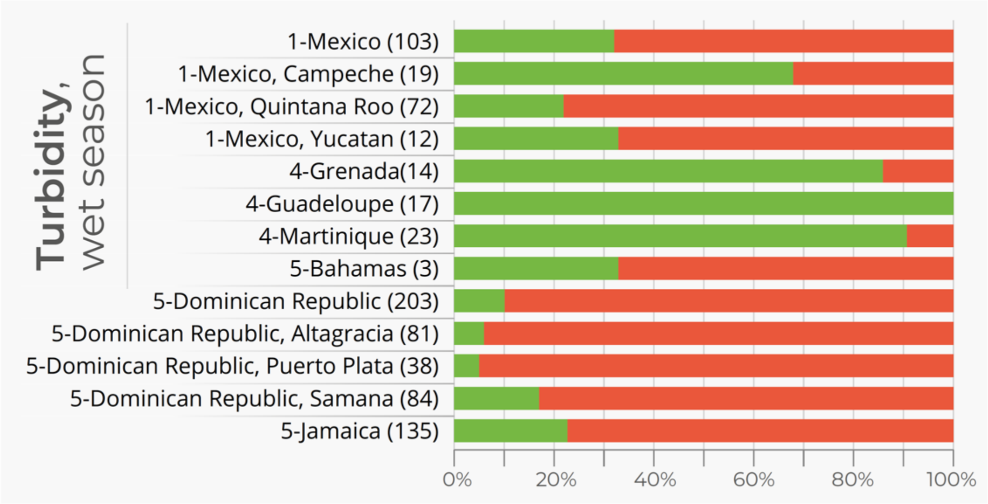


Figure 3.5 SOCAR assessment of turbidity in monitored sites during wet season. Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). Acceptable range: 0 – 1.5 Nephelometric Turbidity Units (NTU). (UNEP CEP, 2019)

Dissolved oxygen. Bottom dissolved oxygen (DO) is used to indicate the concentration of dissolved oxygen at depth and which is critical for aerobic respiration of organisms including fish and shellfish. A physiological limit of 2 mg O_2 L^{-1} is used, below which aquatic organisms become impaired. Assessment ranges used in SOCAR are: Good when DO > 5 mg L^{-1}; Fair when DO is 2–5 mg L^{-1}; and Poor when DO is below the physiological limit of 2 mg L^{-1}. Shallow waters are often well oxygenated and well-mixed as water interacts with the wind. During the summer, waters can become stratified and the bottom layer may not get enough oxygen beyond diffusion to replenish biotic oxygen demand. During phytoplankton blooms, unconsumed plant biomass settles to the bottom and undergo decomposition, a process which uses up oxygen, and can result in zones of low oxygen, also known as hypoxic zones. As such, bottom DO is best assessed along with other water quality parameters for each site and season, including nutrients and chlorophyll a, to detect bloom cycles among others, during which DO can dip below levels detrimental to water column and benthic biota.

SOCAR assessment of monitoring sites for DO in the wet season indicate 2 sites in the Bahamas and 14 sites in the USA to be oxygen-deficient. The latter coincide with the Gulf of Mexico hypoxic zone. (Figure 3.6). Overall, dissolved oxygen appears to be sufficient for aerobic respiration except for the hypoxic zone in the inner Gulf of Mexico. The case for the Bahamas would need better geographic and temporal coverage to determine persistence of hypoxic state.

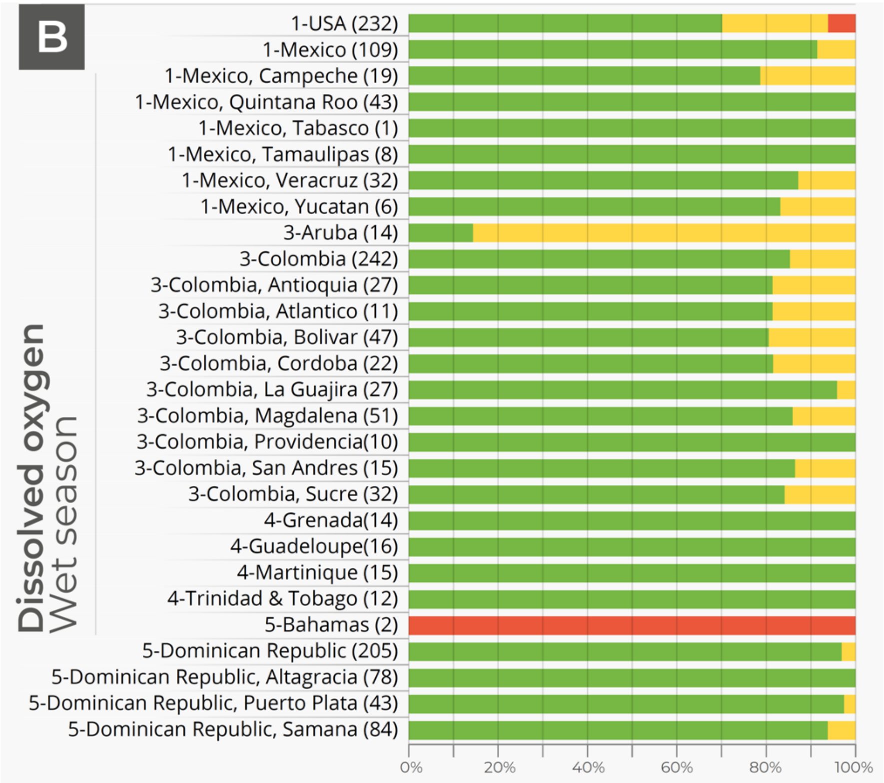


Figure 3.6 SOCAR assessment of monitoring sites for bottom dissolved oxygen (DO) during wet season. Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). Assessment ranges: Good when DO > 5 mg L^{-1}; Fair when DO is 2–5 mg L^{-1}; and Poor when DO is below the physiological limit of 2 mg L^{-1}. (UNEP CEP, 2019)

pH. The acidity of liquids measures the concentration of H$^+$ ions on a logarithmic scale. A pH of 7 is said to be neutral, and measurements below 7 is considered to be acidic; those above 7 are considered to be basic. The concentration of H$^+$ ions is inversely proportional to its pH; the more H$^+$ ions there are, the lower the pH, the higher the acidity. The average ocean pH was 8.2 before the Industrial Revolution; contemporaneous average is now at 8.1, a 26% increase in acidity, largely because of a warming climate with the ocean acting as a sink for about 25% of global emission of CO_2.

For the SOCAR assessment of monitoring sites for pH during wet season, the acceptable range used was between 6.5 to 8.5. In general, the coastal sites assessed were within the acceptable range (Figure 3.7).

Sites with low pH were those located in Louisiana, USA, and in St. Mary and Portland, Jamaica. Decomposing remains of algal blooms through microbial respiration can lower pH by as much as 0.05 units as would be the case in the hypoxic zone below the Mississippi River (Cai et al, 2011). Eutrophication-induced acidification, is in addition to ocean acidification which is driven by atmospheric anthropogenic CO_2 dissolving in oceanic waters.

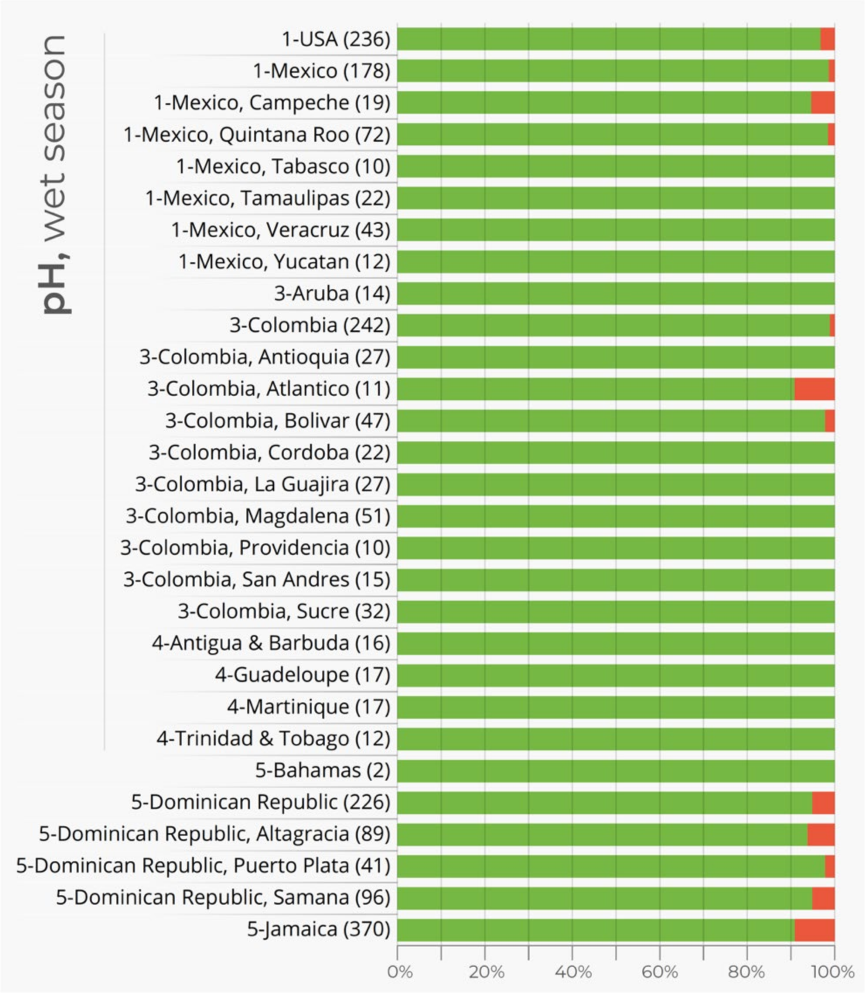


Figure 3.7 SOCAR assessment of monitoring sites for pH during wet season. Site nomenclature indicates: WCR Sub-region, Country/Territory, 1st level administrative unit (number of sites assessed). Acceptable range: 6.5 to 8.5. (UNEP CEP, 2019)

Integrating individual indicator-based assessments. The assessment of sites as presented above is a requisite step in initiating the periodic evaluation of how the WCR is impacted by land-based sources of pollution. Moving forward, the LBS Working Group will need to develop a conceptual framework that allows for the integration of the assessment results per parameter into an ecological index or grade for each monitoring site. Given the design of national monitoring programs that are statistically robust, representative sites when assessed, could generate ecological states at site scale to a generalized state of national coastal waters. When aggregated to the scale of sub-regions, a more representative picture of the environmental state of coastal waters in the WCR region can emerge. These national initiatives can be complemented by global and regional models that can help to integrate empirical trends and modeling outcomes at regional and global scales given the broader spatial and longer temporal dimensions that models usually subsume, and to target priority sites for mitigation and for protection.

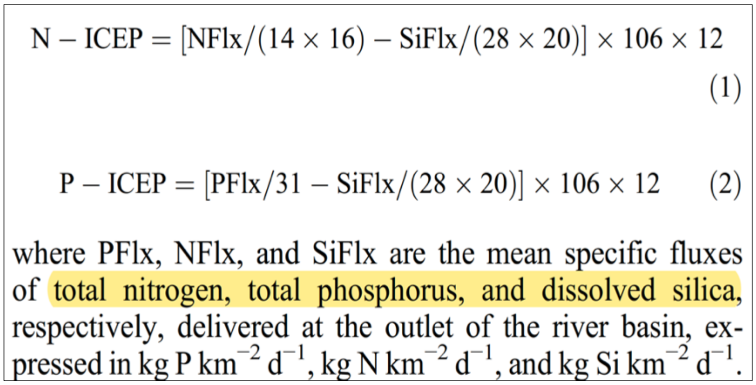
The assessment of water quality based on statistically robust monitoring of representative sites is one component of an overall assessment of the coastal environment and the ecosystems that comprise it. As such, the monitoring and assessment of key habitats under the Special Areas and Wildlife (SPAW) Protocol of the Cartagena Convention, can be integrated, to provide an overall state of the environment in the WCR region. This integration of ecological components (water column attributes, habitat and biodiversity features of benthos and pelagic ecosystems) and the identification of sites both for their biodiversity and vulnerability to land-based sources of pollution, notably nutrients and pathogens, are the scientific underpinnings that are required for developing strategies and action plans. At the level of the Secretariat of the Cartagena Convention, initiatives to integrate Convention Protocol-based assessments are actually underway, and with a vision to make data reporting and evaluations for these implemented in a more sustained and operational fashion within an overall rubric of adaptive management.

3.1.2 Nutrient pollution causes eutrophication of coastal waters

One of the global data sets accessed during the SOCAR assessment was the Global NEWS dataset V2 by Mayorga et al (2010). It provides estimates of loads of dissolved inorganic and organic forms of nitrogen (DIN, DON), phosphorus (DIP, DOP), particulate and dissolved organic carbon, and dissolved silica for model year 2000. These input parameters allow for an estimation of the nutrient-specific **Index of Coastal Eutrophication Potential (ICEP),** the new production of non-siliceous algal biomass potentially sustained in the receiving coastal water body by either nitrogen or phosphorus delivered in excess over silica (Billen and Garnier 2007). The data set provides data for 261 WCR-draining basins at a resolution of 0.5° X 0.5°. The ICEP is a milestone index to use as it has been adopted to be a key indicator for assessing marine environment status under the 2030 Agenda for Sustainable Development. Sustainable Development Goal #14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development – includes 14.1 Target to “prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution” by year 2025.

The nutrient-specific ICEP compares the availability of all forms of N, P and silica (Si) in loads to promote the growth of non-siliceous phytoplankton when either N and P are delivered in excess of Si, based on the Redfield molar ratios of Carbon C: Nitrogen N: Phosphorus P: Si of 106C: 16N: 1P: 20Si. When nutrient deliveries follow the Redfield ratio, the presumption is that silica-bearing phytoplankton called diatoms are favored. When in excess, non-silica bearing phytoplankton such as dinoflagellates, are favored to proliferate. Further conditions to a potential for eutrophication include nitrogen to be limiting relative to phosphorus, that is N:P flux ratio is below 16, when N exceeds silica. Likewise, the N:P flux ratio should be P-limiting, i.e. above 16, when P exceeds silica fluxes.

For this report, the authors computed the N– and P– ICEP for each of the 261 WCR-draining basins resolved by the Global NEWS V2 dataset using the following relationships (Billen and Garnier 2007, Garnier et al. 2010; Mayorga et al 2010):



$$N-ICEP = [NFlx/(14 \times 16) - SiFlx/(28 \times 20)] \times 106 \times 12 \quad (1)$$

$$P-ICEP = [PFlx/31 - SiFlx/(28 \times 20)] \times 106 \times 12 \quad (2)$$

where PFlx, NFlx, and SiFlx are the mean specific fluxes of total nitrogen, total phosphorus, and dissolved silica, respectively, delivered at the outlet of the river basin, expressed in kg P km^{-2} d^{-1}, kg N km^{-2} d^{-1}, and kg Si km^{-2} d^{-1}.

In interpreting computational results of these indices, the following should be noted:

- A negative value of ICEP indicates that silica is present in excess over either N or P, and would thus characterize the absence of eutrophication problems
- Positive values indicate an excess of N or P over the requirements for diatom growth, thus a condition for potentially harmful non-siliceous algal development, such is the case of harmful dinoflagellate blooms.
- Positive values of N-ICEP has a high likelihood to result in eutrophication when the N:P flux ratio is below the Redfield molar value of 16, i.e. nitrogen is limiting.
- Positive values of P-ICEP has a high likelihood to cause eutrophication when the N:P flux ration is above the Redfield molar value of 16, i.e. phosphorus is limiting.
- These likelihoods of eutrophication also depend on a dynamic interplay among controlling nutrients, biota and abiotic factors. While there is consensus that nitrogen limits primary production in coastal waters, controlling mechanisms can cause seasonal switches between nitrogen and phosphorus, including co-limitation, with the mediation of other factors such as their interactions with micronutrients, the degree of oxygenation, and the changes in acidity caused by microbial respiration (Howarth and Marino 2006, Guignard et al. 2017, Howarth et al. 2021)

- In terms of data analysis, these nutrient indices are scale-sensitive, so that all nutrient flux parameters have to be at catchment scale. Nutrient daily fluxes aggregated across multiple basins can easily mask catchment-specific eutrophication potential states, because of the aggregated loading values of nitrogen, phosphorus and silica, across basins.

Figure 3.8A shows the distribution of basins relative to their coastal eutrophication potential – basins located to the right of vertical 0 line have nitrogen in excess of silica; and basins plotted above the horizontal 0 line have phosphorus in excess of silica. Around 105 (40%) of 261 WCR unique basins showed positive potential for eutrophication: 63 basins because of excessive nitrogen fluxes; and 85 due to excess in phosphorus fluxes (Figure 3.8B). Forty-three (43) basins common to both categories have both nitrogen and phosphorus fluxes that were in excess of silica. The condition of nitrogen to be limiting relative to P when nitrogen exceeds silica is met in 49 basins. In the case of +P–ICEP basins, only 3 basins show phosphorus being limiting relative to nitrogen. As such, in the case of the coastal waters in the WCR, nitrogen is considered the more limiting nutrient based on these model outcomes. Majority of the sites clustered relatively near a zero eutrophication potential value and it may be hypothesized that these sites may be reassessed towards positive eutrophication given the increasing trends in loading both for N and P, from multiple nutrient sources (Chapter 2).

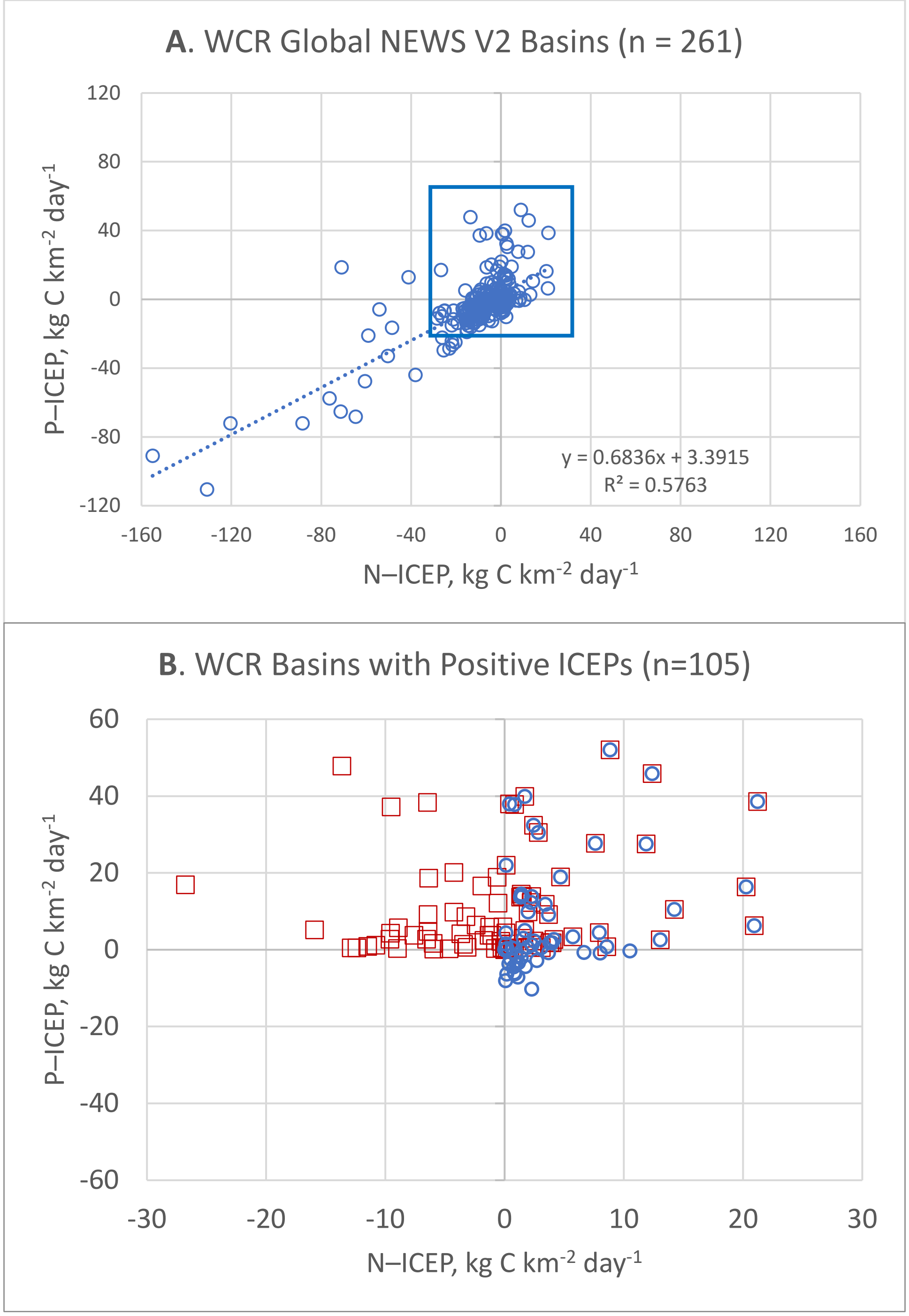
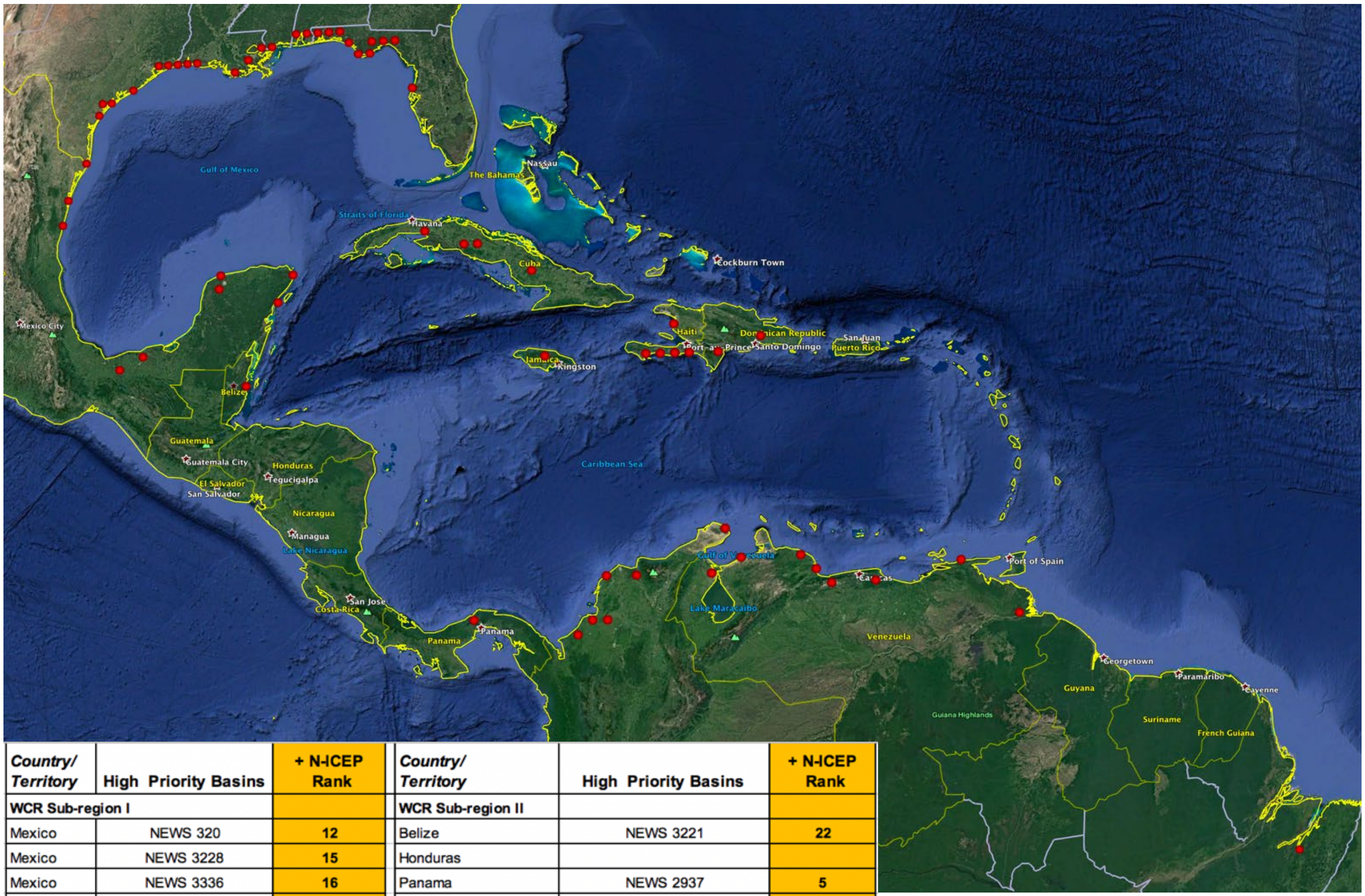


Figure 3.8 Nutrient-Index of Coastal Eutrophication Potential for WCR basins. A. WCR basins resolved by the Global NEWS V2 dataset (n=261) were assessed for their potential to become eutrophic using both the daily N and P fluxes. The inset includes 105 basins that had positive ICEP potentials. B. The inset is magnified to reveal 63 basins with +N–ICEP shown in blue circles (right of vertical zero axis, and 85 basins with +P–ICEP shown in red squares (above horizontal zero axis); and 43 (combined symbols) were positive for both indices (upper right hand quadrant). Forty % of the resolved basins showed positive eutrophic potential because of excess nitrogen or phosphorus fluxes in model year 2000.

Figure 3.9 indicates the location of basin river mouths with positive N-ICEPs. Each of these river basins would have its chronology of land use, demographic and urbanization patterns, and nutrient loading histories that are beyond the scope of this chapter to discuss. Twenty five river basins in the USA include those that unload to the inner Gulf of Mexico, where a persistent hypoxic zone has been documented since a dead zone mapping programme began in 1985. This dead zone continue to be sustained by nitrogen legacies stored in sediments, and which contribute as much as 55% of current annual N loads (Turner et al. 2008, Van Meter et al. 2016), making nutrient pollution reduction a truly wicked challenge. Nine sites in Mexico, two sites in Central America, 15 surrounding the continental countries in WCR Sub-region III, and the Capim/Yaqui River in North Brazil, make up another 25 with +N ICEPS. For insular states, the big islands of WCR Sub-region 4 contribute 13 river basins with the potential to go eutrophic because of excessive N flows. Given that the model year is 2000, and with no ongoing WCR-wide nutrient reduction program, it is very likely that these estimates are conservative and that a greater number of basins would show contemporaneous excessive nutrient loads if a more updated set of input model parameters are available and models implemented to simulate more current watershed and loading conditions.

Annex 3.1 contains preliminary mapping of watersheds among continental and insular states and territories in the WCR. A future initiative will focus on resolving the major rivers coursing through the watersheds at the appropriate spatial resolution, especially for river basins that have modelled data. Annex 3.2 lists the 26 transboundary river basins (straddling two or more countries) in the WCR.

Evidence from the scientific literature outside of the national data contributed to SOCAR and modeled data from Beusen et al. (2015, 2016) and from Mayorga et al (2010) are used in the sections below to track the impacts of flows of nutrients and associated chemicals in the WCR. These impacts constitute a next tier of knowledge that broadens the information base and compelling justification for implementing this nutrient pollution strategy and action plan.



Country/ Territory	**High Priority Basins**	**+ N-ICEP Rank**	*Country/ Territory*	**High Priority Basins**	**+ N-ICEP Rank**
WCR Sub-region I			**WCR Sub-region II**		
Mexico	NEWS 320	12	Belize	NEWS 3221	22
Mexico	NEWS 3228	15	Honduras		
Mexico	NEWS 3336	16	Panama	NEWS 2937	5
Mexico	NEWS 1891	26			
Mexico	NEWS 1873	17	**WCR Sub-region III**		
Mexico	NEWS 3368	32	Colombia	NEWS 1211	1
Mexico	NEWS 3343	38	Colombia	NEWS 3018	2
Mexico	NEWS 3370	46	Colombia	NEWS 697	4
Mexico	**NEWS 35 - Rio Grande**	63	Colombia	NEWS 2894	8
USA	NEWS 3584	3	Colombia	NEWS 3080	39
USA	NEWS 1985	10	Colombia	NEWS 2929	40
USA	NEWS 295	11	Venezuela	**NEWS 25 - Orinoco**	18
USA	NEWS 1345	14	Venezuela	NEWS 262	30
USA	NEWS 467	21	Venezuela	NEWS 1680	35
USA	NEWS 1973	25	Venezuela	NEWS 3017	37
USA	**NEWS 4 - Mississippi**	28	Venezuela	NEWS 3016	42
USA	NEWS 3625	29	Venezuela	NEWS 3004	48
USA	NEWS 673	33	Venezuela	NEWS 1690	56
USA	NEWS 566	34	Venezuela	NEWS 3039	62
USA	NEWS 328	36	Brazil-LME17	**NEWS 37 - Capim/ Yaqui**	23
USA	NEWS 137	41			
USA	NEWS 1354	43	**WCR Sub-region V**		
USA	NEWS 3656	44	Cuba	NEWS 3434	19
USA	NEWS 616	45	Cuba	NEWS 3357	20
USA	NEWS 1357	47	Cuba	NEWS 3397	31
USA	NEWS 3632	49	Cuba	NEWS 3405	59
USA	NEWS 913	50	Dominican Republic	NEWS 3276	6
USA	NEWS 141	51	Dominican Republic	NEWS 3248	9
USA	NEWS 312	52	Haiti	NEWS 1816	13
USA	NEWS 915	53	Haiti	NEWS 3250	24
USA	NEWS 1344	55	Haiti	NEWS 3249	27
USA	NEWS 1356	57	Haiti	NEWS 1808	54
USA	NEWS 1068	60	Haiti	NEWS 3251	58
USA	NEWS 776	61	Jamaica	NEWS 3253	7

Figure 3.9 Location of 63 WCR basins with +N-ICEP (denoted by red dots on map above). The table on the left identifies each basin with the model name “NEWS” followed by a numeric ID, and its corresponding N-ICEP rank. [Reconciliation of the basin numeric IDs with the common river names will be done in a future initiative.] Because of the 0.5° X 0.5° spatial resolution of the NEWS model, basins for the smaller islands in WCR Sub-region IV were not resolved. Top ranked for N-induced eutrophication potential is Basin NEWS #1211 in Colombia; Orinoco River basin is #18; Mississippi River basin, #28; and Rio Grande River basin is last at #63. Model year is 2000.

3.1.3 Nutrient pollution favors the formation of harmful algal blooms (HABs)

The loading of nutrients, nitrogen and phosphorus, and other micronutrients, in non-Redfield ratios and in flows that are in excess relative to silica paints a simplified set of dynamics for the onset of non-siliceous and often harmful algal blooms (HABs). The increasing frequency of HABs, as recurrences or newly reported events, is a confluence of physiology, environment including global warming, acidification and deoxygenation, along with interactions HABs assemblages have with co-occurring species (Glibert and Burford 2017, Glibert 2020, Griffith and Gobler 2020; Paerl et al. 2020) (Figure 3.10). That a warming, acidifying and deoxygenation ocean because of climate change, favors the proliferation of HABs when anthropogenic nutrients are present in excess, makes these bloom events as climate co-stressor in aquatic ecosystems, and behooves societies to make nutrient pollution reduction a contemporaneous imperative (Griffith and Gobler 2017, Gobler 2020).

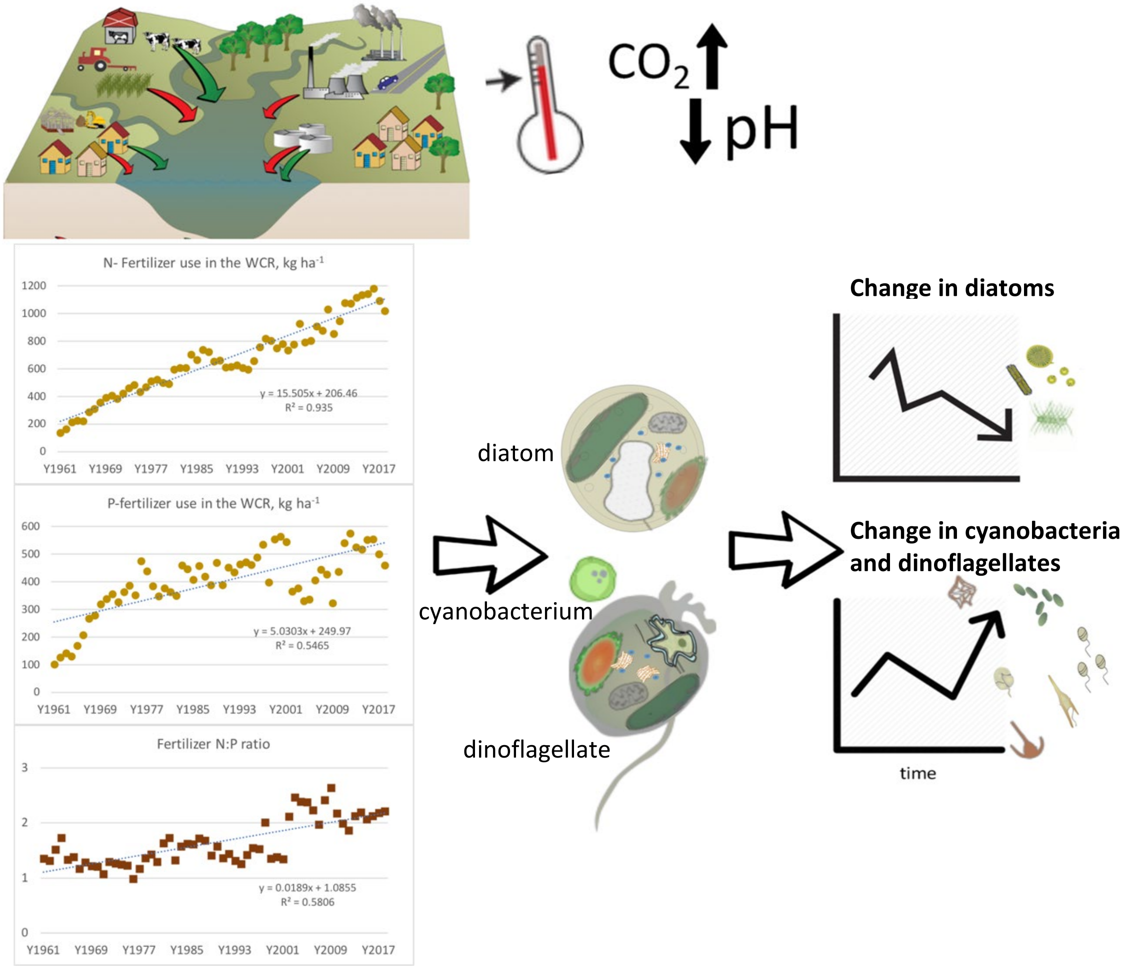


Figure 3.10 Conceptual diagram showing the factors that influence the formation of HABS such as cyanobacterial and dinoflagellate blooms, including fertilizer loadings that dominate land-based nutrient flows, warming, acidification and deoxygenation, all of which influence phytoplankton dynamics in the WCR (modified from Glibert (2020).

The most up-to-date compilation of HABs status in Latin America, the Caribbean and South America reports detailed taxonomic records of HAB forming species from 1956 to 2018 using global and regional databases (Sunesen et al. 2021). The existence of two International Oceanographic Commission (IOC) Regional Working Groups, Algas Nocivas de America Central y el Caribe (ANCA), and the Floraciones Algales Nocivas en Sudamerica (FANSA) are critical in the documentation of HAB events in the WCR, using the Harmful Algae Event Database (HAEDAT) along with other global databases on biodiversity. It should be noted that HAEDAT records only include events that have caused adverse impacts at social, economic, environmental or health levels, so that complementary data on less impactful HAB events should be sought to assemble a more complete mosaic of HABs in the region. Data and information up to 2019 include presence of toxic species, the known geographic distribution of these, the detection of novel toxins in the region, as well as HAB events during the covered period of study. Salient points of this latest report and compilation are briefly discussed here to examine temporal patterns, causative species forming HABs, the nature of toxins and the extent of toxicity on the impacted consuming public. The ANCA and FANSA regions overlap with the WCR so the findings for these HABs regions are presented below.

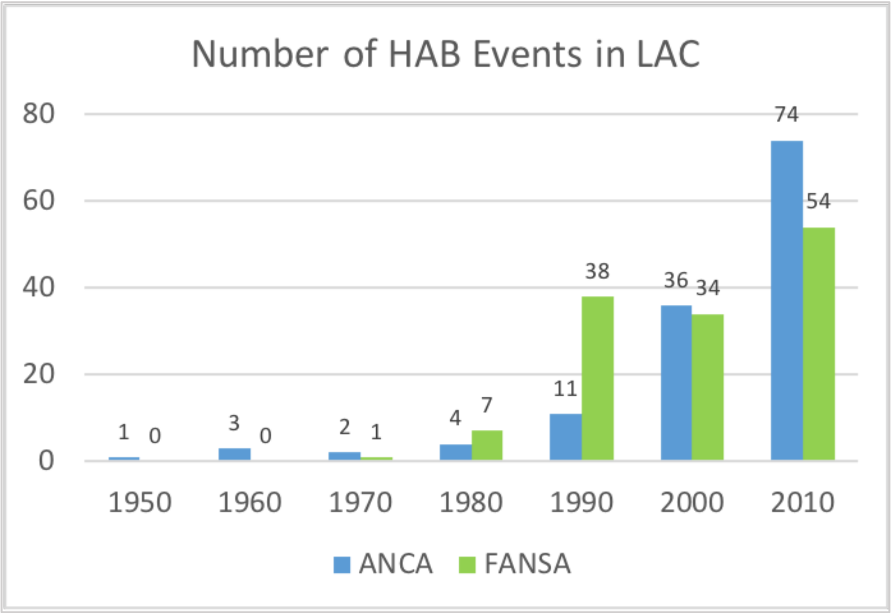
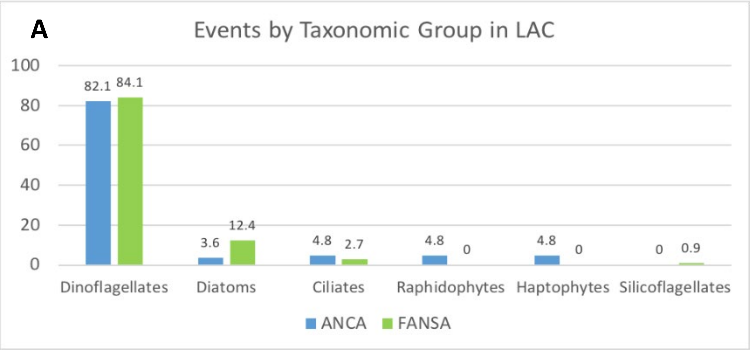
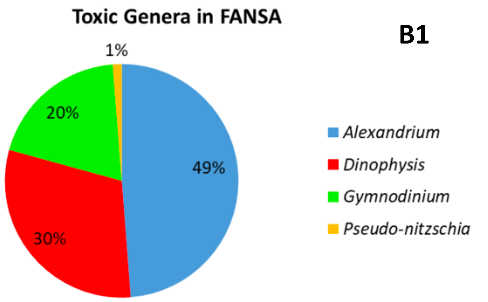


Figure 3.11 Number of HAB events in the ANCA (Caribbean and Central America) and the FANSA (South America) regions analyzed by decade. (Source: Mendez et al. 2018).

HAB events in the WCR show an increasing trend over the documented period with 4 events in the 1980s, increasing to 11 in the 1990s; to 36 in 2000s and 74 from 2010 to 2018, in the ANCA region (Mendez et al 2018, Sunesen et al. 2021). For South America, events increased from 7 in the 1980s to 38 in the 1990s; becoming 34 in 2000 and increasing to 54 in the last study decade.

About 80% of HABs in LAC (both ANCA and FANSA regions) are caused by dinoflagellates (Figure 3.12A), with relatively minor contributions by other groups. Cyanobacteria were not included in the assessment because of inadequate records but were included among the species inventory for the FANSA region, but not in the Caribbean. Toxin- bearing genera are shown in Figure 3.12 B1 for the FANSA region and B2 for the ANCA region. Toxic genera include dinoflagellates *Alexandrium, Gymnodium, Pyrodinium, Dinophysis*





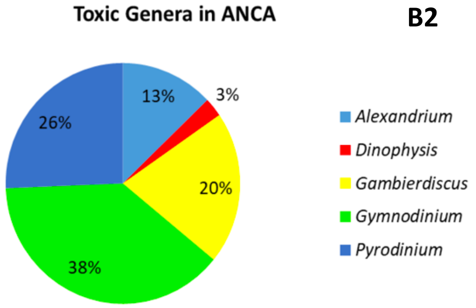
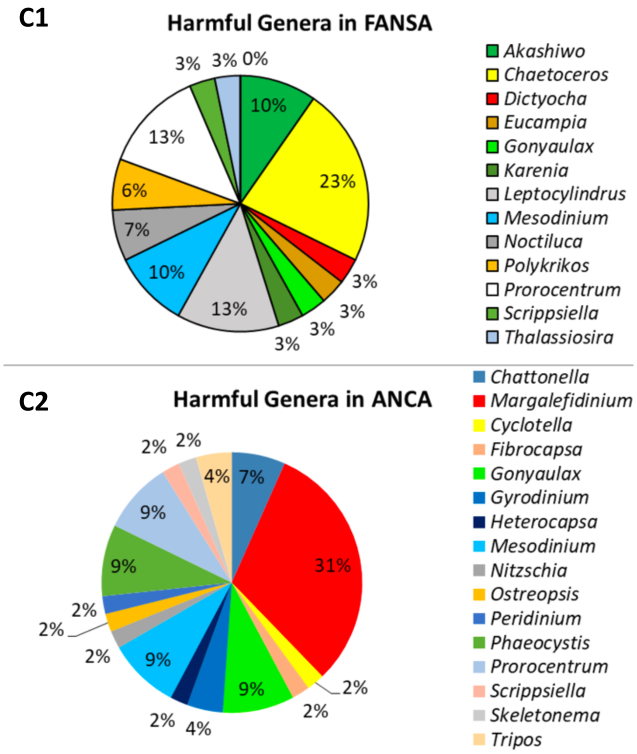


Figure 3.12 (A). Causative organisms of HABs. Toxic genera in FANSA (B1) and ANCA (B2) regions; harmful genera in FANSA (C1) and in ANCA (C2); and (D) geographic distribution of causative organisms in Latin America and Caribbean (Source: Mendez et al. 2018).



and Gambierdiscus, and one diatom species Pseudonitzschia.

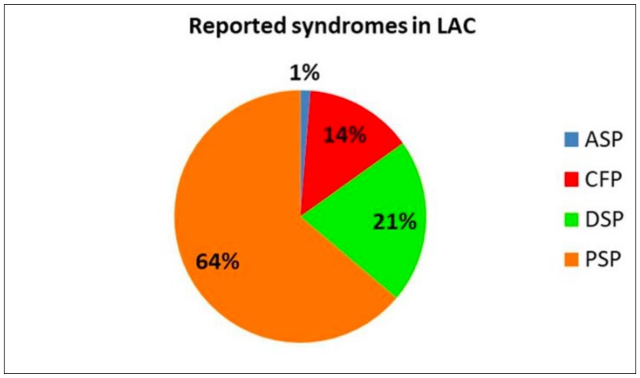


Figure 3.13 Reported clinical toxin syndromes in LAC. Amnesic Shellfish Poisoning (ASP), Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish Poisoning (DSP)., and Ciguatera Fish Poisoning (CFP) (Source: Mendez et al. 2018).

In the LAC region, 75% of 265 HAB records were toxic events which occurred over the 7-decade time coverage of the study. These are broken down by toxin syndromes that afflict humans: Amnesic Shellfish Poisoning (ASP), Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish Poisoning (DSP)., and Ciguatera Fish Poisoning (CFP). Ciguatera is restricted to the Caribbean while ASP is to South America and both PSP and DSP are distributed throughout LAC. PSP, by far is the dominant toxin syndrome in Latin America at 64%. PSP results from poisoning by saxitoxins found in a number of species belonging to the genus *Alexandrium*, and species including *Gymnodinium catenatum, Pyrodinium bahamense*, and *Trichodesmium erythraeum*.

Of the toxic HAB events, 22% impacted humans, but the HAEDAT monitoring did not document the number of afflicted individuals. Future HABs monitoring should partner with health agencies, so that the toxin syndromes are assimilated in public health databases, which can then be used in more accurate assessments of public health and social costs of HABs. There are no routine diagnostic tests for any of the clinical syndromes, nor is there an antidote for any of the toxins (Grattan et al. 2016). As such, the only effective measures are preventive including: environmental monitoring with toxin detection, identifying at risk individuals and communities, enhancing HABs outreach programmes, and improving reporting and documentation of HABS and illnesses.

Harmful, as differentiated from toxic, algal events can lead to mortality of fish and invertebrates through deoxygenation or by physical effects such as lesions or gills clogging or the secretion of haemolytic compounds, or if species are found to contain toxins detected through bioassays (Lassus et al. 2016). *Chaetoceros,* a diatom, dominates the harmful genera in FANSA while *Margalefidinium* is most common in ANCA region (Figure 3.12 C1 and C2). The latter species has been associated with mass mortalities of marine organisms through its production of reactive oxygen species, hemolytic and neurotoxin-like substances (Lopez-Cortes et al. 2019), costing up to US$140 M of economic impacts on aquaculture in Asia and North America. An economic assessment has not been done in Latin America. The geographic distribution of causative genera is shown in Figure 3.12D. Reporting and documentation of the ecological impacts of HABs are necessary in developing predictive models and risk scenarios, so that operational measures to mitigate damage can be developed. The root causes of nutrient pollution reduction is fundamental to programmes that hope to address HABs including its public health and livelihood impacts.

3.1.4 Nutrient pollution triggers the formation of hypoxic zones in stratified waters

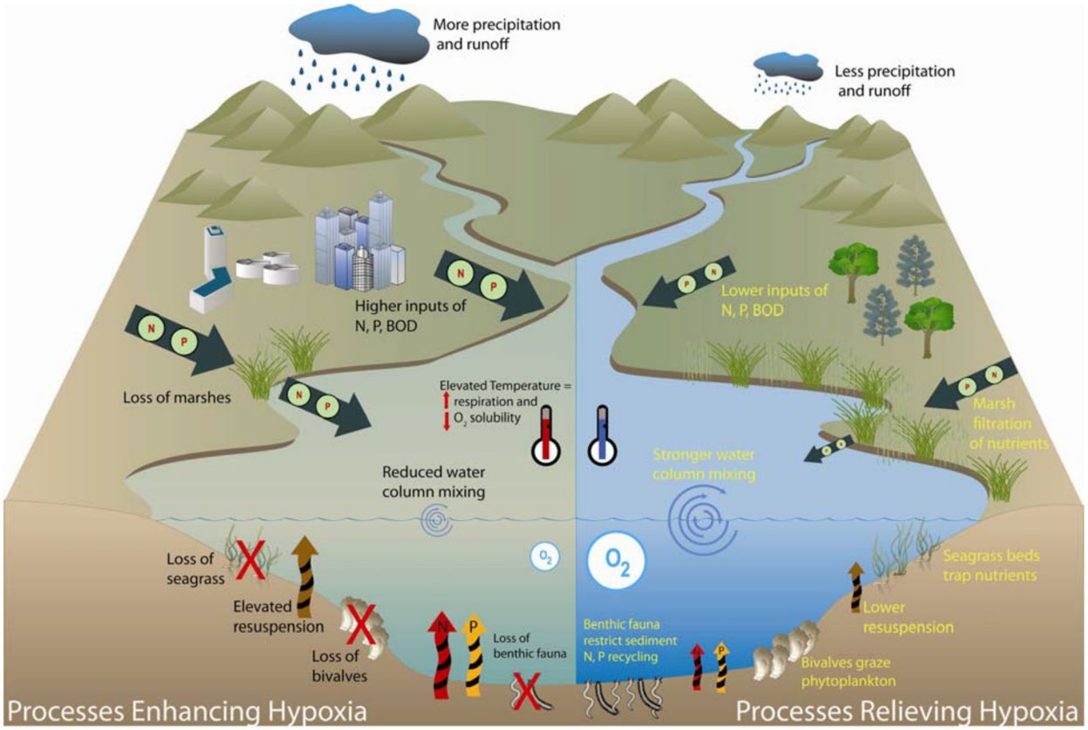


Figure 3.14 Conceptual diagram of factors controlling hypoxia. Left side indicates processes that increase hypoxic conditions including increased precipitation, high nutrient inputs, reduced water mixing, elevated temperature which increase respiration and reduced oxygen solubility. Right side show processes that alleviate hypoxia including lesser precipitation, reduced inputs of nutrients, and filtration of nutrients by vegetation. (Source: Kemp et al. 2009).

In coastal waters where microalgal blooms occur in response to excess nutrient loads, predation by phytoplankton-consuming herbivores is not sufficient to cope with the excess microalgal production. As a result, the unconsumed biomass fall to the ocean bottom and are decomposed by microbes through aerobic respiration, which uses up dissolved oxygen in the process. This process also releases carbon dioxide which acidifies the waters at depth (Cai et al 2011). As such, eutrophication can lead to the formation of hypoxic zones given favorable biogeochemical and physical conditions. The two major drivers of hypoxia are stratification and nutrient loads (notably the previous May nitrate and nitrite loads) (Turner et al. 2012, Obenour et al. 2012). A hypoxic zone is operationally defined as the area where bottom-water dissolved oxygen (BWDO) concentrations are below 2 mg DO L^{-1}. Not all eutrophic coastal systems develop hypoxia, such as in areas where stratification is weak or where water retention times are shorter, despite similarly excessive nutrient loads (Breitburg et al 2009). In open ocean waters, ocean warming decreases the solubility of oxygen, and accounts for more than 50% of oxygen loss in the upper 1000 m of the ocean (Breitburg et al . 2018, Oschlies et al. 2018). For coastal systems experiencing enriched nutrient loads, ocean warming is predicted to intensify deoxygenation through similar mechanisms as the open ocean: increased intensity and duration of stratification, decreased oxygen solubility and elevated respiration (Altieri and Gedan , 2015) (Figure 3.14).

Diaz et al. (2011) compiled 777 scientifically documented hypoxic zones worldwide. Of these, 164 sites in the inventory were located in the WCR, with only 15 located outside of the USA (Table 3.1, Figure 3.15). In comparison, this report assessed 37 river mouth with loads that are N-ICEP positive outside of the USA, indicating the possibility that there are more sites in the WCR that have high potential for eutrophication, but have not been scientifically documented, hence excluded from hypoxic site inventories. Countries with no ongoing research programmes on hypoxia or related research would not be included in such inventories even if hypoxic sites exist in their coastal waters. The establishment of the Global Ocean Oxygen Network (GO2NE) under the aegis of the International Oceanographic Commission, and which is committed to providing a global and multidisciplinary understanding of deoxygenation including promoting capacity development (https://en.unesco.org/go2ne), would go a long way in enabling developing countries to address coastal hypoxia with the best guidance science to national scientists a global community can offer.

Table 3.1 Reported hypoxic zones in the Wider Caribbean Region (Data source: Diaz et al. 2011, *https://www.wri.org/resources/data-sets/eutrophication-hypoxia-map-data-set*).

WCR Sub-region	Country	Reported hypoxic sites
I	Mexico	3
I	US-Florida	91
I	US-Texas	29
I	US-Louisiana	15
I	US-Mississippi	11
II	Belize	2
III	Colombia	3
III	Venezuela	3
IV	Antigua and Barbuda	1
IV	Barbados	1
IV	US Virgin Islands	1
V	Cuba	1
V	Jamaica	1
V	Puerto Rico	2
	Total	**164**

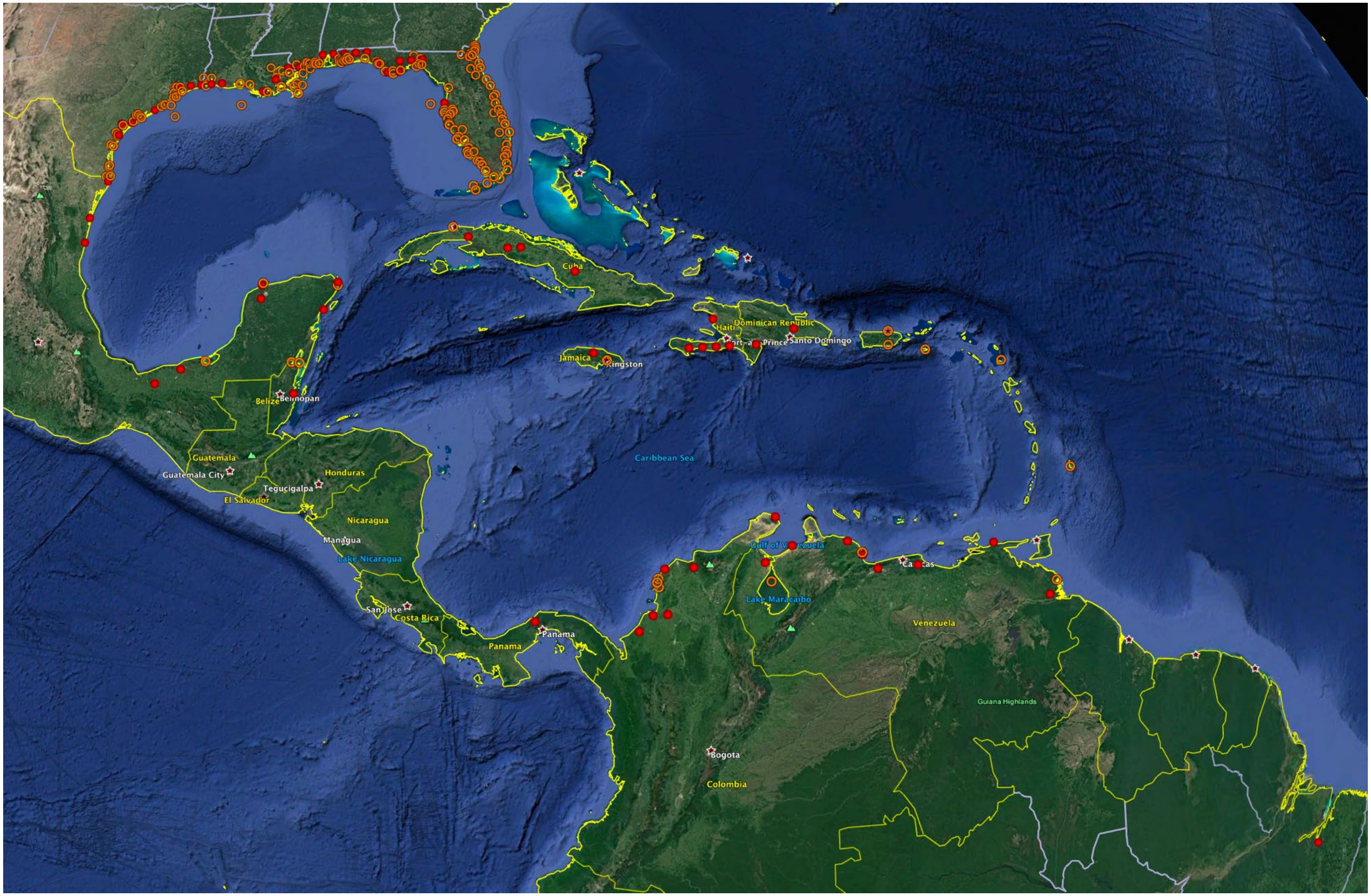


Figure 3.15 Scientifically documented hypoxic and eutrophic sites in the WCR (n=164) compiled by Diaz et al. (2011) in orange open circles. Solid red dots indicate river mouths with nutrient loads assessed in this report to be positive for N-ICEP based on model outcomes for year 2000 at coarse spatial resolution of 0.5° (Mayorga et al. 2010) (See section 3.1.2). The NEWS Model resolved watersheds in continental countries and the big islands of WCR Sub-region V, but not the small islands of Sub-region IV. This report found 37 N-ICEP positive sites outside of the USA; the Diaz et al. inventory had 15 eutrophic and hypoxic sites outside of the USA; hence the potential that more hypoxic sites exist but not yet documented remain high. (Draft map only).

When eutrophic sites become minimum oxygen zones, the risk to biodiversity and ecosystem functions and social as well as economic consequences increase in gravity as well. Diaz and Rosenberg (2008) note that hypoxia follows at the heels of eutrophication with the increased deposition of organic matter, providing enhanced amount of substrate for microbial growth and respiration, which is oxygen consuming (Figure 3.16). If waters become stratified because of local circulation patterns that create a temperature differential between surface and bottom waters, and spring nitrate and nitrite loads are in excess, dissolved oxygen levels can be depleted. With sustained nutrient loading via surface runoff or groundwater nutrient fluxes or both, hypoxia can occur seasonally or over extended periods with serious impact on biota. The much reduced levels of oxygen during hypoxia favors r-selected benthos, i.e. shorter life spans and smaller sizes that characterize opportunistic species. With further accumulation of organic matter and nutrients in the sediments, the system progresses into anoxic condition which favors the release of H_2S. The rechanneling of energy from mobile predators when a system has normal oxygen levels (normoxia) to microbes during severe hypoxic or anoxic state means the loss of structural and functional biodiversity when microbes are favored over the macrobenthos. It also means curtailing the ability of coastal ecosystems to provide services that make up an area's blue economy by the altered geochemistry of sediments and bottom water (Figure 3.16).

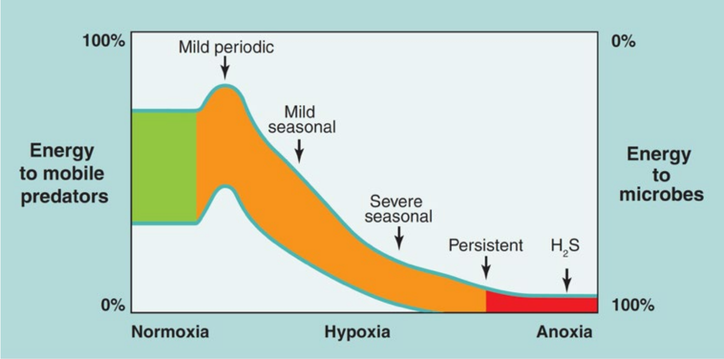


Figure 3.16 How hypoxia alters ecosystem energy flow. Initial increase in phytoplankton biomass (green) provides big but short-lived energy bonus for mobile predators. As oxygen declines, the proportion of benthic organic matter transferred to microbes (orange) increases. Microbes process organic matter with the release of H2S under anoxic conditions. (Source: Diaz and Rosenberg, 2008)

The Gulf of Mexico (GOM) dead zone exemplifies the system shifts of a coastal basin that is subject to sustained flows of nutrients and stratifying waters as described above. Seasonal hypoxia began in the 1950's and accelerated in severity in the 1970s, occurring consistently on an annual basis as borne by a mapping programme initiated in 1985 (Rabalais and Turner, 2019). The area of the hypoxic zone delimited by the 2 mg DO L^{-1} limit has varied, depending on freshwater discharge, and nitrate-N load in the previous May, and further influenced by mixing processes induced by hurricane or tropical storm disturbances or sustained winds that change the water mass configuration. The BWDO can extend up to 23,000 km^2, second only to the Baltic Sea, and up to 140 km^3 in volume (i.e. approx. 6 m above seabed on average; lower 10 m on the eastern Louisiana shelf; 2-5 m above bottom on western Louisiana shelf). It is very important to note that hypoxia has not been a perpetual feature of the gulf, even if stratification is. Persistence of less than 1 mg L^{-1} DO can last from 0.5 to 2 months from May to September, and continues as long as stratification is maintained by the absence of mixing. As such, nitrate-nitrogen loading remains the major driver of hypoxia including an increasing pool of legacy nitrogen; and stratification, the amplifying driver, in the Gulf.

3.1.5 Nutrient pollution, hypoxia and fisheries

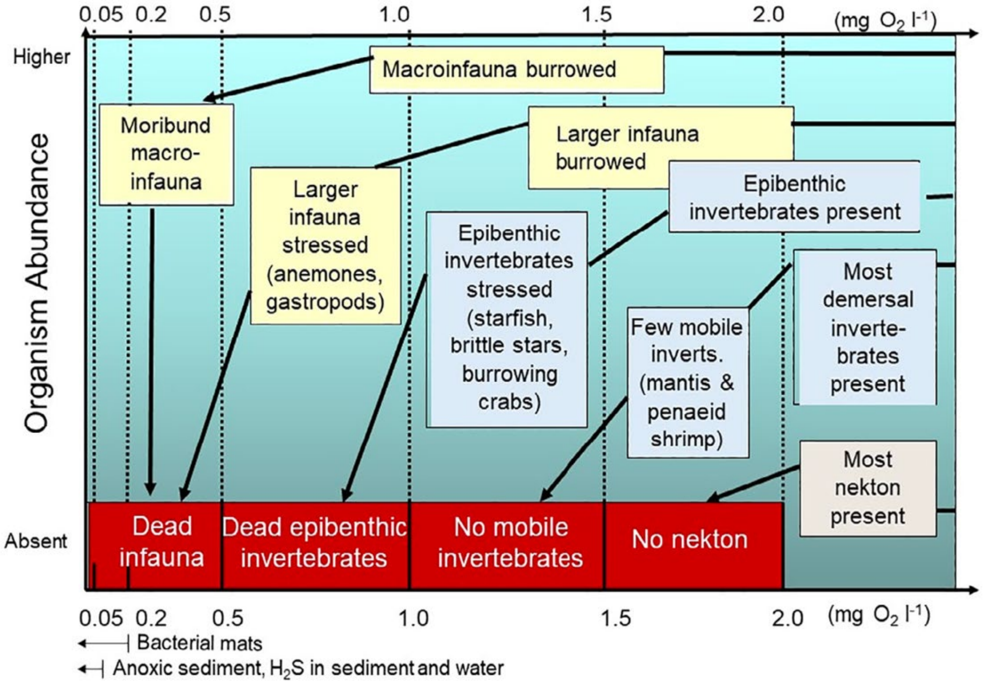


Figure 3.17 Changes in fish and invertebrates as bottom-water dissolved oxygen (BWDO) decreases from 2 mg L^{-1} (hypoxia) to 0 mg L^{-1} (anoxia) (Rabalais and Turner, 2019).

Nekton including fish and shrimps are displaced by low DO concentrations and move away from hypoxic waters. Infauna, those living in the sediments like polychaetes and echinoderms experience die-offs during prolonged periods of suboptimal DO levels (Figure 3.17, Rabalais and Turner, 2019). These are replaced by smaller and fast reproducing species that can tolerate low levels of DO. As such, hypoxic zones have depressed levels of secondary production even post-hypoxia.

How does depressed secondary production in hypoxic zones impact fisheries system-wide? In examining data on fisheries and nutrient pollution status of 30 estuaries and marginal seas, Breitburg et al. (2009) found that hypoxia does not translate to a reduction in fish landings, except in systems where raw sewage is released and which directly impacts critical habitats. Compensatory mechanisms limit the local-scale and adverse effects of hypoxia to be expressed at system scale. An earlier analysis by Micheli (1999) show similar results in that while nutrients generally increase phytoplankton biomass and carnivores decrease herbivore biomass; there remains a weak interaction between phytoplankton and herbivores and expressions of direct interactions diminish through pelagic food webs. A spatially explicit ecosystem model to examine the effects of hypoxia on fish and fisheries in the northern Gulf of Mexico showed that increases in primary production outweigh the decreases because of hypoxia, but that these are species-specific (de Mutsert et al. 2016). The expression of hypoxia on fish landings and on pelagic food web interactions could be insensitive to the direct impacts of hypoxia.

Roman et al. (2019) propose the use of a metrics such Oxygen Stress Level (OSL) which integrates oxygen demand in relation to oxygen availability, along with the critical and lethal species-specific partial pressures of O_2 in describing and comparing hypoxic habitats. Such metrics, which are size- or age-sensitive, capture the interplay of oxygen and temperature as combined drivers of habitat quality or its stress level and could be most relevant in assessing the impacts of hypoxia on secondary production including that of fisheries under conditions of climate warming (Figure 3.18).

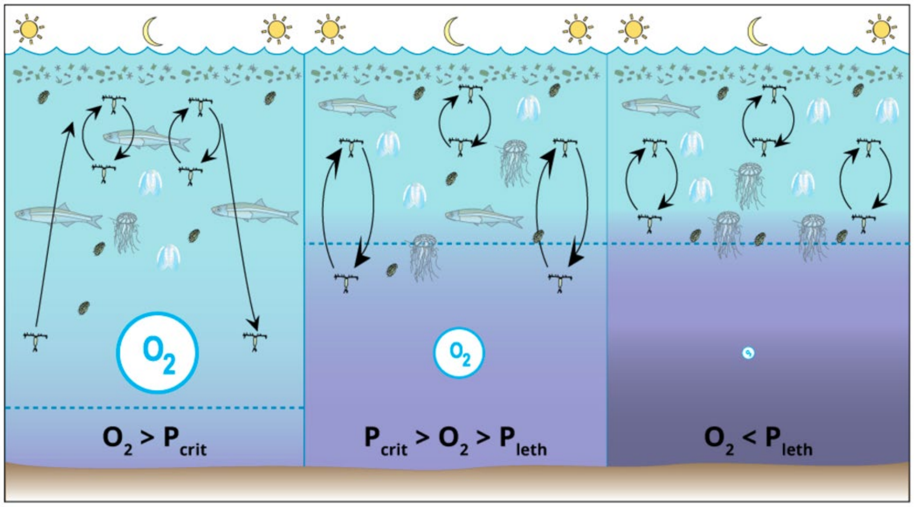


Figure 3.18 A conceptual diagram of food web interactions on a diel cycle including vertical zooplankton migration during normoxia (left when oxygen is abundant (light blue color) and above critical oxygen threshold,i.e. when respiration becomes limited by oxygen supply), hypoxia (middle when oxygen is above lethal oxygen threshold but below critical oxygen threshold), and anoxia (right when oxygen is below the lethal oxygen threshold (purple color). These oxygen thresholds are species and age-specific. With decreasing oxygen concentration, pelagic habitat is reduced, vertical migration is truncated (indicated by the length of down and up arrows, an increase in gelatinous zooplankton abundance, and decrease in forage fish abundance (Roman et al. 2019)

The attempts above to discern the impacts of hypoxia on fisheries have yielded little by way of significant interactions because of the confounding effects of fishing behavior in optimizing catch in areas where hypoxia occurs. Huang et al (2010) developed a bioeconomic model that took into account the lagged effect of hypoxia on the brown shrimp *Farfantepenaeus aztecus*, allowing the authors to integrate oxygen monitoring date with fishery data in time and space. They found that hypoxia could have caused a 13% annual decrease in the brown shrimp fishery during the period 1999 to 2005. Smith et al. (2016) used market prices of size-disaggregated brown shrimp to quantify the impact of hypoxia on the fishery. Hypoxia caused the increase in relative price of the large shrimps compared with that of the small shrimps, as the shrimp population changed in size distribution. Price was naïve to the confounding effects of the movements of the shrimp and the fishing fleet. Because it was disaggregated by size, which in turn was limited by oxygen, a decrease in the fishery was detected.

3.1.6 Nutrient pollution, coral reefs and seagrass communities

This section offers a brief update on the status of coral reefs and seagrass communities of the WCR with respect to nutrient pollution based on recent references for the period 2009 to current. Coral reefs are the foundation of marine tourism in the Wider Caribbean with all reef-associated tourism (on-reef and reef-adjacent tourism) in the insular Caribbean valued at \$8 billion of expenditure and over 11 million visitors per year (Spalding et al. 2018). Coral reef health is pretty much the lifeblood of small island states and territories, and it is at risk from land runoff and domestic waste.

Coral reef status was last examined at regional scale in 2004 through an assessment report called *Reefs at Risk in the Caribbean*, and which highlighted that about a third of reefs were at medium to high risk from sediment and pollution from agricultural land and other land use (Burke and Maidens 2004) (Figure 3.19). Ten years later in 2014, a quantitative status and trends report based on 35,000 quantitative reef surveys, covering the period 1970 to 2012 was published, for the first time documenting foundational and quantitative biological attributes of reefs including coral cover, macroalgal cover/ biomass, sea urchin and reef fish density. Average coral cover for 88 locations with data was 35% (1970 to 1983) to 19% (1984 to 1998) to 16% (1999 to 2011), noting that the decline was significant at 75% of sites with data. Along with this declining coral cover was the increase in macroalgal cover from 7% to 24% during the period 1984 to 1998 and which remained steady, but at even greater variability than the coral cover trends. These opposing trends constituted what was termed a phase shift from coral dominated to macroalgae dominated coral communities and which has persisted for 25 years then (from 1984). The drivers for this massive change considered in the report were: population increase, overfishing, ocean warming (data for all three were available); and coastal pollution and invasive species (for which data was wanting). Except for Secchi disk readings, no water quality parameter or proxy measures were included in the study for lack of consistent monitoring data (Jackson et al. 2014). The control of increasing macroalgal cover, whether by overfishing of herbivorous fish, and/ or by nutrient enrichment, could not then be established at regional scale. The report called for a more systematic and extensive monitoring of water quality throughout the wider Caribbean.

A number of significant studies have continued to examine the role of multiple drivers that influence coral reef dynamics in the region. Examples of published work that quantify nutrient flows from land and document their effects on coral communities in the region are shown in Table 3.2. A number of review papers that have explored the factors that control macro-algal dominance in Caribbean reefs as well as other updated status assessments are provided in Table 3.3. Under present-day conditions, local stressors such as nutrient pollution and overfishing (Littler et al. 2006; Furman and Heck, 2008; Lapointe et al. 2010; Slijkerman et al. 2014; Duran et al. 2018; Lapointe et al. 2019; Gonzalez-de Zayas et al. 2020); sedimentation (Roder et al. 2009), wastewater pathogens (Wear and Thurber, 2015), submarine groundwater discharge (Prouty et al. 2017; Gordon-Smith and Greenway, 2019); and global stressors such as warming temperature, and transport of nutrient enriched-dust (Pawlik et al. 2016), all need to be examined to paint a comprehensive picture of how corals will survive the 21st century. Among these interacting stressors, mitigation of nutrient pollution is addressed in Chapter 5. A broader blueprint of how to save coral reefs and coastal ecosystems that are foundational to the region's blue economy would need to be designed along with their terrestrial counterparts.

Table 3.2 Nutrient pollution impacts on study sites in coral reefs and seagrass beds in the WCR based on literature review from 2009.

Reef location	Findings	Reference and notes
Carrie Bow Cay, Belize Barrier Reef complex	Tested the Relative Dominance Model to explain grazing and nutrients as controls of macroalgal dominance. Findings: 1. Reduced nutrients in combination with high herbivory eliminate all forms of harmful micro- and macro-algae. 2. Eutrophic systems may lose their resilience to inundation by macroalgae, with herbivores being swamped by nutrient-induced harmful algal blooms. Growth of reef-building corals can be inhibited under elevated nutrients even though herbivory remains high.	Littler et al. 2006. Study conducted over 24 months. All forms of DIN ($NH_4^+ + NO_3^- + NO_2^-$), soluble reactive phosphorus (PO_4^{3-}) were determined
Coral reefs, lower Florida Keys, USA	Tested the single and interactive effects of Diadema antillarum grazing and nutrient enrichment on macroalgal community dynamics and concluded that nutrient enrichment is an unlikely explanation for algal overgrowth of coral reefs in the Florida Keys	Furman and Heck, 2008. Field experiment carried out over 78 days; elemental C:N:P carried out
Coral reefs, Cahuita National Park, Costa Rica	Degraded due to chronic siltation with eutrophication, shifting to algal-dominated reef	Roder et al. 2009. Water sampling parameters measured.
Coral reefs, SeaFlower Biosphere Reserve, Caribbean Colombia	Heavily impacted by nutrients and fecal and total coliforms, with sewage discharge as major pollutant	Gavio et al 2010; Water quality parameters measured
Buccoo Reef Complex and fringing coral reefs of Tobago, Trinidad and Tobago	Buccoo Point heavily impacted by wastewater discharges from Tobago with high macroalgal biomass	Lapointe et al. 2010; Water quality parameters measured
Coral reef systems of Cuba off Havana	1. Coral cover uniformly low (approximately 10%), and increased macroalgal cover to approximately 65%. 2. Nitrogen content in algal tissue (Nitrogen DW% and δN^{15}) increased with proximity to Havana suggesting increasing contribution of anthropogenic N sources to reefs 3. Coral reef decline is attributed to local stressors such as coastal pollution and overfishing of herbivorous fish; and to global stressors such as hurricanes.	Duran et al. 2018. Measures of δN^{15} and %DW Nitrogen in *Sargassum histrix* were obtained for all study sites.
Coral reefs, Looe Key, Florida Keys, USA	Degraded from land-based N loading from Everglades discharges	Lapointe et al 2019 based on 30-year monitoring data; Water quality parameters measured
Coral reefs of Cuba and Mexico	1. Majority of sentinel organisms inhabiting the most developed coastal areas, in terms of population and tourism showed higher N contents, lower C;N ratios and higher values of δN^{15} than those near less developed coastal areas. 2. Land-based nutrients from municipal wastewater constitute the primary source of N pollution 3. There is an urgent need to accelerate progress in wastewater treatment systems, in terms of capacity and efficiency, to significantly reduce nutrient inputs to coastal ecosystems	Gonzalez-De Zayas et al. 2020.

Table 3.3 Post-2014 assessments of the status of coral reefs and seagrasses, including reviews of factors controlling macro-algal dominance and resilience of coral reefs in the WCR.

Area of study	Findings	Reference and Notes
Seagrass beds, Caribbean-wide (CARICOMP)	43% of 35 long-term (1993–2007) showed signs of environmental deterioration from increased terrestrial run-off (sewage, fertilizers and/ or sediments) (qualitative observations)	Van Tussenbroek et al. 2014; monitoring did not include water quality parameters because of limited resources
Low resilience of Caribbean coral reefs	1. Coral loss resulted in more abundant seaweeds that release dissolved organic carbon (D)C) consumed by sponges, which release nutrients that enhance seaweed growth. 2. The altered carbon and nutrient cycling alters microbial activity which negatively impacts the coral microbiome. 3. River discharge and windblown dust influence these interactions	Pawlik et al. 2016.
Coral reef systems of Cuba	1. Havana - severely impacted by nutrients and sediments 2. Artemisa - impacted 3. Los Colorados 4. Isla de Juventud 5. Los Canarreos - healthy 6. Peninsula Ancon – low impact 7. Jardines de la Reina- near pristine	Gonzalez-Diaz et al. 2018;
Mexican Caribbean reef systems: Puerto Morelos, Akumal, Cozumel, Boca Paila, Mahahual, Chinchorro Bank	Increase in fleshy macroalgae cover associated with substantial eutrophication and water pollution caused by inadequate wastewater treatment	Rioja-Nieto and Alvarez-Filip, 2019
USA coral reefs	1. Southeast Florida : 62% (Impaired) 2. Florida Keys: 71% (Fair) 3. Dry Tortugas: 73% (Fair) 4. Flower Garden Banks, Gulf of Mexico: 89% (Good) 5. Puerto Rico: 70% (Fair) 6. US Virgin Islands: a. St. Croix: 73 (Fair) b. St. Thomas & St. John: 69% (Fair) Scoring scheme: • **90 to 100% (Very Good**): All or almost all indicators meet reference values; conditions not impacted, minimally impacted or have not declined. • **80 to 90% (Good):** Most indicators meet reference values; conditions are lightly impacted or have lightly declined. • **70 to 79% (Fair):** Some indicators meet reference values. Conditions in these locations are moderately impacted or have declined moderately.	These assessments are Coral Reef Status Reports 2020 by the NOAA Coral Reef Conservation Programme. No explicit indicators for water quality were used.

	• **60 to 69% (Impaired):** Few indicators meet reference values. Conditions are very impacted or have declined considerably. • **0 to 59% (Critical):** Very few or no indicators meet reference values. Conditions are severely impacted or have declined substantially	
Caribbean coral reefs	1. Caribbean coral reefs have been under assault from climate change-related maladies since the 1970s 2. Macroalgal dominance appears not to be a stable alternative community state. 3. Loss in regional coral cover and associated changes in the benthic community are related to punctuated discrete events with known causes (coral disease and bleaching)	Precht et al. 2020. Study was based on a review of a regional data set of information on the benthic composition of Caribbean reefs spanning the years 1977-2001.

3.1.7 Nutrient pollution and nuisance *Sargassum* bloom

Drivers, origin and maintenance of *Sargassum* bloom

Since 2011, pelagic *Sargassum* wracks have been beached annually along the coasts of insular Caribbean, the Caribbean coasts of Mexico and Central America, the US Gulf states, and the Atlantic coastline of tropical West Africa, in variable but unusually large quantities. The optical signature of this massive bloom formation has been called the "great Atlantic *Sargassum* belt" (Wang et al. 2019). Under normal conditions, pelagic species *Sargassum fluitans* and *S. natans* are inhabitants of a sub-tropical oligotrophic gyre known as the Sargasso Sea (Figure 3.19). The spread of these species well beyond the Sargasso Sea is a subject of scientific investigation given its immediate economic consequences on tourism and growing public health impacts in the WCR. A brief review of *Sargassum* wracks in this section aims to explore if land-based pollution can potentially contribute to the maintenance of this nuisance macroalgal bloom.

Johns et al. (2020) provides a comprehensive hypothesis for the origin, spread and maintenance of the *Sargassum* bloom as a basin-scale (i.e. Atlantic basin) long distance dispersal event that has reached a new equilibrium state beginning in the winter 2009-2010 when the spread began. The features and chronology of this hypothesis are described below (https://www.aoml.noaa.gov/chasing-sargassum/) (Figure 3.19):

a. "During the winter of 2009-2010, winds that typically blow to the east from the Americas to Europe, strengthened and shifted to the south, a very unusual event that triggered a long-distance eastward dispersal of *Sargassum*, from the Sargasso Sea, toward the Iberian Peninsula in Europe and West Africa.
b. "After exiting the Sargasso Sea, the *Sargassum* drifted southward in the Canary Current (CC) and entered the tropics. In this new and favorable tropical Atlantic habitat, with ample sunlight, warm waters and nutrient availability, the floating macroalgae flourished and has since continued to grow.
c. "Having established a new population, the *Sargassum* now aggregates almost every year in April–May in a massive windrow or "belt" north of the equator, along the region where the trade winds converge (Inter-Tropical Convergence Zone or ITCZ).

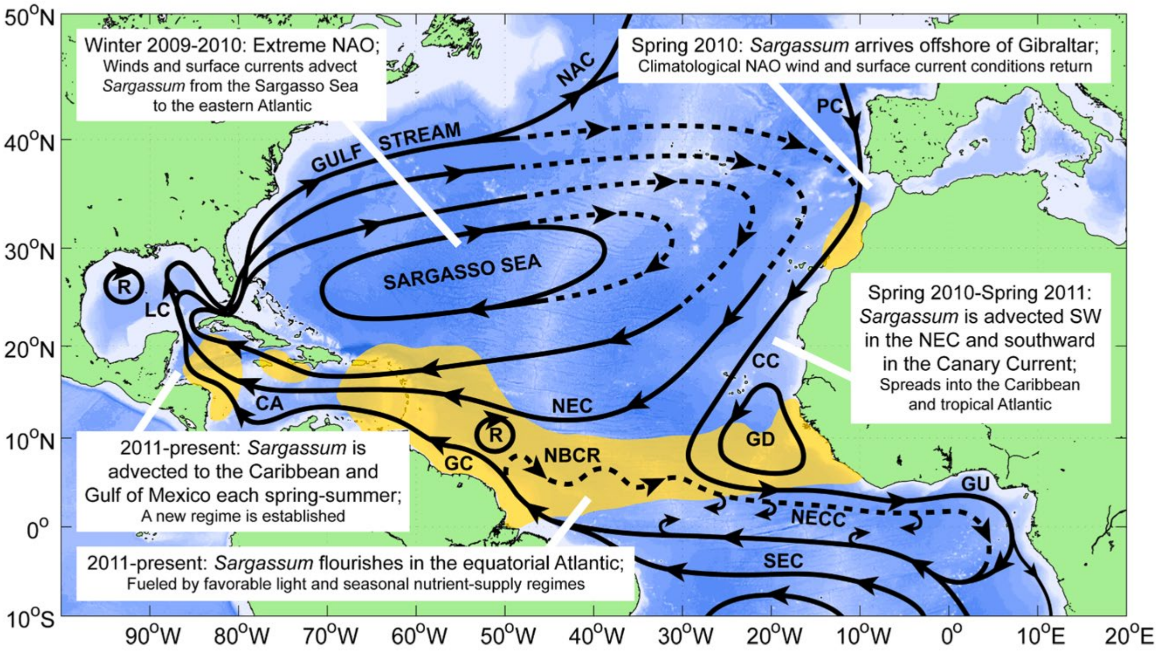
d. “During the spring, the *Sargassum* follows this convergent region’s northward seasonal excursion. By June, the belt stretches across the entire central tropical Atlantic.

e. “Large portions of the algae are then transported to the Caribbean and Gulf of Mexico via the North Equatorial Current (NEC) and Caribbean current systems.

f. The western portion of the macroalgal accumulation also benefits from nutrients in the Amazon River plume. However, a 2021 study by Jouanno et al. provides 15-year data on riverine nutrient export of the rivers Amazon, Orinoco and Congo to the tropical Atlantic. Their analysis showed decreasing trends in phytoplankton biomass for the period 2004-2018, leading them to conclude that riverine plumes are not likely the first order drivers of the nuisance macroalgal bloom.

g. In October, the convergence of the trade winds starts to move back south, weakens and loses the ability to concentrate *Sargassum.* A large *Sargassum* row is left behind and remnant patches of the macroalgal population remain dispersed in the central tropical Atlantic around 10-15°N. The remnant patches provide a seed population for the accumulation under the convergence zone the following year.

h. Nutrients distributed by eddy diffusion and wind mixing of the surface water layers, including those of the Amazon and Orinoco Rivers, and the West African Upwelling, sustain the remnant blooms, till the following year.



Winter 2009-2010: Extreme NAO;
Winds and surface currents advect *Sargassum* from the Sargasso Sea to the eastern Atlantic

Spring 2010: *Sargassum* arrives offshore of Gibraltar;
Climatological NAO wind and surface current conditions return

Spring 2010-Spring 2011: *Sargassum* is advected SW in the NEC and southward in the Canary Current;
Spreads into the Caribbean and tropical Atlantic

2011-present: *Sargassum* is advected to the Caribbean and Gulf of Mexico each spring-summer;
A new regime is established

2011-present: *Sargassum* flourishes in the equatorial Atlantic;
Fueled by favorable light and seasonal nutrient-supply regimes

Figure 3.19 Schematic showing the chronology of formation and transport of *Sargassum* bloom in 2009-2011 to present. (Source: Johns et al. 2020)

As a pelagic seaweed, *Sargassum* provides critical habitats for open ocean organisms including important fish species such as tuna, dolphin, wahoo and billfish, as well as sea turtles and marine birds. As such, a Fishery Management Plan for Pelagic *Sargassum* Habitat in the US South Atlantic Region was approved in 2003, and the plan since then has implemented strict restrictions on commercial harvest of this important fish habitat (https://safmc.net/fishery-management-plans-amendments/sargassum-2/).

Impacts of *Sargassum* blooms

When *Sargassum* wracks are transported across shallow coastal waters where corals and seagrasses grow, and land on beaches throughout the WCR, they become nuisance macroalgae with adverse consequences not yet fully understood for biota and people alike. In coastal waters, their decomposition along the Mexican Caribbean coast in 2015 led to reduction in light, oxygen and pH (van Tussenbroek et al. 2017). The nutrient influx was estimated at 6150 kg N km^{-2} and 61 kg P km^{-2}, approaching eutrophic conditions, and causing the replacement of meadows of the seagrass *Thalassia testudinum* with drifting algae and epiphytes. Leachates from decaying *Sargassum* caused hypoxic conditions and reduced the diversity of food sources for a keystone herbivorous sea urchin *Diadema antillarum*, and exacerbated by reduced dissolved oxygen that is crucial to the physiological survival of this sea urchin and many other reef biota (Cabanillas-Teran et al 2019). These two sites were not eutrophic before the arrival of *Sargassum* strandings. A question remains how coastal waters that are already eutrophic or hypoxic before the macroalgal bloom from land-based sources further enhance the growth of *Sargassum*, which would also be in active bloom phase. The hypothesis elaborated by Johns et al. (2020) indicates that enriched river plumes from Amazon and Orinoco help feed the bloom during transit. The same interaction can happen with coastal eutrophic waters.

In addition to precipitating eutrophic and hypoxic conditions in coastal waters, *Sargassum* strandings were found to harbor potentially pathogenic bacteria, including Vibrio and Alteromonas (Michotey et al. 2020). High *Sargassum* growth rate seemed to favour successful colonization by pathogenic bacteria. More studies are required to see if the overall algal growth rate throughout the algae's dispersal routes would allow viable colonization by pathogens that would impose additional health risks when wracks reach coastal areas.

Once algal strandings reach land, these encroach on a much valued natural asset of tourism, the sandy beaches of the Caribbean. Mexico has spent $17 million removing the seaweed since it drifted to its Caribbean-facing shores in 2011., where clean-up costs was estimated at $1000 per meter of coastline (Chavez et al. 2020, Taylor 2019). After 48 hours on shore, decaying *Sargassum* begins emits hydrogen sulphide and ammonia gases, which can cause gaseous intoxication and potentially fatal lesions (Resiere et al. 2018). Between January and August, 2018, when the *Sargassum* reached its widest extent to date, Guadeloupe reported over 3300 cases, Martinique with 8000 cases of acute exposure. The French Government committed to supply equipment for seaweed removal within 48 hours from seaweed beaching, monitor H_2S gas concentrations on impacted shores, and to train medical personnel in toxicology , to the tune of Euro 10 million.

A systematic assessment of the ecological, economic, and public health impacts of *Sargassum* strandings at national and regional scales are at an incipient stage. In 2018, the UNEP Caribbean Regional Coordinating Unit sent out a survey to National Focal Points to provide a rapid regional-scale albeit qualitative assessment of the extent of *Sargassum* influx in the WCR (Figure 3.20). The island states and territories of the Lesser Antilles (WCR Sub-region IV), the USA and Mexico experienced the most severe strandings in the region in 2018. Tourism and fisheries were considered by 86% and 75% of survey respondents, respectively, to be the top economic sectors most affected by the nuisance macroalgal bloom (Figure 3.21a). Beach fouling and dead fish were noted by 71% and 61% of respondents, resp. as the most widespread consequences (Figure 3.21b).

To aid in the comprehensive monitoring of *Sargassum* influx, Trinanes et al. (2021) described the *Sargassum* Inundation Report (SIR), a weekly overview of the risk of *Sargassum* strandings in the WCR. The weekly risk forecasts are based on satellite observations, beginning July 2019 and are available for public access at https://www.aoml.noaa.gov/phod/*sargassum*_inundation_report/. Annex 3.1 provides weekly *Sargassum* inundation risk reports for the week of March 31 to April 6, 2020; and for the week of March 30 to April 5, 2021 to enable comparison of weekly risks s over a one-year interval.

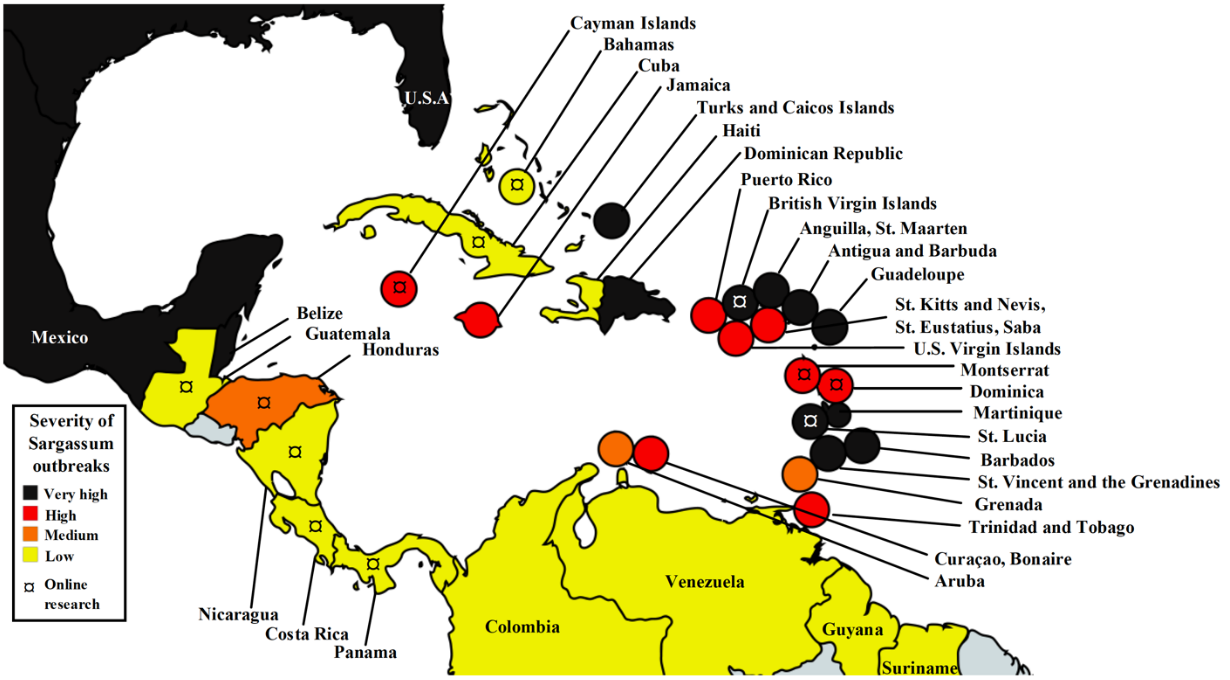


Figure 3.20 Severity of *Sargassum* strandings in the Wider Caribbean Region based on survey responses by 22 National Focal Points, satellite observations and online searches. (Source: UNEP CAR/RCU, 2018).

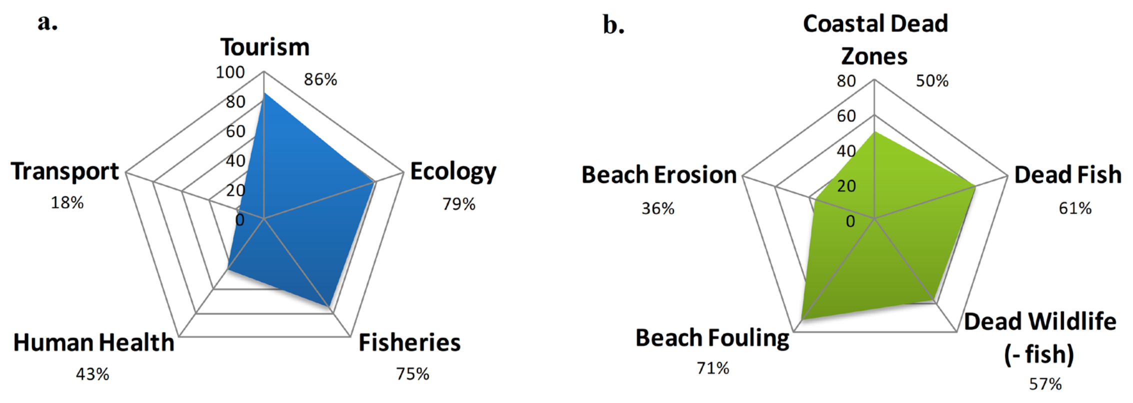


Figure 3.21 Percentage of territories where ecology and economic sectors have been adversely affected by Sargassum blooms (a); and where ecosystem impacts have occurred as a result of the strandings (b). Survey sample size, n = 28 territories. (Source: UNEP CAR/RCU, 2018).

Sargassum as potential economic resource

An obvious question is whether there are opportunities to be had with a nuisance macroalgal bloom that may be poised to become another environmental normal like global warming. An initial quantification of the carbon stock contained in the *Sargassum* bloom is 13.1 billion tons (13.1 Pg) at the global scale, comparable to the above-ground biomass of mangrove forests, salt marshes or seagrass meadows (Gouvea et al. 2020). As such, it could potentially remove CO_2 from the atmosphere through photosynthesis and convert it to biomass if maintained as living algae in bloom proportions. A huge and major question is how to manage carbon sequestration by macroalgae at such a transnational scale given the ecological, public health and economic costs the nuisance algae has so far imposed in the region.

An initial scoping of three morphotypes of the seaweed found that they contained a high amount of arsenic, and as such could not be used for human nutritional products (Davis et al. 2020). The seaweed types also contained low amounts of alginate which is a commercially important additive used in the food industry. Another potential use of *Sargassum* wracks that is being explored is as biosorption and bioaccumulation medium, a non-living biomass that can bind and capture pollutants in coastal waters, and which can be potentially recycled within an overall framework of circular economy (Saldarriaga-Hernandez et al. 2020; Desrochers et al. 2020).

Many questions remain about the nuisance *Sargassum* bloom as a climate change-induced oceanographic phenomenon and as a potentially new normal. Societies in the WCR, and humankind in general, need to seriously strategize how to address it to ensure the viability of blue economies at global, regional and national scales and for the long-term. As if the multifaceted issue of nutrient pollution is not enough, this basin-wide problem appears to magnify humankind's misappropriation of the ecosystem services at global scale and with asymmetric distribution of adverse impacts, so that the WCR faces uniquely grave consequences:

Scale	Nature of nuisance *Sargassum* bloom	Mitigation (see Chapter 5)
Global	**Root cause**: Wanton use of fossil fuels is heating up the planet and changing climate patterns	Acknowledgement and commitment to mitigate at global scale by reducing global carbon emissions that will minimize the *Sargassum* bloom in extent and duration. Formal articulation should be Incorporated into the Paris Accord. The IPCC should model and validate whether the 1.5°C temperature goal is sufficient to dissipate the *Sargassum* bloom in its periodic assessments, if at all possible.
Basin-wide (Atlantic basin)	**Proximal cause**: Trade winds convergence zone is pushed southward triggering the basin-wide dispersal of pelagic *Sargassum* eastward to the Iberian coast, then southward and westward to the Caribbean Sea >>Patches of the seaweed to seed the blooms have already been dispersed beginning in winter of 2009-2010	
Regional (WCR)	**Immediate manifestation**: Nuisance *Sargassum* bloom is wreaking havoc on coral reefs and seagrasses, on tourism and fisheries, and is putting public health at risk. Given its genesis, a return to pre-bloom condition may not be possible. **Potential resource use:** Processing of seaweed to fertilizer, paper, cosmetics and other marketable products are being explored while addressing the issue of hydrogen sulfide, arsenic and other heavy metals that can exacerbate further negative impacts when leached into the marine environment as bioactive compounds.	The Regional NPRSAP provides a framework for reducing nutrient pollution from land-based sources, including the potential to develop Sargassum sp.-based livelihoods

If the premise is true that the root cause of the *Sargassum* bloom is climate change, then it must be acknowledged as such by the global community. Further, its mitigation should be incorporated into the Paris Agreement on Climate Change including community modelling to determine climate conditions that can possibly disrupt the formation and maintenance of the bloom. The WCR countries, notably the region's small island states, should receive development aid (capacity building in science and technology) to strategically address the impacts enumerated above. The region needs to minimize its exposure from the nuisance seaweed bloom-induced eutrophication by curbing land-based sources of nutrient pollution emanating from the region's watersheds (Chapter 5), including those from the Amazon and Orinoco river basins.

3.2 SOCIAL IMPACTS

The social impacts of environmental health referenced to nutrient pollution would include exposure of people to hazardous substances in the air, water, soil and food, climate change, occupational hazards, and the built environment, following a framework used by US Office of Disease Prevention and Health Promotion (https://www.healthypeople.gov/2020/topics-objectives/topic/environmental-health). The issue of vulnerable populations as it relates to gender, age and occupation will be included where data is available.

3.2.1 Exposure to pesticides

The use of chemicals for crop protection is discussed in Chapter 2, Section 2.3. Part of the the WCR are five of the top 10 countries with the highest pesticide application rates in the world, based on averages over a 28 year period from 1990 to 2018: Bahamas (#1), Costa Rica (#2), Barbados (#3), Saint Lucia (#5) and Colombia (37) per ha of cropland per year. Costa Rica uses the most pesticide per person than any other region in the world – 2.4 kg pesticides per person per year averaged from 2000 to 2004 (Bravo et al. 2011). Calibrated to every individual farm laborer for the same period, the estimate for Costa Rica is 42.5 kg active ingredients per laborer per year. In terms of toxicity, the pesticide imports for Central America over the 5 year study period was classified by toxicity level of active ingredients as follows:

(1) acute, high to extremely high toxicity: 22.4%;
(2) moderate to severe toxicity: 36.1%;
(3) chronic toxicity, 29.7%; and
(4) pesticides in at least one hazard group 65.2%.

The groups overlap since the toxicity levels are determined at the level of active ingredient, and the pesticide products each comes in combination of one or more active chemicals. Notwithstanding the combination of toxicity levels each individual farm worker handles, a usage of 42.5 kg/ year over 300 workdays in Costa Rica translates to about 0.85 kg per week of exposure.

The Population Reference Bureau in its 2001 study estimated that Central America would have roughly 4.6 million child workers between the ages of 5 to 14; of which 70% or 3.2 million would be working in the agriculture or forestry sectors. The likelihood that they were exposed to pesticides at the estimated rates above was highly likely. Data reported by the Pan American Health Organization (PAHO) reported about 6,500 cases of acute (i.e. short-term) pesticide poisoning in Central America in year 1999, of which 60% was labor-related. In 2000, PAHO documented 247 cases of children suffering from pesticide poisoning under the age of 15 in El Salvador, 142 cases in Honduras, 101 in Costa Rica and 60 in Guatemala, with 16 fatalities.

Older data sets provide further insights on populations at risk of exposure to pesticides. During the period 1980 to 1986, farm workers in Costa Rica with the highest incidence of pesticide injuries were those age 20 to 29 years, because of faulty equipment, windy conditions during spray application or spills during transfer or mixing (Araya et al 2014). A 1996 study that cross-referenced banana plantation workers with the Costa Rican National Tumor Registry showed an elevated risk of melanoma and penile cancer in men, an increase risk of cervical cancer in women, as well as a heightened risk of leukemia and lung cancer for banana plantation workers in general (Wesseling et al. 1996). A follow-up study in 1998 showed that areas in Costa Rica where coffee farms were concentrated, and which heavily used the pesticide paraquat, the incidences of lip, esophagus and stomach cancer were elevated (Wesseling et al. 1998). In areas where banana plantations dominated and which frequently used pesticides chlorothalonil, mancozeb and dibromochloropropane, respiratory, ovarian and prostate cancer had increased frequencies.

The human toll from pesticide exposure is very much underestimated given the paucity of up-to-date data and absence of systematic studies to quantify and disaggregate the labor force by gender and age group. The lack of occupational protection for children, women and men who grow the region's food and export crops should be addressed for serious public and environmental health concerns. As mentioned in Section 2.3 of this report, the application of pesticides can be done in prophylaxis mode, and at rates that protect workers and ecosystems, as well as crops and produce. Occupational safety standards would need to be established, and outreach programs developed to ensure that risks are reduced. A good model to emulate regarding design of safety standards in the region is one done by the Ghanian Banana Occupational Health and Safety Initiative (BOHESI) which produced a set of guidelines on healthy and safe employment of women in the Ghanaian banana industry (BOHESI 2019). The guidelines were explicit and detailed in explaining the key hazards and risks for women that were unique to their physical and physiological make-up. Likewise, it would be wise to have only adult and trained workers to handle pesticides.

3.2.2 Exposure to domestic waste pathogens

Section 2.4 of this report provided model estimates of untreated sewage released in the environment for year 2000 at 23.3 thousand tons N, and 3.1 thousand tons P (Beusen et al. 2016). An inventory-based estimate updated for year 2010 was computed by the authors at 39 thousand tons N and 13 thousand tons P. Beyond the nutrient contribution of untreated sewage is the pathogen load these amounts carry. An analysis of available data on diarrhea for the period 1990 to 2016 was analyzed by the authors to determine the extent to which environmental factors contributed to diarrhea disease risks. Figure 2.8 indicates that environmental factors (unsafe water, sanitation and handwashing) increased risk of diarrhea from 29% in 1990 to 65% in 2016, for both sexes, and all ages. Diarrheal diseases that caused the most deaths for children under 5 years were Cholera, rotaviral enteritis and shigelliosis; diseases that led to death for all ages were Cholera, *Clostridium difficile* and rotaviral enteritis.

In a 2007 study of the UN Economic Commission for Latin America and the Caribbean (ECLAC), it was found that in 15 countries of the LAC, around 28 million children aged 0 to 5 years had difficulties to access drinking water and a sewage system (Hopenhayn and Espindola 2007). For 7 countries for which data was disaggregated, rural populations have the least access to sanitation, with indigenous and children and adolescents of African descent, being most affected. The age group 0-5 is the period of high risk to infectious-contagious diseases, dehydration, mortality due to child diarrhea and malnutrition, with long-term cognitive impairment and inferior school performance (ECLAC 2007). Providing improved drinking water and access to improved sanitation is an investment for the next generation's well-being, including a healthy environment.

3.2.3 Exposure to Harmful Algal Blooms (HABS) and nuisance *Sargassum* bloom

The environmental impacts of HABs is discussed in Section 3.1.3; and those of the *Sargassum* bloom in Section 3.1.7. Populations affected by HABS and *Sargassum* have not been well documented. It is important that health officials treat these environmental health diseases or syndromes like any disease, requiring full medical documentation that can be co-designed with environmental scientists so that the chronology from symptoms to full disease presentation is captured including associated environmental factors. These data sets can then be analyzed from the dual lens of health and ecology so that mitigation is holistic and strategies can be focused at the nexus. The identification of human subpopulations (e.g. children, women, fisheries and tourism workers) most at risk can help design programs for both awareness raising and prevention.

3.2.4 Environmental nutrient enrichment and disease emergence

The increase of nutrients from land to sea can trigger an upsurge of parasitic and infectious diseases that can threaten humans, livestock and wildlife (Figure 3.22) (McKenzie and Townsend, 2007; Johnson et al. 2010; Rohr et al. 2019). Coral pathogens respond positively to nutrient enrichment as in the cases of aspergillosis and agents of Yellow Band Disease which increased in outbreaks with increases in nutrient runoff (Johnson et al. 2010).

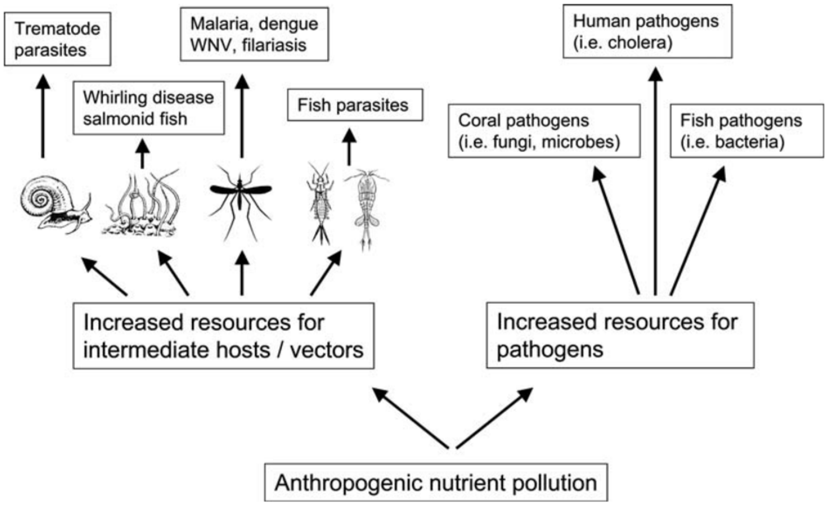


Figure 3.22 Conceptual diagram showing how disease intermediate hosts and vectors and pathogens can respond positively to environmental nutrient enrichment. (Source: McKenzie and Townsend, 2007).

In wetland areas of the Caribbean such as in Belize, phosphorus-enriched runoff from agriculture and settlements caused a replacement of rush vegetation with tall dense cattails. Cattails provided habitat for the mosquito *Anopheles albimanus*, which is an efficient vector of the malaria parasite *Plasmodium* (Grieco et al. 2006*).*

In public health jargon, parasitic and infectious diseases afflict those in poverty and are often overlooked by the health sector. These are referred to as Neglected Diseases of Neglected Populations (Ehrenberg and Ault, 2005). Parasitic diseases, whether transmitted by vectors, via food, or water-borne, often afflict school-age children, women of childbearing age or heads of households (male or female). As such, reducing nutrient pollution, becomes even more compelling in light of vulnerable populations with the heightened risk they face with increasing nutrient flows.

3.3 ECONOMIC IMPACTS

Shortle and Horan (2017) consider nutrient pollution as a wicked problem for economic valuation given the complexity of interactions and the multiple sources, pathways, fates and cycles involved and made manifest at multiple scales. Even if entirely manmade in origin, just like plastics, the issue of nutrient pollution is both planetary (because of ocean circulation and land-sea-air interactions) and watershed-scale at the same time. In assembling the information for this section, there is no attempt to make dollar estimates cohesive across topics; and are enumerated to provide minimal estimates of partial costs incurred that are associated with the most direct impacts.

3.3.1 Costs of Nutrient Pollution in Freshwater Systems

The US Environmental Protection Agency (US EPA) compiled cost data for nutrient pollution. For this document, valorized items relevant to freshwater events are selected and are summarized in Table 3.4.

Table 3.4 External costs of nutrient pollution in freshwater systems (US EPA 2015). Total costing is not possible as the estimates were from disparate sources with sites of different spatial scales and temporal coverage.

Category	Cost	Economic Effect
Lakeside Tourism and Recreation	\$37 to \$47 million	Declining restaurant sales, increased lakeside business closures, decreased tourism spending
Property values	\$61 to 85,000	Amounts indicate the change in value with 1-meter difference in water clarity; not the entire value of a property
Drinking water treatment costs	\$13 million in 2 years	Treatment of lake water affected by algal blooms
Mitigation	\$11,000 for a single year of barley straw treatment; \$28 million in capital; \$1.4 million in annual operations	Site-specific costs
Restoration	\$2.4 million across 3 years	Site-specific costs

3.3.2 Costs of Harmful Algal Blooms in Coastal Waters

Hoagland et al. (2002) estimated the economic effects of harmful algal bloom events in coastal waters in the US during the period 1987–1992. The authors noted the accounting issues and data gaps that could make the estimates less meaningful. The costs included four basic types of effects: public health, commercial fisheries, recreation and tourism, and monitoring and management. Because the study was done at national scale for all components, the authors were able to provide total costs as minimum estimates.

Table 3.5 Summary of economic effects of HABs in the USA (year 2000 $ millions)(Hoagland et al 2002). This report updated the total costs to 2021 USD.

Category	Min	Avg	Max	Economic effect
Shellfish Poisoning	<1	<1	1	Productivity losses and medical costs of morbidities and mortalities from poisonings
Ciguatera Fish Poisoning	15	19	22	Productivity losses and medical costs of morbidities and mortalities from poisonings
Commercial Fisheries	7	12	19	Direct output impacts of fishery closures in actual fisheries
Untapped Fishery Resources	0	6	9	Direct output impacts of fishery closures in hypothetical (untapped) resources
Recreation and Tourism	0	7	29	Reduced expenditures from recreational fishery closures; slowed coastal hotel and restaurant trade and tourism
Monitoring and Management	2	2	2	Government budgets and expenditures for environmental sampling, administration of closures and seafood consumption warnings and beach cleanups
Total costs 2000 $	24	46	83	Majority of effects across categories are direct output impacts
Total costs 2021 $ (2000$ X 1.52)	36	70	126	Inflation rate adjusted costs.

3.3.3 Costs of Nuisance *Sargassum* Bloom

Table 3.6 lists the preliminary costs and events associated with the nuisance *Sargassum* bloom. A systematic assessment may provide approximate costs of impacts at the scale of the WCR. Affected countries could provide national data which can be assessed using a common indicator-based framework, so that these could be scaled up to the region.

Table 3.6 Summary of economic effects of nuisance *Sargassum* bloom. No full costing of damages has been done in any of the affected sites in the WCR.

Category	Costs	Economic effect
Beach Clean-up	$1,000 per meter of beach (Mexico) $45 million per year (Florida, USA)	$17 million spent by Mexico since 2011 to remove 520,000 tons of seaweeds, plus $2.6 million to remove 85,000 tons in 2019 (Chavez et al. 2020) or removal cost of $33/ton of seaweeds;
H_2S and NH_3 Gas Intoxication	No data	Euros 10 million grant by the French government to do medical surveillance and training and beach cleanup in Guadeloupe and Martinique (Resieri et al. 2018)
Damaged coral reefs	No data	Caused by nuisance-bloom induced eutrophication over Mexican coral reefs (Cabanillas-Teran et al 2019)
Damaged seagrasses	No data	Caused by nuisance-bloom induced eutrophication over Mexican seagrasses (van Tuessenbroek et al. 2017)
Lost Tourism Revenues	No data	Occupancy dropped during nuisance blooms and hurricanes
Lost Fishery Revenues	No data	Barbados: Losses by harvest and post-harvest sectors for the period 2010-2015 (Ramlogan 2017)

3.3.4 Costs of Mitigating Nutrient Pollution-Induced Diseases

In Section 3.2, the social impacts of nutrient pollution is discussed. The costs of mitigation programs to minimize the risk of affected populations should be assessed in order to get a more complete picture of the benefits of nutrient pollution reduction. Curbing nutrient and pesticide flows saves money, minimizes exposure to risks of disease caused by eutrophication, and destresses ecosystems. That tipping points in ecosystem or climate states appear to have been crossed leading to an almost perpetual nuisance algal bloom should compel the design of strategies to be systemic and strategic. A plan that acknowledges the interplay between nutrient pollution and climate change can prioritize medium- and long-term targets, and create a buffer to soften the impacts of non-linear and unpredictable eventualities (Figure 3.23) (see Chapter 5).

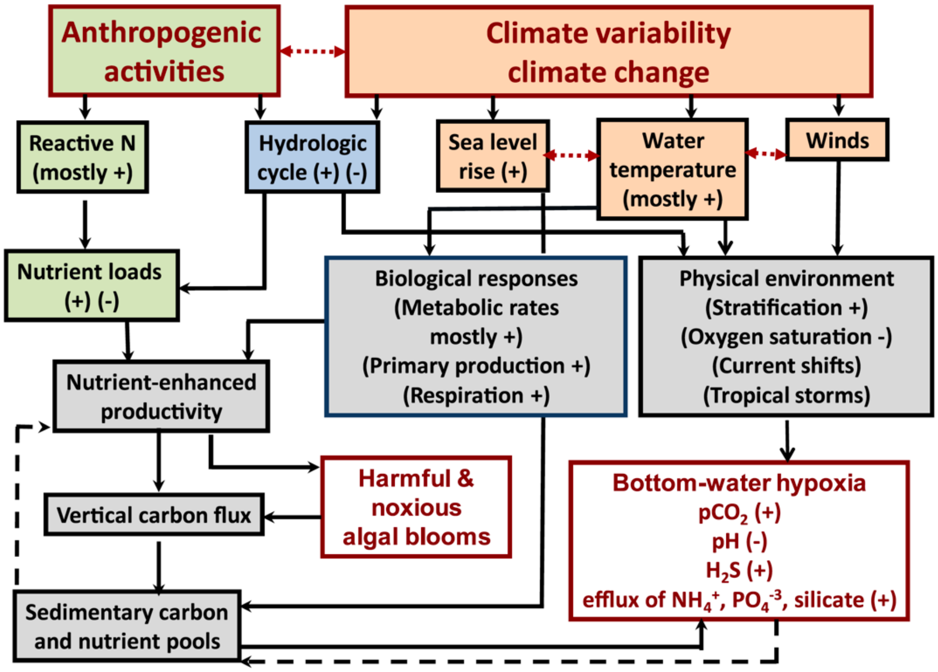


Figure 3.23 Interactions between climate and nutrient pollution -induced changes (Rabalais and Turner 2019). Positive (+) interactions indicate processes or parameters that will increase; negative (–) interactions show those that will decrease. Dashed lines show negative feedback process that can dampen nutrient-enhanced production and resulting hypoxia. The dotted line between Anthropogenic Activities and Climate change indicates that humans mostly drive contemporary climate change, and that climate change will have consequences that seriously affect human activities. (Source: Rabalais and Turner, 2019).

4 EXISTING FOUNDATION FOR ADDRESSING NUTRIENT POLLUTION IN THE WIDER CARIBBEAN REGION

4.1 INTRODUCTION

The preceding chapters provide an overview of nutrient pollution in the Wider Caribbean Region (WCR) countries and territories including pollution sources, nutrient loads to coastal waters from land-based sources and activities and the state of coastal waters. Chapter 4 presents an overview of the current governance approaches and the situation in the region in terms of existing capacities (enabling conditions) for nutrient pollution and identifies some of the major gaps and barriers that will need to be addressed for effective implementation of the RNPRSAP and action plan (Chapter 5). The information in this chapter can contribute to establishing a baseline against which implementation of the strategy can be assessed. The focus of Chapter 4, which is not intended to be an exhaustive analysis, is on the national level with information provided at the regional and global levels where appropriate. Chapter 5 integrates the country level information with global and regional information in a wider analysis of enabling conditions that are necessary for implementation of the RNPRSAP.

Information on the countries is based primarily on the sub-regional reports for the English and French-speaking countries and territories (IMA, 2020) and the Spanish-speaking countries (CIMAB, 2020), and the national reports for the North Brazil Shelf Large Marine Ecosystem (NBSLME) countries (University of Para, 2020). Much of the information for the English and French-speaking countries and territories was obtained through surveys conducted by the Institute of Marine Affairs (IMA) and UNEP Caribbean Regional Coordinating Unit (UNEP CAR RCU). A challenge was the low response rate, with only 12 countries/territories having responded. Another source of information for this chapter was a regional baseline assessment (2011-2015) by Fanning and Mahon (2020) using the Governance Effectiveness Assessment Framework (GEAF).

The GEAF assessment is based on information obtained through a survey among the countries and territories and relevant intergovernmental organizations addressing fisheries, pollution and habitat degradation/ biodiversity. For the GEAF pollution assessment, which focused on land-based sources (industrial wastewater effluent, domestic wastewater effluent, sediment in run-off, nutrients in agricultural run-off and solid waste) and marine-based sources of pollution (oil pollution, wastewater and solid waste), responses were obtained from 24 countries and territories. Because of the low response rates in the two surveys, the results should not be considered conclusive. Nevertheless, the information obtained was useful in providing a general overview of the situation in the region. A comprehensive assessment of capacities, gaps, and barriers at the regional, sub-regional, and national levels will be necessary during the implementation of the RNPRSAP.

4.2 NUTRIENT POLLUTION GOVERNANCE

4.2.1 Institutional framework

The WCR has a large array of national, sub-regional/ regional and international institutions and mechanisms that are relevant to addressing pollution of the marine environment (See Table 10.1 in UNEP CEP, 2019), although not all explicitly address nutrient pollution. The Cartagena Convention Secretariat/UNEP CAR RCU is the main regional body with a mandate related to pollution of the marine environment. Through its pollution and marine biodiversity sub-programmes, the Secretariat plays a major lead role in support of the protection of the WCR marine environment including through coordinating projects and activities related to the Protocol Concerning Pollution from Land-Based Sources and Activities of the Cartagena Convention (LBS Protocol). While this Protocol provides a regional coordinating mechanism and common framework for nutrient pollution, to date, it has been ratified by only 16 countries. Associated with the LBS Protocol are institutional mechanisms that serve different functions: Scientific and Technical Advisory Committee (STAC); LBS Monitoring and Assessment Working Group; and LBS Regional Activity Centres (RAC) – IMA and the Cuban Center for Research and Environmental Management of Transport (CIMAB) – and the Regional Activity Network (RAN) of technical institutions and individuals that provide technical support. The Cartagena Convention also provides a mechanism for the implementation of several Multilateral Environmental Agreements (MEA) and other global and regional commitments such as the 2030 Agenda and SDGs, in particular Goal 6 on Water and Sanitation and Goal 14 on Oceans. This coordination ensures that programmes, projects, and activities are implemented in an integrated manner and respond directly to the region's needs and priorities.

The Caribbean Environment Programme (CEP) Regional Strategy for the Protection and Development of the Marine Environment of the Wider Caribbean Region (2020-2030) and UNEP's Oceans Strategy specify operating and guiding principles on promoting source-to-sea approaches in management of land-based pollution; enhancing ecosystem-based management; expanding sustainable consumption and consumption patterns; fostering natural capital considerations in resource management; and strengthening the science-policy interface. The four Strategic Objectives of the CEP Regional Strategy are very pertinent to the development of the WCR RNPRSAP.

The main global platform established to steer dialogues and actions to promote effective nutrient management is the GPNM (Box 1.1, Chapter 1). As mentioned in Chapter 1, the GPNM Caribbean Platform was launched in 2013, with the purpose of translating the work of UNEP and the GPNM down to the country level to drive policy and encourage implementation of best nutrient management practices to minimize adverse impacts on the marine environment. The GPNM and the Cartagena Convention Secretariat convened the second meeting for the Caribbean Platform in 2016, which was co-hosted by the IMA. The meeting contributed to greater awareness of nutrient management issues in the Caribbean, considered recommendations from the first meeting, presented a draft action plan, and proposed possible institutional mechanisms to support the work of the Platform within the region. The meeting agreed on: (i) a plan of action for the operationalization of the Caribbean Platform for Nutrient Management, (ii) mechanisms for mainstreaming and building sustainability for the Platform into existing frameworks, and (iii) identified immediate opportunities from ongoing or planned projects to support nutrient related activities in the region.[2] The RNPRSAP will further develop and consolidate these initial proposals. Together with the LBS Protocol, the GPNM Caribbean Platform will become the major regional platform for a harmonized approach to nutrient management in the WCR. This is supported by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA).

Other mechanisms that specifically focus on nutrient pollution and its impacts include the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) Regional Harmful Algal Bloom (HAB) Networks (Caribbean Network for Harmful Algae in the Caribbean and Adjacent Regions, and the South American Network for Harmful Algae Blooms in South America) and the *Sargassum* Working Group,

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[2] Proceedings, GPNM Second Regional Planning Meeting of the Caribbean Platform for Nutrient Management Workshop, February 24-25, 2016, Port-of-Spain, Trinidad & Tobago

the latter of which was created during the Conference of Parties (COP) 10 of the Cartagena Convention held in Honduras in 2019.

Relevant sub-regional integrating mechanisms are the Caribbean Community (CARICOM), Central American Integration System (SICA)/ Central American Commission for Environment and Development (CCAD) and the Organization of Eastern Caribbean States (OECS), each with its respective sub-regional environment and sustainable development policy framework. Sub-regional projects and initiatives that are relevant to nutrient pollution include:

- CARICOM: Under the goal ‘to reduce vulnerability to disaster risk and the effects of climate change and ensure effective management of the natural resources across Member States’, CARICOM has developed a strategic initiative ‘Enhancing Management of the Environment and Natural Resources’, which aims at pollution prevention and control, and waste management.[3] A regional action framework for integrated water resources management (IWRM) for the CARICOM Region is being developed under the Global Environment Facility (GEF) project “Integrating Water, Land, and Ecosystems Management in Caribbean Small Island Developing States” (IWEco).
- SICA: The Regional Environmental Strategy Framework 2015-2010 includes strategic actions for several areas including environmental quality, integrated water resources management, ocean, forests, and biodiversity, among others. SICA/CCAD is executing the GEF project “Integrated Ridge to Reef Management of the Mesoamerican Reef Ecoregion” (MAR2R), in Belize, Guatemala, Honduras, and Mexico. The MAR2R project aims to create the enabling conditions necessary to bring the key regional, national, and local actors along the ridge to reef continuum to collaborate and manage the freshwater, coastal, and marine resources of the MAR.
- OECS: The OECS Development Strategy 2019-2028 includes strategic actions to promote and facilitate proper chemical, waste, and pollution management.[4] Environmental Integrated Watershed Management Policy Frameworks have been developed for three OECS islands (Saint Lucia, Saint Vincent, and Saint Kitts).

An important regional agency is the Caribbean Public Health Agency (CARPHA) of which the Environmental Health and Sustainable Development Department (EHSD) plays a lead role in key areas related to environmental management for optimal public health. Its specialized laboratories support the surveillance, prevention, promotion, and control of important public health problems in the Region.

For the Amazon Basin, the Amazon Cooperation Treaty Organization (ACTO), with Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela as members, has an important role in the sustainable development of the Basin. The project "Strengthening of the Amazon Cooperation Treaty Organization" (or Amazon Regional Program), which is implemented by the GIZ, is focused on strengthening the capacities of ACTO to meet the demands of the Amazon countries for sustainable development in the Amazon. Under the GEF Project “Integrated and Sustainable Management of Transboundary Water Resources in the Amazon River Basin considering Climate Change and Variability”, a Strategic Action Programme (SAP) was developed for implementing transboundary IWRM in the Basin.

The large number and diversity of institutional frameworks and mechanisms in the region requires strong coordination at all levels, which needs to be improved (Fanning *et al*., 2007; Mahon *et al*., 2013). Fanning

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[3] CARICOM. Building Environmental Resilience. https://caricom.org/about-caricom/what-we-do/srtategic-priorities/building-environmental-resilience

[4] OECS Development Strategy 2019-2018. Available at: https://drive.google.com/file/d/1fpfs1PLNIldV5xMskqP0jALZp0MM8_pP/view

and Mahon (2020) examined the region's governance framework in the context of the five stages of the policy cycle (data and information, synthesis and provision of advice, decision-making, implementation, and review and evaluation). They suggested that the CLME+ SAP Interim Coordinating Mechanism[5] (ICM) can be considered a regional coordination mechanism that covers pollution. The ICM contributes to the coordinated implementation of the CLME+ SAP and monitors, evaluates and reports on SAP implementation, with a focus on habitat degradation, pollution, and unsustainable fisheries, while giving due attention to climate change. The ICM's exact role in implementation of the strategy will need to be determined.

At the national level, various institutions and mechanisms exist in all the countries (government ministries and departments, environmental protection agencies/authorities, research and academic institutions, environmental laboratories, NGOs, and CBOs, among others) that perform different functions related to environmental protection and management. In most cases, responsibility for implementing and enforcing the different laws and policies that are applicable to nutrient pollution is spread among different government departments and agencies, with variable levels of coordination among them. Multi-agency and multi-sectoral mechanisms that explicitly address pollution appear to be absent in most of the countries and territories. A notable exception is the US Gulf of Mexico Hypoxia Task Force (HTF), which consists of representatives of different federal and state agencies (including those with responsibilities for activities in the Mississippi River and its basin, and in the Gulf of Mexico) and the tribes. The role of the HTF is to provide executive level direction and support for coordinating the actions of participating organizations working on nutrient management within the Mississippi River Watershed. Among other countries with national inter-institutional committees for various thematic areas, including marine pollution, is Colombia.

A mechanism that can potentially fulfil a coordinating role is National Inter-ministerial/Inter-sectoral Committees (NIC). Results of a 2015 survey of NICs in the CLME+ region showed that about two-thirds of the countries had NICs of some type (McConney *et al*., 2016). However, there is room for improvement regarding all functions that NICs can serve, with the weakest area being in linking national and regional processes (Fanning and Mahon, 2020).

The WCR contains major transboundary rivers and transboundary groundwater aquifers , management of which requires the establishment or strengthening of multi-country mechanisms for nutrient management in the transboundary system (for example, the ACTO; and the joint institutional coordination framework for the Río Motagua watershed proposed under the UNDP/GEF Project "Integrated Environmental Management of the Río Motagua Watershed between Guatemala and Honduras").

Chapter 5 of this strategy discusses the WCR institutional framework for pollution in the context of the multi-scale, LME governance framework (Fanning *et al*., 2007). This framework is based on a generic policy cycle and consists of a set of nested and laterally linked governmental and non-governmental actors and institutions. Based on an analysis of existing policy cycles to identify their strengths and weaknesses, the multi-scale cycles and linkages will need to be established and/or enhanced for implementation of the strategy.

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[5] The CLME+ ICM was established in 2015 and brings together 10 intergovernmental organizations with an ocean-related mandate: UNEP, represented by the Cartagena Convention Secretariat; Food and Agriculture Organization of the United Nations (FAO) on behalf of the Western Central Atlantic Fishery Commission (WECAFC); Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO-IOC); Organization of Eastern Caribbean States (OECS); Caribbean Regional Fisheries Mechanism (CRFM); Central American Fisheries and Aquaculture Organization (OSPESCA); Central American Commission for Environment and Development (CCAD); and the Caribbean Community (CARICOM).

4.2.2 Governance instruments

Collectively, the WCR countries have ratified several relevant MEAs, as shown in Figure 4.1. The Cartagena Convention is the only regional MEA that addresses protection and sustainable use of the Caribbean Sea. To date, 26 countries have ratified the Cartagena Convention and 16 have ratified the LBS Protocol, the latter being the lowest among the Convention's three Protocols and across all the other relevant frameworks, as shown in Figure 4.1.

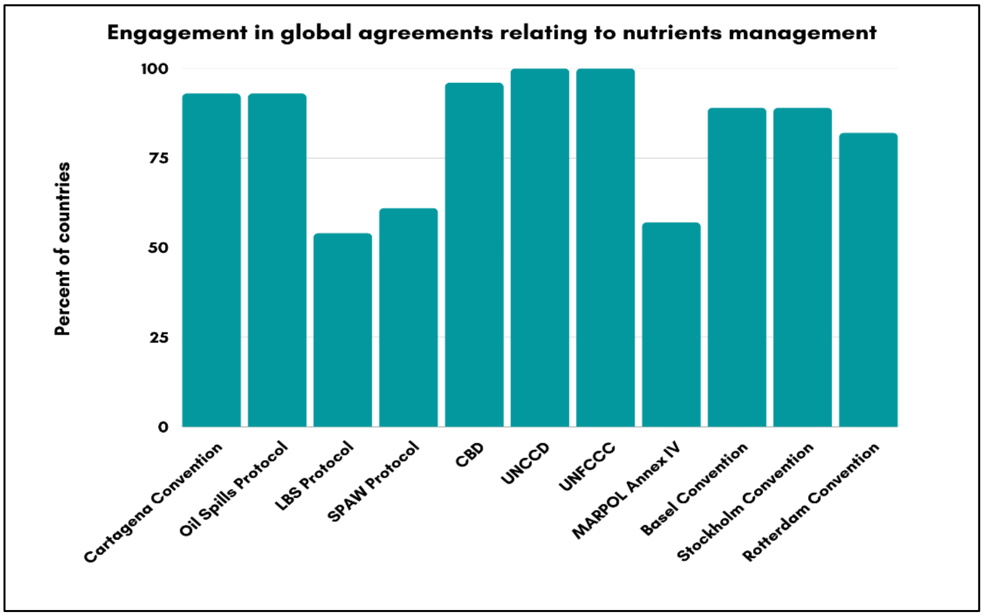

Figure 4.1 Proportion of countries engaged in MEAs of relevance to nutrients (Prepared by UNEP CAR RCU).

The goal of the LBS Protocol is to control, prevent, and reduce pollution from land-based sources and activities. Projects and activities assist WCR governments to establish effluent and emission limits for domestic wastewater; use appropriate pollution prevention technologies and practices; and exchange scientific and technical information on pollution including cooperation in areas of planning, monitoring, and research. The issue of nutrient pollution is explicitly addressed in Annex I of the LBS Protocol (which includes domestic sewage and agricultural non-point sources as well as a number of industries that contribute to nutrient pollution among the priority source categories and activities affecting the Convention Area; and nitrogen (N) and phosphorus (P) compounds among the primary pollutants of concern); Annex III on domestic wastewater (point sources); and Annex IV on agricultural non-point sources.

There are challenges in implementation of the Convention and Protocols at the national level (Corbin 2013; UNEP CEP 2019), which also extend to implementation of other MEAs. Strengthening the capacity of countries to fulfil their obligations as parties to MEAs is being addressed by the Organization of African, Caribbean and Pacific States (ACP) MEAs programme, which is a joint partnership between the European Union, the ACP States, UNEP, and FAO. The current third phase focuses on the effective implementation, enforcement, monitoring, and reporting of MEAs and related commitments in the chemicals, waste, and biodiversity clusters. The Cartagena Convention Secretariat is executing activities under the third phase.

Table 4.1 shows the governance instruments (policies, strategic plans, management plans, legislation and regulations) in place to address land-based sources and marine-based sources of pollution based on all the possible regional governance arrangements: International Maritime Organization-International Convention on Oil Pollution Preparedness, Response, and Co-operation (IMO-OPRC) and Port State Control-Memorandum of Understanding (PSC MoU); UNEP Cartagena Convention Oil Spill and LBS Protocols) and sub-regional bodies (CARPHA, CCAD) that could be in place to address these pollution sources (Fanning and Mahon, 2020). Policies and strategic plans were the governance instruments most in place by regional and sub-regional organizations during the baseline period.

Table 4.1 Regional and sub-regional governance instruments in place to address land-based and marine-based sources of pollution (Fanning and Mahon, 2020). nr: no response

Pollution Sources	Arrangements	Governance Instruments				
		Policies	Strategic plans	Management plans	Legislation	Regulations
Land-based wastewater discharge	UNEP-LBS Protocol	✓	✓	✓	✓	✓
	CARPHA	✓	✓	✓		
	CCAD	nr	nr	nr	nr	nr
Land-based solid waste disposal	UNEP-LBS	✓				
	CARPHA					
	CCAD	nr	nr	nr	nr	nr
Marine-based oil spills	UNEP-Oil spill protocol	✓	✓	✓	✓	✓
	IMO-OPRC	✓	✓	✓	✓	✓
Marine-based other liquids	IMO -PSC MoU					
	UNEP- Cartagena Conv	✓	✓			
Marine-based solid waste disposal	IMO - PSC MoU	✓	✓	✓	✓	✓
	UNEP - Cartagena Conv	✓	✓			

Of particular relevance is the Small Island Development States (SIDS) Accelerated Modalities of Action (SAMOA) Pathway, in view of the large number of SIDS in the WCR. Among the agreed priority areas is 'Oceans and Seas', in which governments are called upon to address marine pollution, including through the development and implementation of relevant arrangements such as the UNEP GPA and, as appropriate, instruments on marine debris and on nutrient, wastewater and other marine pollution, and through the sharing and implementation of best practices.

At the national level, all the countries have governance instruments and programmes that address pollution in general (Annex 4.1). It should be noted that much of the information in Annex 4.1 originated from the national (NBSLME countries) and sub-regional reports prepared for this strategy as well as from the questionnaire responses for the 12 English and French-speaking countries and territories (it is possible that there are inconsistencies in this annex since in many cases the information provided was unclear and open to interpretation). The extent to which these instruments and programmes explicitly address nutrient pollution varies among the countries, ranging from not specifically targeting nutrients, to comprehensive nutrient pollution reduction strategies of the US Mississippi River basin (Box 4.1) and the European Union (EU) Nitrates Directive, the latter of which sets European standards for the reduction of nitrate discharges of agricultural origin.

The *Sargassum* problem in the region has triggered a flurry of policy responses and initiatives at the national and regional levels. This perhaps represents the only regional effort to explicitly address an issue to which excessive nutrient runoff to coastal waters is thought to contribute (e.g., Wang *et al*., 2019; Johns *et al*., 2020). Development of management protocols, for example, the Puerto Morelos and Puerto Rico protocols, and the Caribbean Regional Fisheries Mechanism (CRFM) protocol for the management of *Sargassum* in OECS Member States (CRFM, 2016) are examples of *Sargassum* policy responses. Additionally, at the first International Conference on *Sargassum* held in October 2019, several WCR countries and territories along with various regional and international organizations signed a '*Sargassum* Declaration' and agreed to establish a Caribbean Cooperation Programme against *Sargassum* (SARG'COOP). Most of these responses, however, appear to focus on mitigation of the impacts of *Sargassum* strandings rather than on the underlying causes of its proliferation.

Box 4.1. US Environmental Protection Agency (EPA) activities related to regulatory programmes for nutrient pollution

- Reviewing and approving state water quality standards that contain numeric nutrient criteria under the Clean Water Act.
- Establishing National Primary Drinking Water Regulations for nitrate and nitrite.
- Including toxic cyanobacteria ("cyanotoxins") on the drinking water priority Contaminant Candidate List and monitoring 10 cyanotoxins as part of the fourth Unregulated Contaminant Monitoring Rule.
- Publishing effluent guidelines for industrial and municipal discharges that may contain nutrient-related limits.
- Working with states to identify water bodies impaired by N and P pollution and to develop Total Maximum Daily Loads (TMDL) to restore or protect waters.
- Administering a wastewater permit program that establishes discharge limits and monitoring requirements necessary to protect water quality standards and the environment from point sources of nutrient-related pollutants, i.e., from municipal and industrial facilities, concentrated animal feeding operations (CAFOs), and stormwater.
- Providing states, the regulated community, and the public with guidance on the regulatory requirements of nutrient management plans for regulatory requirements of nutrient management plans for CAFOs.
- Working to reduce nitrogen oxides air emissions through emissions standards, the nitrogen oxides trading program and the acid rain program.
- Helping states reduce air pollution and attain clean air standards and manage interstate air pollution from power plants.
- Agricultural stormwater and return flows from irrigated agriculture are exempted from regulation under the Clean Water Act.

(https://www.epa.gov/nutrient-policy-data/what-epa-doing-reduce-nutrient-pollution)

Sector-specific laws and policies related to nutrient pollution

Fanning and Mahon (2020) found that, among major land-based sources, CLME+ countries and territories had the highest number of legislations in place for domestic wastewater effluents while the lowest number was for nutrients in agricultural run-off and for sediment run-off (Figure 4.2). Note that because of the low response rate to the survey, the results should not be considered representative of the region.

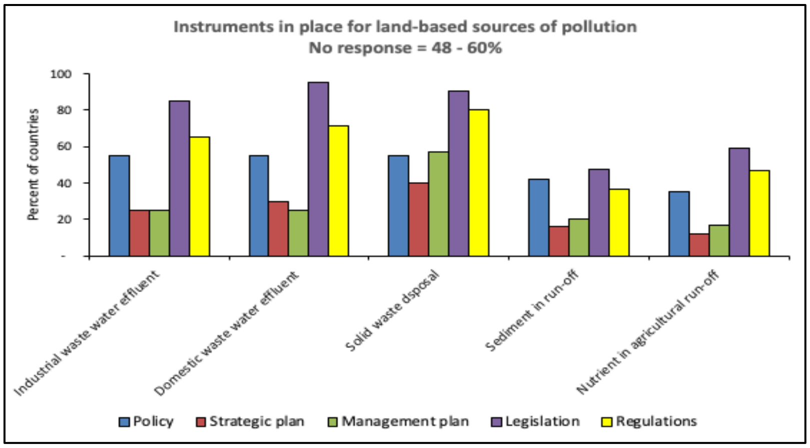

Figure 4.2 Percent of responding CLME+ countries and territories having governance instruments in place for land-based sources of pollution (Fanning and Mahon, 2020).

For the 12 English and French-speaking countries and territories for which responses were available, only about half of the respondents indicated that there were sector-specific laws and regulations targeting nutrient pollution from the five main sectors identified in the survey, while others indicated that sector-specific regulations were in preparation (Figure 4.3).

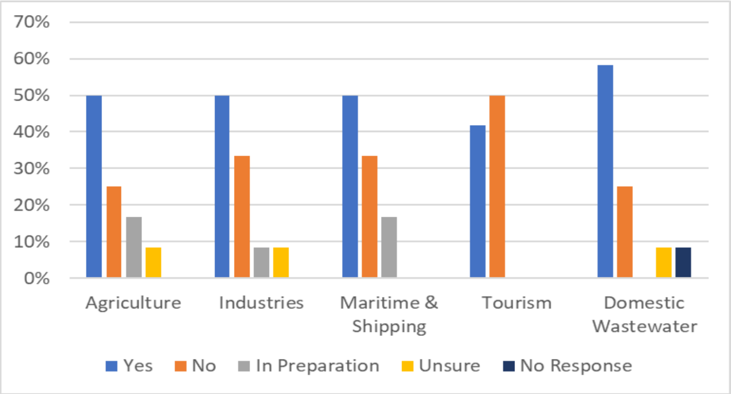

Figure 4.3 Information on the specific sectors that are targeted by nutrient pollution control policies, laws and plans in 12 English and French-speaking countries and territories.

The sector with the highest number of sector-specific laws for pollution was domestic wastewater (similar to findings by Fanning and Mahon, 2020) while the sector with the least number of such laws was tourism (Figure 4.3). Some countries, such as Jamaica, indicated that their regulations for effluent discharge cut across all sectors. In general, the Spanish-speaking countries and the NBSLME countries have comprehensive policies and regulations for domestic wastewater.

Figure 4.4 illustrates the assessment of the current level of treatment of industrial wastewater, domestic wastewater, sediments run-off, agricultural run-off and solid waste in CLME+ countries (Fanning and Mahon, 2020). While the expected target for stress reduction efforts should be for all countries reporting “at agreed level” or “better than agreed level”, the majority of the respondent countries and territories fell far below this target, with “no agreed level” (yellow) and “worse than agreed level” (red) accounting for over 70 percent of the respondents. This suggests that more effort is needed to establish criteria and standards and to monitor and reduce the level of stress from these land-based sources of pollution. Of particular relevance is the proportion of countries with "no agreed level" of treatment (yellow), which was highest for nutrients in agricultural run-off. Also, it is notable that slightly over 10 percent of respondents considered the level of nutrient in agricultural run-off and sediment in run-off to be "not applicable" (Figure 4.4, black), which was the highest among the five sources. The highest proportion of countries had the level of treatment of domestic and industrial wastewater worse than agreed level.

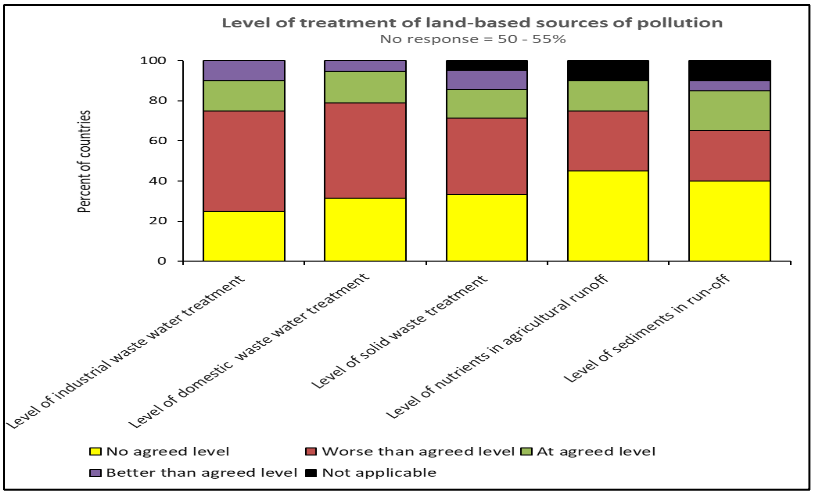

Figure 4.4 Level of effort among CLME+ countries to reduce stress from land-based sources of pollution (Fanning and Mahon, 2020).

Some WCR countries recycle and reuse wastewater to a limited extent. For example, in many Eastern Caribbean islands, 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 the Point Lisas Industrial Estate.

As mentioned above, the only existing frameworks that explicitly address nutrient pollution including from agriculture are the nutrient reduction strategies of the US Mississippi basin states and the EU Nitrates Directive (France). Based on the sub-regional reports, national policies and regulations related to agricultural fertilizers and pesticides exist in Antigua and Barbuda, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Guyana, Honduras, Mexico, Nicaragua, Panama, Saint Lucia, Suriname, USA and Venezuela. All the countries require permits for the import of pesticides and fertilizers and most keep records of fertilizer and pesticide imports and use. The Central American Countries (Panama, Costa Rica, Nicaragua, Honduras, and Guatemala) have defined a regional technical regulation that establishes the requirements for the registration of fertilizers for agricultural use. In general, fertilizer application rates are not regulated although some countries have recommended rates for specific crops, for example, Guyana and Suriname for rice. Subsidies on agricultural inputs such as fertilizers and seeds have been common in LAC countries (International Institute for Sustainable Development, 2010). Chemical nitrogenous fertilizer use is the most widespread, promoted and often subsidized by agricultural programmes and local governments, but without concomitant education, extension or consultant support towards a reduction in fertilizer use or an improvement in nutrient use efficiency (Sutton *et al*., 2013).

All the countries/territories have some form of legislation and regulations for shipping and maritime activities, but the extent to which these cover nutrient pollution varies. Twenty-six countries have ratified the MARPOL Convention Annexes I and II, although sewage from ships is addressed by Annex IV. All countries have regulations for sectors such as energy and transport, which produce air-borne pollutants among which are greenhouse gases including nitrogen oxides (NO_x). The latter contribute to nutrient pollution in marine waters through atmospheric deposition.

Integrated approaches

In many cases, there is little harmonization among the regulations and their responsible agencies, and water quality monitoring and enforcement are weak in many countries (Norville and Banjoo, 2011). Furthermore, while the general trend in the countries is for existing policies to focus on single issues, the multi-dimensional nature of nutrient pollution and nutrient cycles highlights the need for an integrated watershed management framework. Based on the sub-regional reports, at least 10 of the countries have policies and programmes for integrated management such as integrated coastal zone management, integrated watershed management and integrated watershed and coastal area management (this is likely to be an underestimate due to the unavailability of information). However, information on the extent to which these programmes cover nutrient pollution was largely unavailable.

The US Mississippi basin strategy adopts an integrated watershed management approach while the EU Water Framework Directive requires river basin management plans to link coastal and river objectives. Mention was made in the sub-regional report of a nutrient management strategy of Jamaica, which will target the tourism and agriculture sectors in the first instance, but details were unavailable. The lack of a clear national policy and integrated management across sectors is a major barrier to addressing nutrient pollution in the WCR and was identified as high priority by survey respondents in the English and French-speaking countries/territories.

Criteria and standards for effluents

The LBS Protocol has not established effluent discharge limits or coastal water quality standards for nutrients. For SOCAR, coastal water quality criteria for good, fair and poor conditions for dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), Chlorophyll a (Chl-a) and dissolved oxygen (DO) were based on the US EPA's thresholds. Endorsement of SOCAR in 2019 by the LBS Protocol STAC and Cartagena Convention COP may pave the way for the formal adoption of regional standards for coastal water quality including for nutrients.

At the national level, many of the countries have established (or are preparing) criteria, and numerical standards and limits for effluent discharges and coastal water quality with respect to nutrients (Annexes 4.2 and 4.3). Based on the sub-regional reports and other information, at least 57 percent of the 37 WCR countries and territories have criteria, guidelines, and standards for nutrients (N and P) in domestic wastewater discharges. A similar proportion (57 percent) of the countries have standards and limits for industrial effluents. This proportion is higher for individual groups of countries. For the English and French-speaking countries and territories, standards and criteria for effluent discharge limits and point source monitoring of nutrient pollution are currently in place in just over 80 percent of the countries/territories. All the countries/territories that responded to the survey indicated that they either have or are preparing standards and criteria for effluent and ambient water quality. A snapshot of the situation with respect to programmes, standards, and criteria for nutrient pollution in the 12 English and French-speaking countries/territories is given in Table 4.2. Under the US Clean Water Act, TMDL for nutrients are established to meet water quality standards in an impaired receiving water body (Karr and Yoder, 2004). The Clean Water Act is generally focused on two types of controls for point source discharges of pollutants to US waters: (1) water quality-based controls, based on state water quality standards, and (2) technology-based controls, based on effluent limitations guidelines and standards (US EPA, 2018). State water quality standards contain numeric nutrient criteria under the Clean Water Act.

Table 4.2 Proportion (%) of the 12 English and French-speaking countries/territories with programmes, standards and criteria for nutrient pollution management (IMA, 2020).

Nutrient pollution management programme, standard and/or criteria	Yes	No.	In Prep
Designated agency for monitoring nutrient pollution	67	25	8
Monitoring programme for nutrient pollution	67	17	8
Laboratories and human resources for nutrient pollution analysis	75	8	8
Point source monitoring of nutrient pollution	67	25	8
Non-point source monitoring of nutrient pollution	50	33	17
Annual nutrient pollutant load monitoring to the coastal/marine environment	25	50	8
Standards and criteria for industrial effluent discharge limits for nutrient pollution	58	0	17
Standards and criteria for domestic effluent discharge limits for nutrient pollution	42	0	17
Standards, guidelines and criteria for defining coastal and marine environmental quality status	50	17	17
Standards and criteria for safe discharge in the environment, sensitive areas, nearshore, offshore	42	17	17

Most of the Spanish-speaking countries have standards and maximum permissible limits for N and P in the discharge of domestic and industrial wastewater to receiving water bodies and sewers (Annex 4.2). Exceptions to the latter are Colombia, Cuba, Honduras and Mexico, which do not have maximum permissible limits for discharge into sewers. However, since the final discharge of wastewater from the sewer system (with or without treatment) is to a receiving water body, the discharged wastewater must comply with the discharge requirements for the water body. For Cuba and Mexico, among others, the maximum permissible limits are specified according to the designated use (class) of the receiving marine/coastal water body.

Some countries including Colombia, Dominican Republic, Guatemala, and Nicaragua distinguish the limits according to the type or origin of the wastewater (domestic, industrial, services, agricultural, livestock, municipals, among others). For the Spanish-speaking countries, the maximum permissible nutrients limits are specified in terms of concentration and not of the actual pollutant load. The latter must be taken into account when assessing the impact of substances that can cause damage to the receiving water body and in relation to its carrying capacity for nutrient inputs. There is a marked variation in the maximum permissible concentrations for the different forms of N and P, even for similar types of receptor water bodies, across the countries for which this information was available.

For the NBSLME countries, the Brazilian national environmental policy establishes standards and conditions for domestic wastewater effluents to be discharged into the collection and drainage networks, as well as the analytical standards to determine the correct destination for treatment and final disposal, carried out in laboratories accredited to the competent public bodies. In the case of direct pollution of receiving bodies, the Resolutions 430/2011 and 357/2005 of the National Council for the Environment are adopted.

Similarly, Guyana has regulations for the discharge of domestic effluent into water and provides for the establishment of water quality standards, in addition to interim guidelines for industrial wastewater. Venezuela has overarching laws governing water management, water quality, effluent wastewater/discharge and environmental standards. From the information provided in the reports for these three NBSLME countries, the extent to which the regulations in these three countries explicitly address nutrient pollution is unclear. In Suriname, there are no regulations for wastewater and sewage pollution including standards and limits, although some pieces of legislation address sanitation practices and disposal of wastewater. A recent study of water quality in rice polders in Suriname used Dutch standards for certain pollutants including nitrate, nitrite, and phosphate (Kramer, 2017).

Water quality criteria and standards

Only about 40 percent of the countries for which information was available have water quality criteria and standards for freshwater and coastal-marine water in relation to N and P (Annex 4.1). Of the nine Spanish-speaking countries, only four (Colombia, Cuba, Dominican Republic and Mexico) have water quality standards and regulations related to N and P (Annex 4.3). These standards are linked to criteria reflecting the designated uses (e.g., drinking water, recreational, industrial, port, navigation) or ecological criteria. Only a few of the countries have water quality standards for silica (Si), which is an essential nutrient for the growth of diatoms and other algae, and an indicator used in the calculation of the Index of Coastal Eutrophication Potential[6] (ICEP). The French territories monitor Si in groundwater, rivers/lakes and coastal-marine waters, and it is presumed that there are discharge limits and water quality standards for Si, although the EU Urban Wastewater Treatment Directive and the Nitrates Directive (which together tackle the problem of eutrophication) address only nitrates among the nutrients of concern.

The forms of N and P monitored by the countries are diverse, which was also observed in the water quality data submitted for SOCAR. These include ammonia, nitrite, nitrate, Kjeldahl nitrogen, total nitrogen, phosphate, orthophosphate, total phosphorus, DIN, DIP, and silicate. This heterogeneity in the indicators monitored as well as in sampling and laboratory protocols will present challenges for the definition of regional standards and criteria for the discharge of nutrients to the WCR marine environment and for water quality. Other relevant indicators monitored by the countries are DO, Chl-a, and turbidity (based on data submitted for SOCAR).

Among the Spanish-speaking countries, only Cuba has set quality criteria (good, doubtful, or bad) for sediments in waters used for fishing, which include organic nitrogen with concentrations explicitly defined for such criteria.

To effectively manage marine pollution at the local, national or regional level, there is a need for water quality standards that have a scientific foundation that link land-based discharge limits with marine water quality standards, and that are relevant to the ecological thresholds of the receiving marine ecosystems (Tosic *et al*., 2019 and references therein). Various science-based methods have been developed to link water quality objectives for land-based discharges and marine waters. Tosic *et al*. (2019) demonstrated a practical method for setting local-scale coastal water quality targets for end-of-river suspended sediment loads to mitigate offshore coral reef turbidity, and applied this approach to Cartagena Bay, Colombia. The authors considered this approach to be appropriate for local-scale environmental management in countries that are still developing their water quality policies.

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[6] SDG 14.1 indicator of nutrient pollution

Enforcement

Nutrient policies can benefit from a mix of voluntary approaches, economic approaches and regulations, recognizing the diverse structure within and between nutrient source sectors and between regions (Sutton *et al*., 2013). Many of the English and French-speaking countries/territories relying on command-and-control mechanisms, such as discharge permits, to regulate nutrient pollution. The command-and-control approach is based on the development of appropriate standards and water quality criteria that must be met by polluters. This requirement is enshrined in legislation, and each country generates its own set of regulations to implement the law. Common regulations include requiring industry to obtain permits for pollution emissions, and to self-monitor and report on a regular basis. For example, in the 12 states involved in the US Gulf of Mexico HTF, 86 percent of sewage treatment plants have permits that require N or P monitoring, an increase of 15 percent compared to 2014 (US EPA, 2019).

Market-based approaches such as water quality trading are other strategies that could be used to promote compliance. Water quality trading allows a permitted facility or a point source to trade water quality credits with another point source or with a non-point source. The US EPA has a comprehensive framework for market-based approaches to improve water quality under the Clean Water Act. The policy promotes the adoption of market-based programmes to incentivize the implementation of technologies and practices to reduce non-point source pollution.

In the WCR countries, even where the appropriate regulations and standards are in place, enforcement of the regulations is often inadequate owing to a combination of factors including limited human capacity and financial resources.

4.3 MONITORING

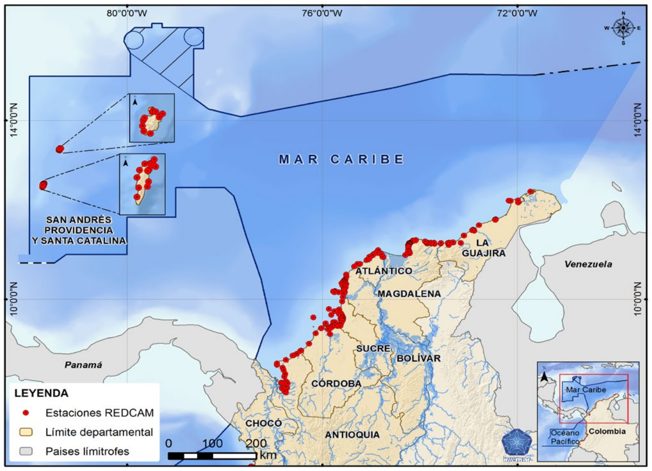
Monitoring programmes discussed in this chapter refer primarily to programmes that are operated by government entities, unless stated otherwise. Available information focuses on monitoring of water quality and effluents. At the regional scale, about 51 percent of the countries/territories conduct coastal water quality monitoring that includes nutrients. Of the 20 countries/territories for which data sets were available for SOCAR, only 20 covered some form of nutrients but estimates of DIN and DIP were possible for only 7 countries/territories because the forms of N and P monitored by the others did not allow estimation of DIN and DIP. Furthermore, in most cases, monitoring is sporadic, with spatial and temporal gaps. For SOCAR, (limited) time series of water quality data were available from Colombia, Mexico, Puerto Rico, US Virgin Islands, and the French territories.

In the Brazilian Amazon region, there is no systematic monitoring of water quality in superficial sources and groundwater. In Suriname, water quality monitoring is conducted primarily in rivers. Among the countries/territories with a regular and comprehensive coastal water quality monitoring programme that includes nutrient parameters are Antigua and Barbuda, Colombia, Cuba, Dominican Republic, Jamaica, Mexico, Trinidad and Tobago, US, Puerto Rico and the French territories (based on the sub-regional reports and data submitted by the countries for SOCAR). Examples of comprehensive monitoring programmes that can be considered best practice are those of Colombia (Box 4.2), Cuba, Mexico, and the US. The latter (US) includes research cruises to monitor bottom oxygen concentration on the Louisiana-Texas continental shelf (https://gulfhypoxia.net). Additionally, the US National Oceanic and Atmospheric Administration (NOAA) issues weekly forecasts (and twice weekly during a HAB event) for the northern Gulf of Mexico and east coast of Florida when conditions become favorable for HABs of the red tide species *Karenia brevis* (typically in August). Data from satellite monitoring of environmental parameters such as land cover, sea surface temperature, sea level and ocean colour/chlorophyll are available from various sources including NOAA, the US National Aeronautics and Space Administration (NASA) and the IOC-UNESCO International Oceanographic Data and Information Exchange (IODE) Ocean Data Portal, among others.

Information on *Sargassum* in the tropical Atlantic is provided in the *Sargassum* Information Hub, of which the IOC Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE) is a partner (https://*sargassum*hub.org/). An early warning system for *Sargassum* using satellite remote sensing is the *Sargassum* Watch System of the University of South Florida, which publishes the *Sargassum* Outlook Bulletin (https://optics.marine.usf.edu/projects/saws.html). The University of the West Indies Centre for Resource Management and Environmental Studies (UWI CERMES) publishes the Sub-regional *Sargassum* Outlook Bulletin for the Eastern Caribbean. Countries such as Mexico, Colombia, Costa Rica, and the US have advanced Geographic Information Systems for *Sargassum* monitoring.

Box 4.2. Colombia monitoring network

The REDCAM "Surveillance Network for the Conservation and Protection of Marine and Coastal Waters of Colombia", which is coordinated by INVEMAR (Instituto de Investigaciones Marinas y Costeras), is a management tool that has been monitoring the quality of surface waters for 20 years, through successful inter-institutional coordination with national and regional entities committed to the prevention, control and monitoring of marine pollution. The programme consists of 223 sampling stations in sites of economic and environmental importance (see map), with sampling carried out twice per year.



Parameters monitored include N and P in addition to inventories of the main anthropogenic marine pollution sources, estimation of wastewater discharges and pollutant loads from the main rivers that discharge to the Colombian coast. The monitoring data are stored in an online marine environmental information system (https://siam.invemar.org.co/), which is regularly updated and to which the general public and others have access. REDCAM technical reports are published annually, the latest for 2019 (INVEMAR 2020). The reports are available at: http://www.invemar.org.co/redcam

For more information: http://www.invemar.org.co/inf-redcam; http://siam.invemar.org.co/redcam

Some water quality monitoring programmes in beaches, marinas or other coastal areas of tourist interest are financed by the private sector, NGOs, international projects or by international cooperation agencies, especially from developed countries. The design of these monitoring programmes varies according to the use of the area and the objectives and/or duration of the project. Several countries have monitoring programmes for beach certifications that include water quality monitoring in their procedures. Although nutrients are usually covered in these monitoring programmes, they are not priority indicators as are the bacteriological indicators since very often the focus is on water quality for recreational use.

Limited monitoring is conducted under regional and sub-regional donor-funded projects, for example, the GEF IWEco Project (http://iweco.org/) and the GEF Project "Strategic Action Program of the Large Marine Ecosystem of the Gulf of Mexico" (https://www.gob.mx/semarnat/documentos/implementacion-del-programa-de-accion-estrategico-del-gran-ecosystem-marino-del-golfo-de-mexico).

Regarding monitoring of effluents, about 59 percent of countries/territories monitor nutrients in domestic effluents while 57 percent monitor industrial effluents. For the English and French-speaking countries/territories, 64 percent of respondents indicated that non-point pollution monitoring was in place but may not be on a regular basis. A snapshot of monitoring in the English and French-speaking countries and territories is shown in Table 4.3. A significant number of respondents in these countries and territories indicated that the lack of sustained monitoring was the first or second priority concern.

Table 4.3 Summary of the parameters and matrices that are monitored for nutrient pollution by 12 respondent English and French-speaking countries/territories (Values are percentages. NR: no response) (IMA, 2020).

Parameter	Domestic wastewater			Industrial Wastewater			Surface Water			Groundwater			Coastal/Marine		
	Yes	**No**	**NR**	**Yes**	**No**	**NR**	**Yes**	**No**	**NR**	**Yes**	**No**	**NR**	**Yes**	**No**	**NR**
Total nitrogen	33	33	33	42	17	17	42	25	33	58	25	17	67	17	17
Total Phosphorus	42	25	33	42	17	17	42	25	33	58	25	17	58	25	17
Silica	8	58	0[1]	0	78	0[2]	17	42	0[3]	17	58	0[4]	17	50	0[5]
Chlorophyll-a	8	58	0[1]	Not Applicable			33	25	0[3]	0	8	0[4]	33	42	0[5]
Faecal coliform	58	25	17	50	17	8	42	25	33	58	17	25	67	17	17
Enterococci	25	50	25	25	42	8	33	33	33	33	42	25	58	25	17
E. coli	33	42	25	25	42	8	42	25	33	42	33	25	58	33	8

[1] For domestic wastewater, the remaining 33% of respondents were unsure about silica and chlorophyll-a monitoring.

[2] For industrial wastewater, 22% of respondents were unsure about silica monitoring.

[3] For surface water, the remaining 42% of respondents were unsure whether silica and chlorophyll-a were monitored in their country/territory.

[4] For groundwater, 25% of respondents were unsure about silica monitoring, and 92% for chlorophyll-a monitoring.

[5] For coastal/marine waters, 33% of respondents were unsure about silica monitoring, and 25% about chlorophyll-a monitoring.

As indicated in Table 4.3, there is considerable variability in the monitoring effort for a variety of parameters among the countries/territories. The most commonly (>50 percent) monitored parameters were faecal coliform in all media, and total N and P in groundwater and the coastal/marine environment. None of the parameters in any media was monitored by more than 70 percent of the survey respondents. Surface waters were among the least monitored medium, while silica and Chl-a were the least monitored parameters. Survey respondents indicated that point sources (industrial effluents) were monitored more closely, while ambient monitoring was generally intermittent, and tended to occur when there was an incident that warranted investigation.

In some of the countries, multiple bodies conduct monitoring for different parameters and media. This creates challenges in coordination and messaging and reduces cost-effectiveness. A unified approach is that used by the US Mississippi/Gulf of Mexico Hypoxia Task Force, which developed a Monitoring, Modeling and Research Strategy (Mississippi River/Gulf of Mexico Watershed and Nutrient Task Force, 2004). The strategy describes what scientific data is needed to inform nutrient pollution management decisions, defines what activities are required to provide the needed information, and how this information should be reported. Coordination and harmonization of monitoring and data sharing will be a major consideration for the region.

Socio-economic parameters

Data on relevant socio-economic parameters are generally available in the countries and through international databases and reports. See chapter 3 of SOCAR and chapters 3 and 5 of this report for some of the key parameters and data sources. Parameters for which data are available include population and demographics, urbanization, water supply and sanitation and other human development parameters, GDP contribution by economic sectors, annual fertilizer imports and land use. On the other hand, the socio-economic impacts of nutrient pollution are not routinely monitored and quantified in the countries. Examples where this is done include the USA where the economic cost of HABs/ red tides are estimated; and the Caribbean Epidemiology Centre (now CARPHA)/Pan American Health Organization records the incidence of water-related illnesses including ciguatera poisoning (intermittently). The IOC-UNESCO Harmful Algal Events Database (http://haedat.iode.org/) includes data on the incidence of illness related to HABs and ciguatera at the national level (to date only for 12 WCR countries). With the *Sargassum* issue being high on the national and regional agenda, information on its impacts including clean-up costs and human health risks is increasingly becoming available, although sporadically. Comprehensive and up-to-date data and information on the socio-economic costs and impacts of nutrient pollution are not available at the national nor regional level. This is a critical gap since socio-economic data and information are essential for raising awareness and for decision making regarding nutrient pollution management.

4.4 LABORATORY AND TECHNICAL CAPACITY

About 59 percent of the countries/territories have analytical environmental laboratories. This proportion is higher at the sub-regional level. For example, 73 percent of the English and French-speaking countries and territories have laboratory and human capacity development and 64 percent have training on field sampling and assessment. However, only 55 percent of the survey respondents indicated that accredited laboratories with standard operating procedures existed in their respective countries/territories. Seven of the nine Spanish-speaking countries have environmental laboratories (the exceptions being Guatemala and Honduras). Among the NBSLME countries, Brazil, Guyana and Venezuela have analytical laboratory capacity within government agencies and/or other agencies. Where this capacity is lacking, the required technical services are outsourced.

At the regional level, the CARPHA Environmental Health Laboratory, which is accredited to ISO 17025 by the Canadian Association for Laboratory Accreditation, is a full-service microbiological and analytical laboratory that provides environmental analyses, including water quality monitoring and other services.

4.5 DATA AND INFORMATION AVAILABILITY

At a minimum, most of the countries have a national statistical office responsible for conducting national censuses and storing national statistics. These offices generally have searchable databases that are easy to access, making them suitable for the storage of environmental data and information. Data and information on the environment and other relevant thematic areas are usually available from national statistical offices (to a limited extent) and government departments with responsibility for environmental management. However, as was the experience with the preparation of SOCAR, sharing of national data and information considered to be 'sensitive' by countries can be a barrier to regional efforts. This is particularly the case in relation to sewage pollution of coastal waters in countries that are dependent on marine tourism. On the other hand, several countries maintain comprehensive environmental databases that are accessible online and/or provide data and information in technical and state of environment reports (e.g., Colombia, France, US). In addition, data and information are available from research and academic institutions as well as (sporadically) in technical publications and project reports. For Brazil, data on coastal water quality is available from the Brazilian Geographic and Statistical Institute).

A major comprehensive source of data and information specifically related to nutrient pollution management is the GPNM online platform (http://www.nutrientchallenge.org/). Other regional and global data sources include the Caribbean Marine Atlas, United Nations Economic Commission for Latin America and the Caribbean CEPALSTAT, SDG Dashboard, IOC Harmful Algal Event Database, and other international governmental and non-governmental organizations. However, the extent to which their contents relate to nutrients varies. Currently, there is no central regional repository for comprehensive environmental data in general and for nutrient pollution in particular, which will be necessary to facilitate a regional approach to nutrient pollution management. A single, central repository for all data and information on nutrient management in the WCR may not be feasible, given the large number of governmental and non-governmental entities involved. A more realistic target may be a central repository in each country/territory, that is indexed regionally (possibly the CLME+ Hub, which is designed to harness knowledge, resources, and tools to accommodate the information needs of CLME+ stakeholders; https://clmeplus.org/).

4.6 ASSESSMENTS

The first regional assessment of the state of the Cartagena Convention Area is the SOCAR. Moreover, this is also the first regional assessment of nutrients (including N and P loads, coastal water quality and the ICEP) using empirical data and modelled results. SOCAR will contribute to the regional State of the Marine Environment and Associated Economies (SOMEE) report for the CLME+ region, which is being prepared under the CLME+ Project. In addition to the SOMEE report, the CLME+ Project is establishing an institutional mechanism for sustained assessment and reporting on the state of the region's marine environment and associated economies. Nutrient loads at river mouths and the ICEP for the CLME, NBSLME and Gulf of Mexico LME were estimated by Seitzinger and Mayorga (2016) under the GEF/UNEP Transboundary Waters Assessment Programme (TWAP) LME Component (onesharedocean.org). Under TWAP, nutrient pollution was also assessed in the world's transboundary rivers as well as in transboundary groundwater aquifers in SIDS (www.geftwap.org). Another regional assessment report is the World Bank report on marine pollution in the Caribbean (Diez et al. 2019), which includes a description of nutrient pollution in the region based on published information.

Several of the WCR countries conduct national state of environment/marine environment assessments, with varying degrees of coverage of nutrient pollution, from no coverage to comprehensive coverage of nutrients. Examples of the latter are the Colombia REDCAM and annual technical reports (Box 4.2), the

Trinidad and Tobago State of the Marine Environment Report 2016 and the US National Coastal Condition Reports (https://www.epa.gov/national-aquatic-resource-surveys/national-coastal-condition-reports).

In terms of assessment of the SDG 14.1 nutrient indicator (ICEP), among the English and French countries/territories only Martinique assesses the ICEP, while none indicated that they use modelling to estimate nutrient loadings. Most countries do not have the empirical data nor the technical capacity to estimate the ICEP and for modelling of nutrient loadings.

4.7 RELEVANT PROJECTS

Among the English and French-speaking countries and territories, 54 percent of respondents indicated that they had executed nutrient management projects in their respective countries, while 15 percent indicated that such projects were in preparation. The focus of these projects ranges from specific nutrient pollution problems (French Guiana) to technological solutions like wastewater treatment plants (Barbados, Jamaica) and policy-related solutions (Trinidad and Tobago). Many of these projects are supported by external donors although some activities are covered by national budgets. Relevant sub-regional, donor-funded projects (completed and ongoing) in the participating countries include CLME+, Integrating Watershed and Coastal Area Management (IWCAM), Caribbean Regional Fund for Wastewater Management (CReW), CReW+, IWEco, MAR2R, the Caribbean Aqua-Terrestrial Solutions programme, and the project “Integrated and sustainable management of transboundary water resources in the Amazon river basin considering climate change and variability”.

4.8 STAKEHOLDER ENGAGEMENT, OUTREACH, AND ADVOCACY

In the English and French-speaking countries and territories, only 25 percent of respondents indicated that they conduct programmes on nutrient pollution targeting the general public and vulnerable communities. Lack of communication and low awareness of nutrient pollution were identified as first and/or second priority by a number of countries/territories. The public awareness programmes identified by survey respondents were mostly general in nature, focusing on pollution and sewage in the aquatic environment, rather than nutrient pollution specifically. On the other hand, almost 60 percent indicated that there were programmes targeting specific industries or activities that may cause nutrient pollution. Among these are programmes for farmers on best practices and use of chemicals including fertilizers and programmes to sensitize users on the impact of cesspool effluents and to assist local communities with compliance related to collective water treatment facilities. Comprehensive stakeholder engagement, outreach and public awareness programmes are conducted by the US HTF and the US Gulf of Mexico States under their respective strategies as well as by the US EPA.

Information on stakeholder awareness, outreach and advocacy activities was not available for the Spanish-speaking countries in the sub-regional report. However, it is likely that such activities are conducted in the countries including through sub-regional and regional projects. In the WCR, many activities related to stakeholder awareness, outreach and advocacy on the environment are conducted through donor-funded environmental projects. These initiatives play an important role in raising stakeholder awareness and exchange of information among countries. However, the extent to which these initiatives address nutrient pollution varies according to the project’s objectives.

Regarding private sector engagement, Fanning and Mahon (2020) found that engagement with the private sector was generally weak among CLME+ countries, although such initiatives and programmes do exist.

For example, in some countries, the tourism sector finances water quality monitoring programmes in beaches, marinas and other coastal areas of tourist interest, and large hotels have on-site wastewater treatment plants and treat and reuse wastewater. The 'Adopt-a-River Programme' in Trinidad and Tobago, which is an initiative developed by the Water and Sewerage Authority, aims to facilitate the participation of public and private sector entities in sustainable and holistic projects aimed at improving the status of rivers and watersheds throughout the country. Developing partnerships including with the private sector is an important activity of the US EPA in its programme to address nutrient pollution. Brazil has an institutional and regulatory framework for the private sector to obtain greater incentives for sanitation, and in 2016, 73 private companies and 1,438 public companies accounted for the implementation of public sanitation policies in the country (CERI/FGV, 2016). Private participation in the sanitation sector increased significantly from 1998 to 2014, as seen in Figure 4.5 (SNIS, 2014).

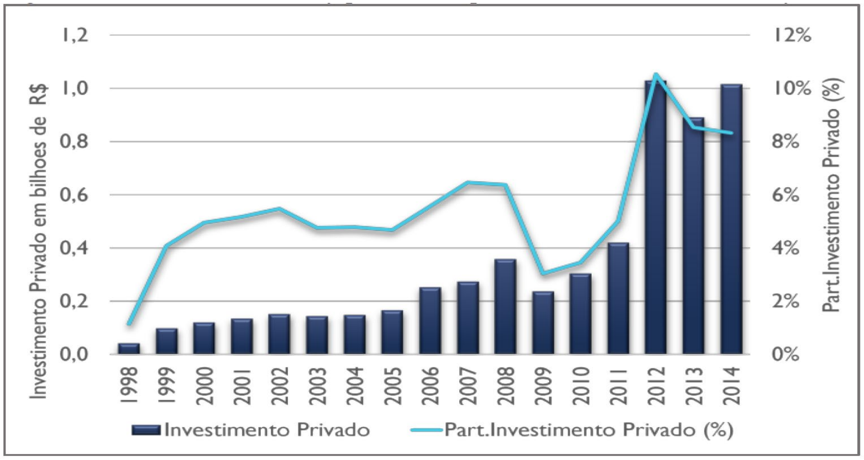


Figure 4.5 Investments made by private companies in sanitation in Brazil (billions of BRL $ / year). Source: CERI/FGV (2016).

In implementing the nutrient pollution reduction strategy, stakeholder engagement, outreach and advocacy will need to be improved. Engagement with the private sector, development banks and other key stakeholders will be critical for the success of the RNPRSAP. The GPNM-Caribbean Platform along with the Cartagena Convention LBS Protocol and associated bodies represent the major regional mechanism to bring together stakeholders involved in nutrient management in the WCR.

4.9 CHALLENGES AND NEEDS

The following is a summary of the challenges and capacity needs identified by the countries and territories (as discussed in the sub-regional reports):

- **Human capacity**: Field personnel (sample collection, in situ monitoring) for point and non-point pollution sources; laboratory personnel (sample processing and analysis) including in new analytical techniques and for emerging pollutants; data collection and analysis for decision-making; modelling (nutrient pollution loading, transport and fate; ICEP determination, the latter done only by Martinique); capacity of professionals and university students in nutrient pollution management.
- **Institutional capacity**: Weak institutional capacity for implementation and operation of sewage collection and treatment systems; lack of capacity to enforce policies and regulatory measures.
- **Infrastructure**: Expansion and/or modernization of the sewage collection and waste treatment systems;

- **Policy and legislation**: Development of nutrient pollution reduction strategies and management plans and policies for point and non-point sources, including integrated nutrient management across relevant sectors and watershed management plans; strengthening of policies to address pollution discharges and of capacity for mitigation of the impacts on water resources.
- **Research:** Topics include emerging issues and those identified in the CLME+ Research Agenda (Acosta *et al.*, 2020).
- **Laboratory and other technical services**: Accreditation of laboratories and associated investment in training and infrastructure; modernization of laboratory equipment; acquisition of reagents and tools; and local availability of maintenance and repair services for laboratory equipment; equipment to collect, process and analyze samples, and necessary data processing and data storage.
- **Monitoring and data sharing**: Water quality monitoring of nutrients (including Si) in coastal waters; monitoring of coastal and marine ecosystems (mangroves, seagrass, beaches and coral reefs); involvement of other actors in monitoring including local communities (citizen science); improved connection to regional monitoring networks and access to information; greater collaboration and sharing of information among stakeholders; data sensitivity issues; and lack of appropriate information systems.
- **Financing**: Sustainable financing and investments for nutrient pollution control and management, including infrastructure, treatment systems and monitoring.
- **Education and awareness**: Training of farmers in nutrient management; stakeholder awareness of nutrient pollution including awareness across sectors.

Priorities at the regional and country levels are also given in the Proceedings of the Second Regional Planning Meeting of the Caribbean Platform for Nutrient Management (February 2016) in terms of the key work areas of the GPNM: Knowledge generation (assessment and monitoring); Technical services (Best practices – agriculture; wastewater management; Governance and policy; and Outreach and advocacy).

The above list covers a diverse range of needs that must be addressed to effectively reduce nutrient pollution. This list, however, is not exhaustive, and as countries develop their own respective nutrient pollution reduction action plans, a comprehensive assessment of priorities, challenges and capacity needs will be required for each country.

4.10 POTENTIAL OPPORTUNITIES

There are significant opportunities to reduce nutrient pollution while contributing to human welfare (opportunities for ‘win-win’ outcomes). Making better use of nutrients, including the reduction of losses and waste, will reduce pollution threats while improving food and energy production and making a significant contribution to the development of ‘green economies’ (Sutton *et al.*, 2013). In many cases, improving nutrient use efficiency will automatically lead to immediate economic, food and energy security benefits. Emphasizing nutrient use efficiency highlights that N, P and other nutrients are a valuable resource. Making better use of this resource with improved recycling provides many cost-saving opportunities, such as reducing the outlay on purchased fertilizers and developing markets for new fertilizer products, e.g., from recycled nutrient streams and capture of NOx from combustion sources.

Domestic wastewater is an important resource for recovery of water, nutrients, and energy. Recycling and reusing sanitation waste has vast potential to benefit the water, agriculture, and energy sectors in the

WCR (Qadir *et al*., 2020). The Latin America and Caribbean region produces domestic wastewater at an estimated rate of 65 m^3/capita/year, from which a significant quantity of nutrient recovery is possible (Qadir *et al*., 2020). In addition, treated wastewater can be used for several different purposes such as agricultural irrigation, aquaculture, industrial cooling and low-quality applications. A study in the Eastern Caribbean found that wastewater reuse can meet up to 38 percent of total water needs in the sub-region (Peters, 2015). Another opportunity is presented by using nitrogen-fixing bacteria (rhizobia), which are used for example in soya production in Brazil where bacteria are inoculated into the soil before sowing, thereby reducing the use of inorganic fertilizers.

Other opportunities for developing the 'green nutrient economy' include upscaling existing technologies and developing new ones that improve the management of nutrient resources and nutrient pollution. Opportunities may also exist with respect to institutional and policy reforms, sustainable financing, stakeholder engagement and public-private partnerships, among others. In implementing the regional nutrient pollution reduction strategy, potential opportunities should be identified and evaluated for development based on existing circumstances at the national and regional levels. Ongoing projects and initiatives such as IWEco, CReW+ and GPNM/GPNM-Caribbean can potentially contribute to the identification and development of opportunities for 'win-win' outcomes.

4.11 CONCLUSION

The foregoing analysis shows that the WCR has many strengths at the national, sub-regional and regional levels that underpin the proposed strategy to address nutrient pollution of the Cartagena Convention area. The Cartagena Convention and LBS Protocol provide a robust regional policy framework, which is essential for the successful implementation of the regional strategy. However, ratification by WCR countries needs to be increased and nutrients more explicitly reflected in the Annexes.

At the national level, while various governance mechanisms and instruments (institutions, policy, legislation, etc.) have been established for environmental management including pollution, few of these specifically target nutrients. Furthermore, in general, the approach to addressing pollution has been sectoral and focused on 'end-of-pipe' concerns. The lack of a comprehensive national policy for integrated management across sectors was identified as a priority concern by many of the WCR countries.

A comprehensive nutrient pollution reduction strategy and action plan that adopts an integrated watershed approach incorporating all relevant sectors and stakeholders is an imperative, in view of the multi-faceted nature of nutrient pollution and given that the drivers and pressures associated with nutrient pollution are increasing. A diverse range of challenges and barriers to effective management of nutrient pollution at the national and regional levels has been identified in the sub-regional reports prepared for this strategy and elsewhere. Addressing these challenges and barriers, among others, will contribute to establishing the enabling conditions necessary for the success of the regional strategy. Chapter 5 presents the draft strategy, which is centered around nine pillars and associated objectives and targets. One of the objectives is to 'Establish enabling conditions for addressing nutrient pollution and its impacts in the WCR' (Objective 9.1). Targets under Objective 9.1. are intended to address the major challenges and barriers at different levels (national to regional), thus creating or strengthening the enabling conditions to implement the proposed strategy and actions at the appropriate scale.

5 WIDER CARIBBEAN REGIONAL NUTRIENT POLLUTION REDUCTION STRATEGY AND ACTION PLAN (2021-2030)

5.1 INTRODUCTION

This chapter presents the regional nutrient pollution reduction strategy and action plan (RNPRSAP) for the Wider Caribbean Region (WCR), which encompasses the Gulf of Mexico, Caribbean, and North Brazil Shelf Large Marine Ecosystems (GOMLME, CLME, and NBSLME, respectively), as illustrated in Figure 1.1. It is underpinned by Chapters 1-4, which provide the background and scientific foundation for the strategy. As discussed in the State of the Convention Area Report (SOCAR) (UNEP CEP, 2019) and Chapter 2 of this report, the major sources of excess loads of nutrients in coastal waters are land-based sources and activities primarily agriculture (crops and livestock) and untreated domestic wastewater, as well as marine sources mainly cruise tourism and commercial shipping. The RNPRSAP focuses on these sources and activities, consistent with the remit of the Cartagena Convention for the Protection of the Marine Environment of the Wider Caribbean Region and its Protocol on Land-Based Sources of Marine Pollution (LBS Protocol). However, it is recognized that other sources and activities contribute to nutrient pollution of the marine environment (such as energy and transport).

An important consideration in developing the RNPRSAP is the balance between environmental protection of marine waters and socio-economic development in upstream areas where the nutrient pollution problem largely originates. This consideration is particularly relevant to the agricultural sector, which is the biggest contributor to enhanced nutrient flows to aquatic systems (Chapter 2). Adequate nutrients are essential for agricultural food production to feed a growing population. Furthermore, agriculture's contribution to food security, livelihoods and poverty reduction in the region is enormous. However, excessive and improper use of nitrogenous fertilizers results in the loss of significant quantities of nitrogen (N) and phosphorus (P) to the environment. As shown in Chapter 2, almost 40 percent of the fertilizer applied in the WCR countries is wasted, producing threats to air, water, soil, and biodiversity, and contributing to greenhouse gas emissions (Lassaletta *et al*., 2014). On the other hand, in certain regions, including parts of Latin America, some farmers do not use enough nutrients, with the resultant nutrient mining degrading the soil and limiting crop yields. Therefore, improving nutrient use efficiency and nutrient management (in the agriculture and wastewater sectors) is central to the strategy, and is a 'win-win' approach whereby multiple environmental, social, and economic benefits can be generated.

In addition to the Cartagena Convention and the LBS Protocol, development of the strategy is guided by outcomes of the Fourth Meeting of the Scientific, Technical, and Advisory Committee (STAC) to the LBS Protocol (Panama City, Panama, 18-20 July 2018), by global initiatives including the Global Environment Facility (GEF) Global Nutrient Cycling (GNC) project and the Global Platform on Nutrient Management (GPNM) as well as by the nutrient pollution reduction strategies of US Gulf of Mexico States.

The strategy is based on nine Pillars, each with corresponding objectives, targets, and indicators. Pillars 1-8 span the entire spectrum of the nutrient challenge, from major point and nonpoint sources to impacts in coastal waters and socio-economic consequences of nutrient pollution of the marine environment. Pillar 9 addresses enabling conditions that are necessary for implementation of the WCR NPRSAP. In addition, a proposed institutional framework and an action framework for implementing the strategy at the regional and national levels are described. Finally, a monitoring and evaluation framework and a compendium of strategies and best management practices (BMP) for addressing nutrient pollution at the source and minimizing its impacts are presented.

5.2 GOAL, OBJECTIVES, AND GUIDING PRINCIPLES

5.2.1 Goal

To establish a collaborative framework for the progressive reduction of impacts from excess nutrient loads on priority coastal and marine ecosystems in the WCR.

5.2.2 Overall Objectives

6. To assist in defining regional standards and criteria for nutrient discharges including regional indicators for monitoring those discharges to the coastal and marine environment;

7. To support institutional, policy and legal reforms relating to nutrients and sediments management including supporting integrated, high-priority interventions to reduce discharge of untreated sewage, nutrients and sediments, and promote recovery of nutrients from wastewater;

8. To contribute to relevant regional and global commitments including United Nations Environment Assembly (UNEA) Resolution 4/14 on Sustainable Nitrogen Management, UNEA Resolutions on Marine Pollution, the Cartagena Convention for the Protection of the Marine Environment of the Wider Caribbean region and its Protocol on Land-Based sources of Marine Pollution, and Sustainable Development Goals (SDG) 6 and 14;

9. To contribute to the operationalization of the Caribbean Platform for Nutrient Management under the aegis of the GPNM;

10. Contribute to the UN Global Campaign on Sustainable Nitrogen Management.

The specific objectives of the RNPSAP are given in Annex 5.1.

5.2.3 Guiding principles

The WCR NPRSAP is based on the following guiding principles:

1. Science-based approach, using the best available science, data and information, and incorporating local/traditional knowledge;
2. Building on the existing foundation established by regional and global initiatives;
3. A ridge to reef, integrated watershed approach that considers nutrient sources in watersheds to their impacts in coastal waters, and the heterogeneity among the WCR countries and territories in terms of biogeophysical characteristics and sectors contributing to nutrient pollution;
4. Balancing ecological, social, and economic imperatives in decision-making throughout the upstream-downstream continuum;
5. Alignment of objectives and targets with relevant national, regional and global policies, frameworks and targets to achieve multiple benefits;
6. Strategic, preventative actions at source that are feasible and cost-effective;
7. Engagement of all key stakeholders including private sector within a multiscale governance framework that encompasses all policy cycle stages;

8. Adaptive management based on robust monitoring and evaluation processes.

5.2.4 Target audience

The intended target audience of the RNPRSAP includes a diverse range of stakeholders, from global to regional/sub-regional and national/ local:

- Parties to the Cartagena Convention and LBS Protocol
- Other WCR Governments
- Regional Seas Programmes
- Sub-regional political groupings: Caribbean Community (CARICOM), Organization of Eastern Caribbean States (OECS), Central American Integration System/Commission for Environment and Development (SICA/CCAD)
- Amazon Cooperation Treaty Organization (ACTO)
- Research and academic institutions
- United Nations Environment Programme (UNEP); other UN and Intergovernmental Organizations (IGO)
- Donor agencies
- Private sector, including farmers (large and small-scale)
- Non-governmental Organizations (NGO)
- General public and local communities

The composition of the target audience represents the main elements of a multiscale governance framework that is required to address the nutrient challenge in the WCR. The specific roles of the key stakeholders in implementation of the RNPRSAP are indicated in the implementation framework in Section 5.6.

5.2.5 Proposed approach

The WCR NPRSAP is based on an integrated approach that examines the land-based and marine sources, fluxes and impacts of nutrient pollution in coastal waters. It provides an integrated basis for exploring strategic ways to reduce excessive quantities of nutrients in aquatic systems including coastal areas. The watershed approach is integrative, acknowledging connections between upstream and downstream areas, and between terrestrial, freshwater (surface and groundwater), and coastal marine waters, both surface and subsurface (Figure 2.1, Chapter 2). Most importantly, it allows for evaluating the impacts of a potentially mitigating measure, not just at point location. With this approach, mitigation measures are often examined for their impacts along the entire watershed and the stretch of associated stream and riverine network of aquatic ecosystems from the headwaters to the receiving coastal waters and sometimes even beyond country borders or exclusive economic zones (EEZ).

Such an approach considers all the major sources of nutrients and the processes promoting their loss to the natural environment and transport across the entire continuum from land to freshwater systems and their eventual deposition in coastal waters (Figure 5.2.1). As such, the RNPRSAP considers the watershed as the geographical management unit on the terrestrial side, and also incorporates major marine sources of nutrient pollution from sectors such as cruise tourism and shipping. This approach considers individual watersheds in the larger countries (continental countries and big islands) while the entire land mass of small islands is considered as the watershed.

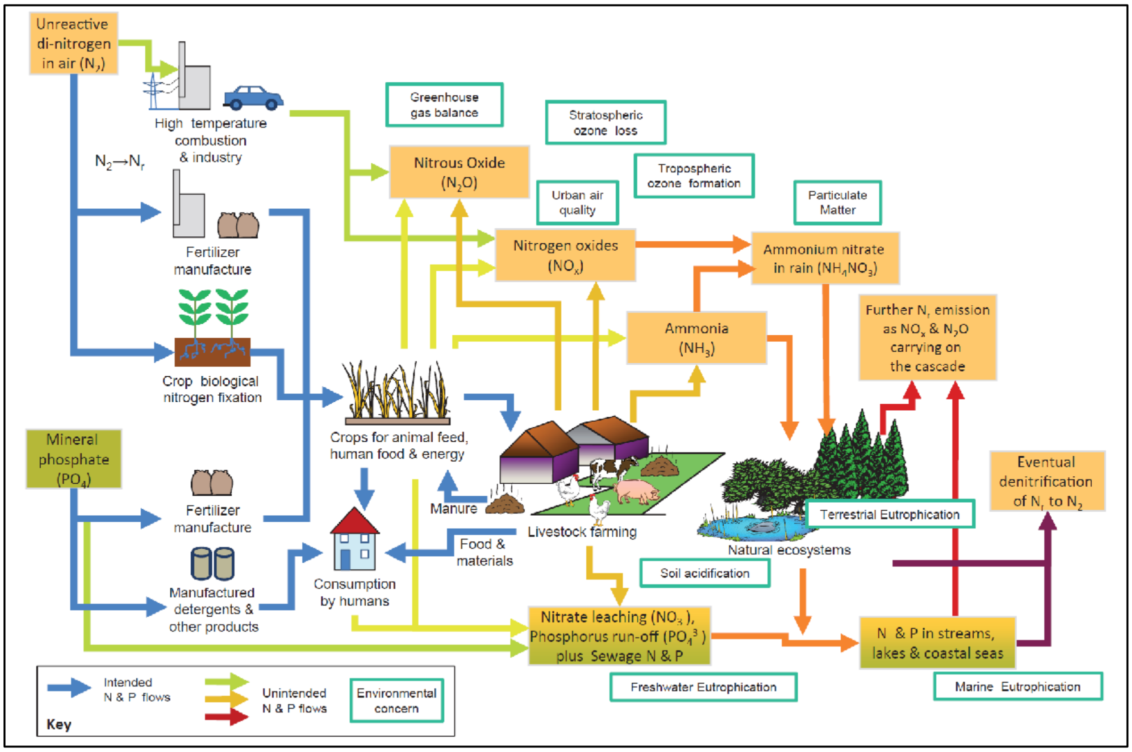


Figure 5.1 Simplified overview of nitrogen (N) and phosphorus (P) flows highlighting major present-day anthropogenic sources, the cascade of reactive nitrogen (Nr) forms and the associated environmental concerns (Sutton et al., 2013). Note: this graphic does not include marine sources of nutrient pollution.

5.3 NUTRIENT SOURCES, LOADS AND IMPACTS

This section presents the main results on nutrient pollution sources and the impacts these have created on people and ecosystems that were discussed in extensive detail in Chapters 2 and 3 of this document.

5.3.1 Methods

Watershed unit as a scale of analysis. A watershed (also called drainage basin or catchment) is defined as an area of land that drains all the streams and rainfall to a common outlet such as the mouth of a bay or any point along a stream channel (Figure 5.2). Every land extent on planet earth is part of a watershed unit. At planetary scale and in all but a few instances, water exits to the coasts via rivers when these are exorheic watershed systems, such are majority of those in the WCR. Endorheic watersheds are those which do not drain to the sea but to lakes or swamps such as the transboundary watersheds like the Cul-de-Sac Depression and Lago Enriquillo, both in Hispaniola. This report focuses on exorheic basins of the region.

In keeping with a full assessment of the water continuum, this report includes marine-based sources of nutrient pollution. While sea-based point sources such as oil-rig installations, shipping and boating discharges from merchant and cruise ships and yachts, remain as unquantified data gaps, available information is presented and the need for further research highlighted (Chapter 2.10).

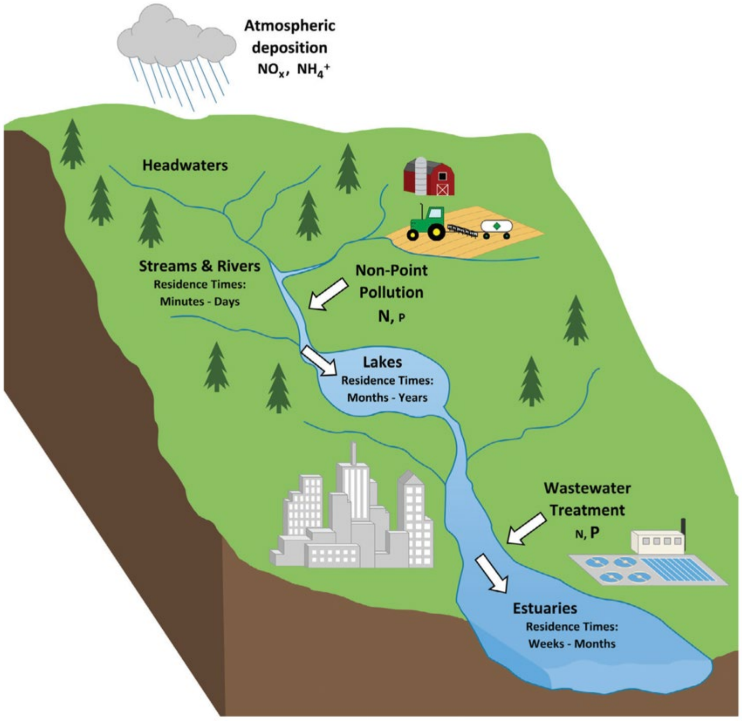


Figure 5.2 A watershed unit includes the land and the stream and riverine network it drains. It is delineated by a drainage divide which is land formation with the highest elevation from which headwaters originate. Included also are non-point and point sources of nutrients leading to estuaries and coastal waters. (Source: Wurtsbaugh et al. 2019)

Input data and analysis. Input data and analysis. To characterize the watersheds and the fluxes and cycles of materials that make up nutrient flows, freely available global datasets were accessed and analyzed. These include:

- HydroAtlas V1.0 database for the watershed features. A total of 3,211 exorheic main basins draining into the WCR were analyzed. Temporal coverage for the watershed parameters generally covers the period from 2000 to 2015. Data resolution was at 15 arc seconds.
- Data on nutrient sources and loads as total nitrogen (TN) and total phosphorus (TP), and which are model outcomes of the Integrated Model to Assess the Global Environment (IMAGE) – Global Nutrient Model (GNM) (Beusen et al. 2016). The model resolved a total of 470 WCR-draining basins. Data resolution was 0.5°.
- Data on nutrient loads in both dissolved and particulate forms of nitrogen, phosphorus, and silica. These are model outcomes of the Global Nutrient Export from Watersheds 2 (Global NEWS 2)(Mayorga et al. 2010). The model results were used to assess the nutrient-specific Index of Coastal Eutrophication Potential (ICEP) at watershed-scale. The data set provides data for 261 WCR-draining basins. Data resolution was a 0.5°.
- National data sets analyzed in the preparation of the SOCAR (UNEP CEP 2019)
- Sub-regional reports synthesizing national data among Spanish-speaking countries (CIMAB 2020), the English- and French-speaking countries ((IMA 2020), and the Sub-region III countries including on the North Brazil Shelf LME (NBSLME) (University of Para 2020).
- Supporting data sets were also accessed including:
    - FAO databases on land use, pesticide use and wastewater
    - Country-scale data on Net Anthropogenic Nitrogen Inputs (NANI) (Han et al., 2020)
    - Transboundary Waters Assessment Programme (TWAP) results for transboundary river basins (UNEP-DHI 2016; Talaue-McManus 2016)

5.3.2 Regional Nutrient Pollution Reduction Strategy and Action Plan (RNPRSAP) Database

All of the core data comparable in methodology, across watersheds or countries, both input and derived, have been assembled as an RNPRSAP Database that is an integral component of the strategy document. The database is meant to initiate the assembly of information that is needed to plan nutrient pollution reduction. Generation of empirical and modelled data to update and maintain this database is feasible when viable nutrient pollution monitoring programmes at national, subregional or regional scales are established where these are currently absent, and strengthened where capacities exist. Currently, the database presents summaries of spatial data at country scale (Table 5.1). Future presentations at watershed scale can be done in the form of GIS products. None-spatial data except for NANI computations, are not included as these are best accessed directly from data providers so that the most up-to-date can be obtained.

Table 5.1 Organization of watershed data in the RNPRSAP Database for the Wider Caribbean Region.

Watershed Features	Land use and Demographic features	Nutrient inputs and Soil-budget based Nutrient Sources	Nutrient Loads	Index of Coastal Eutrophication	Coastal Water Quality (SOCAR National data related to nutrients)
Type					
Big Continental countries: Sub-regions I & III, North Brazil	✓	✓	✓	✓	- Colombia - Mexico - USA
Small Continental countries: Sub-region II	✓	✓	✓	✓	None available
Small islands: WCR Sub-regions III, IV and V	✓	✓	✓	Only Trinidad & Tobago with 2 basin cell counts	- Antigua & Barbuda - Barbados - Dominica - Grenada - Saint Lucia - Saint Vincent & The Grenadines - Trinidad & Tobago
Big islands:WCR Sub-regions V	✓	✓	✓	✓	- Dominican Republic - Jamaica - Puerto Rico
Data sources	Linke et al 2019 using Level 7 (for maps) and Level 12 basin datasets (for data computations)	Han et al. 2020; Beusen et al. 2015 for model year 2000	Beusen et al 2015: Model year 2000 for total nutrients; Mayorga et al. 2015: Model year 2000 for all forms of N and P	Mayorga et al. 2015	SOCAR Report: (UNEP CEP 2019)

5.3.3 Land use change drive nutrient additions to excess

Land use change. Forest land conversion to grow crops and livestock, has been a singular driver of nutrient pollution since the production of synthetic nitrogen fertilizer reached commercial scale in the 1920s (Tilman et al. 2001). Every country and territory within the WCR has a story behind the chronology of land use change incorporating the technology of fertilizer and pesticides. For this document, a harmonized land use data from the Food and Agriculture Organization (FAO) spans a relatively short period from 1961 to 2018. During this period with 1990 as reference year for forest change, continental countries lost one million km^2 of forest cover, during which time cropland and pastures increased, except for the USA (Table 5.2). In the case of small island countries and territories, there were noticeable reductions of forest area and cropland, as these were converted for more urbanized uses. For the bigger islands of Sub-region V, there were significant increases in cropland, and decreases in pastures, including increases in forest area except in the case of Haiti. Contemporary land use (forest, cropland, pasture) is shown in Figure 5.3 and corresponding areas for each including urban extents are shown in Table 5.3.

Table 5.2 Changes in agricultural and forest areas (km^2) among WCR countries and territories. Changes in cropland and pasture are tracked from 1961 to 2018; that for forest covers a shorter period from 1990 to 2019. (Input data: FAOSTAT). Values in red inside (parentheses) are losses.

WCR Sub-region	Area	UN Iso-Code	Cropland		Pasture		Forest	
			Change in Area (2018-1961) km^2	% change 1961 to 2018	Change in Area (2018-1961) km^2	% Change 1961 to 2018	Change in Area (2018-1990)	% Change 1990 to 2018
I	Mexico	MEX	57,950	28%	27,800	4%	(46,440)	-7%
I	United States of America	USA	(220,722)	-12%	(196,264)	-7%	73,450	2%
II	Belize	BLZ	800	190%	130	35%	(3,007)	-19%
II	Costa Rica	CRI	1,025	21%	2,850	31%	947	3%
II	Guatemala	GTM	5,090	33%	7,010	63%	(12,302)	-26%
II	Honduras	HND	1,160	8%	2,600	17%	(5,866)	-8%
II	Nicaragua	NIC	6,100	52%	10,250	46%	(27,918)	-44%
II	Panama	PAN	1,860	33%	4,490	42%	(3,707)	-8%
III	Brazil	BRA	320,740	102%	478,458	38%	(898,466)	-15%
III	Colombia	COL	49,220	99%	46,000	13%	(54,177)	-8%
III	French Guyana	GUF	158	527%	107	357%	(1,153)	-1%
III	Guyana	GUY	1,100	31%	(2,178)	-22%	(1,684)	-1%
III	Suriname	SUR	330	94%	100	167%	(1,568)	-1%
III	Venezuela (Bolivarian Republic of)	VEN	(1,820)	-5%	24,500	16%	(56,882)	-11%
IV	Antigua and Barbuda	ATG	(30)	-38%	20	100%	(19)	-18%
IV	Barbados	BRB	(90)	-53%	0	0%	0	0%
IV	British Virgin Islands	VGB	0	0%	10	25%	(1)	-2%
IV	Dominica	DMA	80	53%	0	0%	(24)	-5%
IV	Grenada	GRD	(120)	-63%	(20)	-67%	0	0%
IV	Guadeloupe	GLP	(183)	-42%	119	85%	(25)	-3%
IV	Martinique	MTQ	(53)	-25%	27	21%	41	8%
IV	Montserrat	MSR	(20)	-50%	0	0%	(10)	-29%
IV	Saint Kitts and Nevis	KNA	(109)	-68%	(31)	-78%	0	0%
IV	Saint Lucia	LCA	(40)	-29%	(24)	-80%	(5)	-2%
IV	Saint Vincent and the Grenadines	SVG	(40)	-44%	10	100%	10	4%
IV	Trinidad and Tobago	TTO	(450)	-49%	20	40%	(130)	-5%
IV	United States Virgin Islands	VIR	(30)	-60%	(50)	-71%	(49)	-20%
V	The Bahamas	BHS	30	33%	10	100%	0	0%
V	Cuba	CUB	19,116	116%	8,384	44%	11,840	58%
V	Dominican Republic	DOM	2,420	24%	(30)	0%	5,330	33%
V	Haiti	HTI	1,900	16%	(100)	-2%	(294)	-8%
V	Jamaica	JAM	(610)	-22%	(280)	-11%	678	13%
V	Puerto Rico	PRI	(2,378)	-78%	(2,093)	-67%	1,750	55%
	Net Change		242,324	10%	411,824	8%	(1,019,709)	-10%

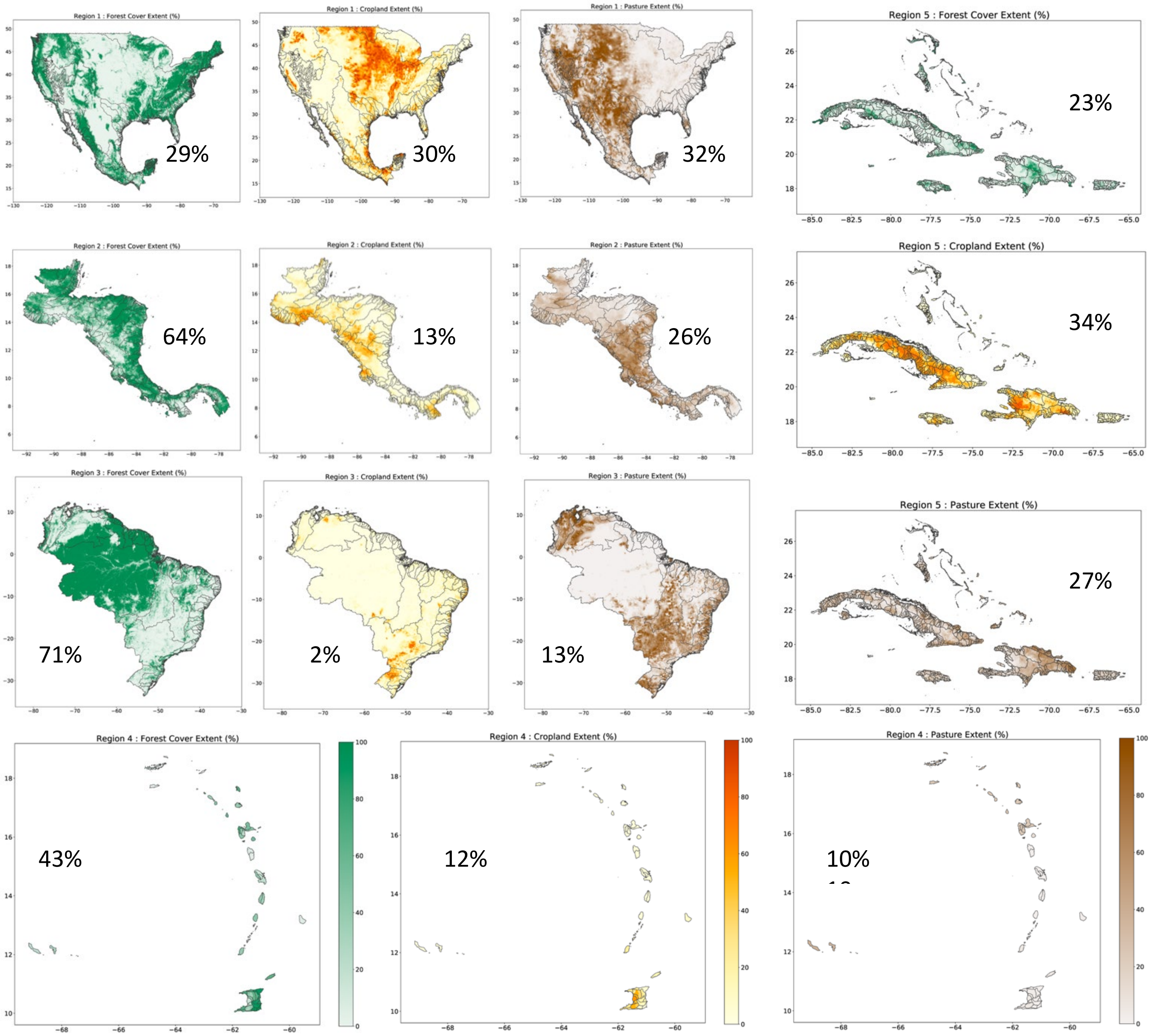


Figure 5.3 Land use in WCR countries in year 2000 (HydroAtlas data, Linke et al. 2019). Percent cover is at sub-regional scale. Forest cover follows a light to dark green scale; cropland yellow-orange scale and pasture light to dark brown scale. Sub-region III combines North Brazil with Sub-region III countries.

Table 5.3 Contemporary land use including urban extents (data processed from HydroAtlas, Linke et al. 2019).

WCR Sub-region	Watershed Area, (km^2)	Forest (km^2)	Cropland (km^2)	Pasture (km^2)	Urban (km^2)
I	5,441,154	1,554,623 **29%**	1,634,232 **30%**	1,740,170 **32%**	106,056 **2%**
II	364,408	234,070 **64%**	46,466 **13%**	95,529 **26%**	6,343 **2%**
III*	6,974,806	4,965,249 **71%**	134,094 **2%**	924,134 **13%**	22,170 **0%**
IV	14,001	6,056 **43%**	1,708 **12%**	1,362 **10%**	2,033 **15%**
V	228,975	52,288 23%	77,292 34%	62,067 27%	13,780 6%

*Includes main basins draining to NBSLME (Amazon basin and others up to Parnaiba estuary and excludes Amazon basins outside of the WCR (i.e. those in Bolivia, Ecuador and Peru))

Loss of forest land, agricultural area expansion and intensification, and the increase of built-up surfaces in the case of small islands, are land uses that mobilize soil, nutrients and other pollutants from the watersheds, making their way to aquatic ecosystems including coastal waters, and beyond the continental shelf for the major rivers. Forests and associated microbiomes tightly cycle nutrients across biotic and abiotic components. In the case of croplands, tillage and other farming practices, including the application of chemicals for crop protection have rendered the soils unhealthy with minimal organic matter for remaining microbes to mediate the cycling of nutrients. Thus begins the use of chemicals to boost crop production and kill organisms that presumably minimize this. In the case of built-up surfaces, aquatic systems visibly degrade when about 10% of land in the surrounding watershed becomes impervious (Klein 1979; Schueler and Holland 2000; Beach 2002).

Fertilizers and nutrient use efficiencies. Over a period of nearly six decades from 1961 to 2018, cropland among WCR countries increased from 2.5 million km^2 to nearly 2.8 million km^2, occupying just 12% of aggregate national land areas in the latest data year. Using the latest spatial data referenced to model year 2000, croplands make up 14% of aggregate WCR-draining watersheds (RNPRSAP Database V3.0). Currently, Latin American and Caribbean (LAC) countries contribute 14% of the global food production, and 23% of agricultural and fish exports. These contributions are projected to increase by more than 5% by year 2028 (OECD-FAO, 2019). A major question is the extent of environmental tradeoffs these increases will exact, in addition to issues of food insecurity and poverty for many farming households in the region (Flachsbarth et al. 2015).

To quantify how fertilizer is used in the region and to determine excess amounts of both N and P, two indices were used to quantify use efficiency and excess nutrient runoff. Note that agricultural runoff and groundwater flows were also estimated for both N and P using Beusen et al. model, which takes into account nutrient retention, transformations and losses. The Nitrogen and Phosphorus Use Efficiencies were calculated without taking these biogeochemical processes into account. Please see section 2.3.1 for details, including Annexes 2.3 and 2.4. The equations for both indices are as follows:

Nitrogen Use Efficiency (NUE) *= (annual harvested crop in Kg N* ha^{-1} yr^{-1}*)/ annual Inputs [Synthetic N fertilizer + symbiotic N fixation, + manure application + atmospheric deposition] to cropland (Equation 1.0)* (Lassaletta et al. 2014)

Phosphorus Use Efficiency (PUE) of the agricultural system and of its subsystems = *Total P harvested in economic outputs such as crops, meat, milk and eggs/ Total P inputs [P fertilizers for cropland, P from mined phosphate rock, atmospheric P deposition in cropland and pasture areas] (Equation 2.0)* (Lun et al. 2018***)***

The nutrient use efficiency indices utilize crop harvest, livestock production and fertilizer use as basic parameters. The relationships above basically state that beyond a certain rate of application, crops can no longer assimilate fertilizers for growth. Unused nutrients become excess or surplus and flow out of the agricultural system with water as the main transport agent. Table 5.4 summarizes the amount of N and P fertilizer that is in excess of what the crops can use for growth. Croplands in the WCR are 57% efficient in utilizing N fertilizers and 57% efficient using P fertilizers. Wastage is very high at **40%**. As such, excess N was almost 12 million tons for model year 2000. Surplus P was estimated to be 640 thousand tons for the same year. Outside of croplands, these nutrients fertilize floating and benthic algae along the water continuum. Comparing these with the model results from Beusen's model, the Surplus N value is 3.5X greater than modeled agricultural N sources, and the Surplus P is almost 2X in magnitude than that estimated for agricultural P sources, since inventory methods do not take into account losses due to nutrient retention or denitrification for N or adsorption for P.

In addition to fertilizers, pesticides are also used to protect the crops during growth and the produce that is harvested until this reaches buyers for distribution and retailers for consumption. Pesticides are biocides and are often non-selective in their killing properties. Used recklessly, these compounds pose serious risks to farm workers, farm and aquatic ecosystems, and the consuming public. There are no use efficiencies for pesticides and estimates of release to the environment can only be made with empirical measurements as cited in Section 2.3.2 of the report. Moreover, current standards apply mostly to levels that protect consumers, not ecosystems or farmworkers. The dosage of pesticide application should ideally be at prophylactic level, and that is cognizant of protecting soil and stream ecosystems and people including the consuming public. An estimated 940,000 tons of total pesticides were applied in year 2018, showing a doubling from 1990 (Figure 5.4).

Table 5.4 Excess Nitrogen (N) and Phosphorus (P) flows generated because croplands were only 60% efficient in utilizing N and P fertilizers. Pastures, which were not fertilized, contributed 15% of total P excess flows from livestock manure, as these were assumed not to be fertilized like croplands.

Model year 2000	Cropland, km^2	Pastures, km^2	Cropland P runoff, tons	Pasture P runoff, tons	Surplus P runoff, 10^3 tons	Surplus N runoff, 10^3 tons
Sub-region I	1,634,238	1,740,175	473,284	35,792	514	9,978
Sub-region II	46,466	95,529	8,873	6,031	15	305
Sub-region III	134,096	924,159	49,931	45,031	95	1,140
Amazon basins (BOL-ECU-PER)[1]	51,655	333,868	10	10	21	**264**
Sub-region IV	2,549	4,223	1,504	343	2	**No data**
Sub-region V	76,431	58,836	13,176	7,398	21	321
WCR Total	**1,945,435**	**3,156,790**	**546,779**	**94,605**	**667**	**12,009**

[1] These are watersheds in Bolivia, Ecuador and Peru, and which form the upper reaches of the Amazon river basin, contributing to nutrient loads of the Amazon river.

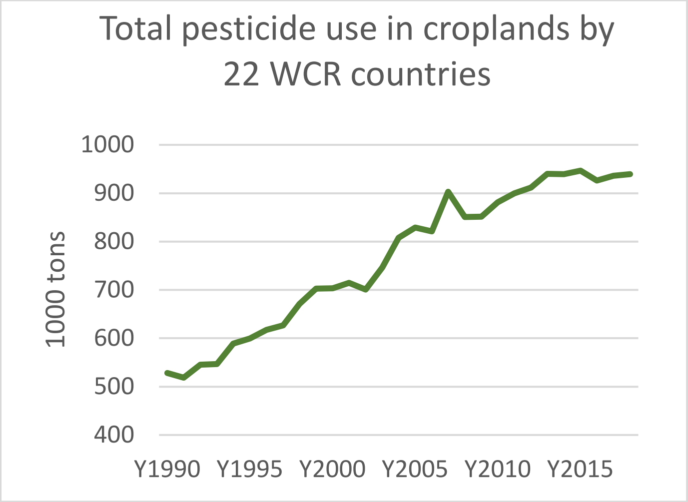


Figure 5.4 Usage of pesticides in WCR countries for the period 1990 to 2015. Data source: FAO Statistics on Pesticides Use in Agriculture, 1990-2018.

5.3.4 Sources of nutrient pollutants: Urbanization and untreated domestic wastewater.

An estimated 890,000 tons of TN and 155,000 tons of TP were released in the form of untreated domestic wastewater in the region, and which are generated by restroom use, bathing, food preparation and laundry, for year 2010 (Table 5.5). This inventory method of estimation does not take into account nutrient retention and other losses such as denitrification. The modeled estimates for sewage TN for model year 2000 are 533,000 tons and 70,000 tons for TP. Given the 10-year difference, estimates for TN are in the same order of magnitude, while the inventory-based TP is 2x that the model estimate. In the WCR, sewage as a nutrient source accounts for 10% of total pollutant flows in model year 2000. For Sub-region V where the big islands of the WCR are located, sewage accounts for almost 25% of total N pollutants. Mitigation is sorely needed to protect public health and ecosystems in Sub-region V where urbanization is high.

Table 5.5 Estimates of untreated domestic wastewater contributing to nutrient pollution. Watershed populations for 2010 in RNPRSAP Database were used to scale the calculations, methods for which are detailed in SOCAR Annex 4.1 (UNEP CEP, 2019).

WCR Sub-region	Population in watershed area draining to WCR, 10^3 (2010)	2010 Untreated Wastewater released to environment 10^9 m^3/yr	$10^{3.}$ tons TN in Untreated Wastewater (2010) (N = 60 g m^{-3})	10^3 tons TP in Untreated Wastewater (2010) (P = 10 g m^{-3})
Sub-region I	198,402	5.68	341	57
Sub-region II	20,262	0.81	48	8
Sub-region III	70,018	4.70	282	47
North Brazil	22,634	0.79	39	13
Amazon watersheds in BOL-ECU-PER[1]	19,298	0.34	20	3
Sub-region III Islands	102	0.004	0	0.04
Sub-region IV	3,014	0.18	11	2
Sub-region V	38,017	2.45	147	25
TOTAL	**372,180**	**15**	**890**	**155**

[1] Amazon watersheds located in Bolivia, Ecuador and Peru, and which contribute to nutrient pollutant load of the Amazon River.

5.3.5 Sources of nutrient pollutants using integrated modeling

Model outcomes that estimate sources of nitrogen and phosphorus in total nutrient form, i.e. combines dissolved and particulate forms, are shown in Tables 5.6 and 5.7. The NBSLME watersheds are kept separate from the rest of the WCR to highlight differences in sources and magnitudes of nutrient sources. The NBSLME has the largest forest area in the WCR. As such 94% of nitrogen comes from natural sources, and 5% from agriculture. In contrast, nitrogen flows from agriculture sources, both surface and groundwater, account for 60% of total flows in Sub-regions I to V. Trends for phosphorus are the same: P fluxes in the NBSLME come almost solely from natural sources and agriculture contributes only 8%. Curbing pollution from agriculture at its source among Sub-region I to V watersheds is absolutely essential. And it must not start from a false dichotomy between increasing food production and sacrificing environmental protection. Agriculture cannot be sustained without healthy soil and healthy water.

Table 5.6 Estimates of nitrogen sources as total nitrogen (TN = dissolved and particulate forms) using Beusen et al. model (2015, 2016).

Nitrogen Sources (Model Year 2000)	Natural sources (Vegetation + non-agr runoff + non-agr gwater)	Atmospheric deposition	Agriculture (surface + groundwater)	Sewage	Aquaculture	All Nitrogen Sources
Sub-region I-V (1000 tons)	1612	58	3278	509	10	5,468
Sub-region I-V (%)	30%	1%	60%	9%	0%	100%
NBSLME (1000 tons)	7973	22	391	23	0	8,411
NBSLME (%)	94%	0%	5%	0%	0%	100%

Table 5.7 Estimates of phosphorus sources as total phosphorus (TP = dissolved and particulate forms) (Beusen et al. 2015, 2016)

Phosphorus Sources (Model Year 2000)	Natural sources (Weathering + Vegetation + non-agri runoff)	Agriculture (Surface runoff)	Sewage	Aquaculture	All Phosphorus Sources
Sub-region I-V (1000 tons)	202	339	66	1	608
Sub-region I-V (%)	33%	56%	11%	0%	100%
NBSLME (1000 tons)	697	23	3	0	723
NBSLME (%)	91%	8%	0%	0%	100%

Using Beusen's model, it was possible to do a retroactive analysis of nutrient loads, the actual amounts which reach the river mouth for offloading to coastal waters. Figure 5.5 shows a doubling of total nitrogen and a 40% increase of P load over 100 years for the combined total of the 5 sub-regions. Brazil's line graphs, in contrast, are almost horizontal because of the high capacity of forested floodplains to sequester nutrients in the form of plant biomass. Losing forest land will alter the slopes of nutrient loads over time under scenarios without mitigation of nutrient pollution.

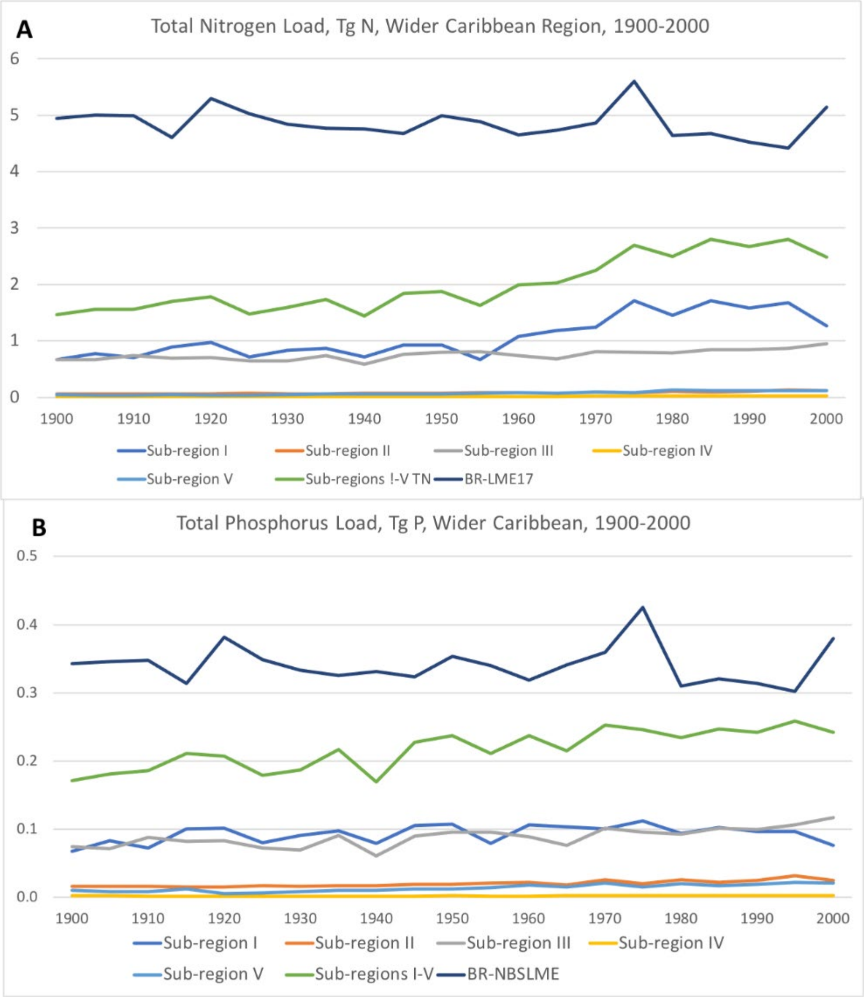


Figure 5.5 Modeled loads of total N (A) and total P (B) for the model years 1900 to 2000, Nutrient loads are estimated amounts of what arrive at the river mouth and are net of river mouth retention. The line graphs refer to individual regions, or the total for Sub-regions I to V combined. The loads over time for North Brazil watersheds show a horizontal slope because of the buffering capacity of vegetated floodplains and forest to cycle nutrients tightly within the forest biome. For the region except Brazil, total nitrogen almost doubled over a century. For phosphorus, there was a 40% increase over the same time period.

5.3.6 Marine-based sources of nutrient pollution

While agriculture is the singular land-based driver of nutrient pollution on land, cruise ship tourism may be the roving collective point source of nutrient-laden wastewater at sea. In the WCR, cruise tourism is the most lucrative form of tourism to date, with revenues reaching US$ 40 billion in 2016; and 24 million passengers arriving in over 30 choice Caribbean island destinations onboard megaships that carry on average 4000 passengers and 500 crew members each (Honey 2016, 2019) (Figure 5.6).

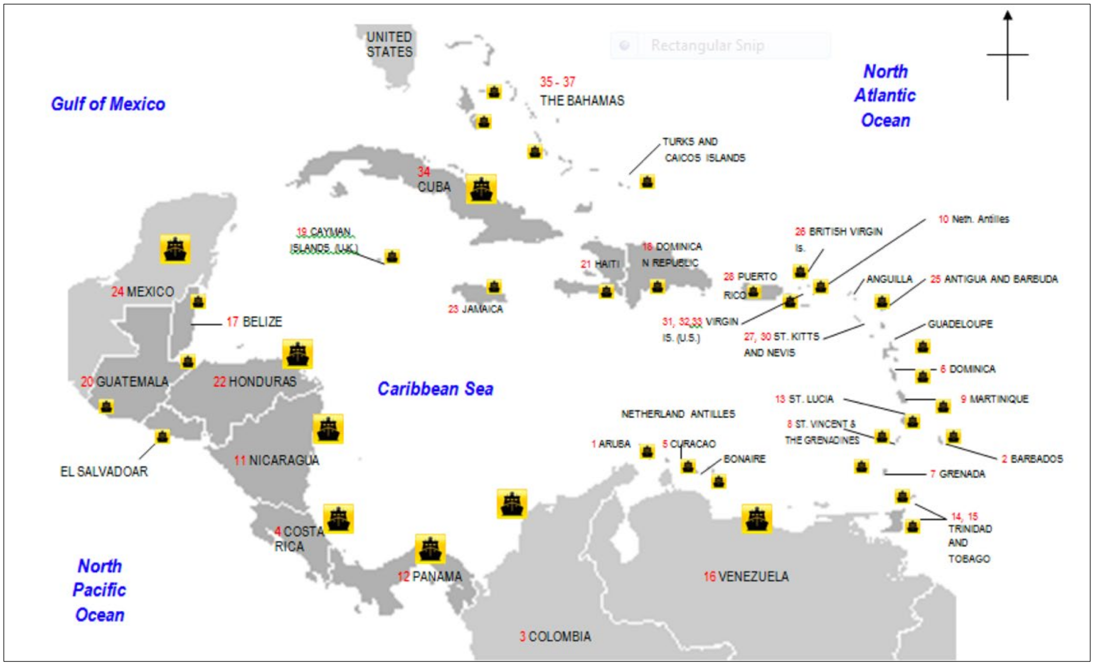
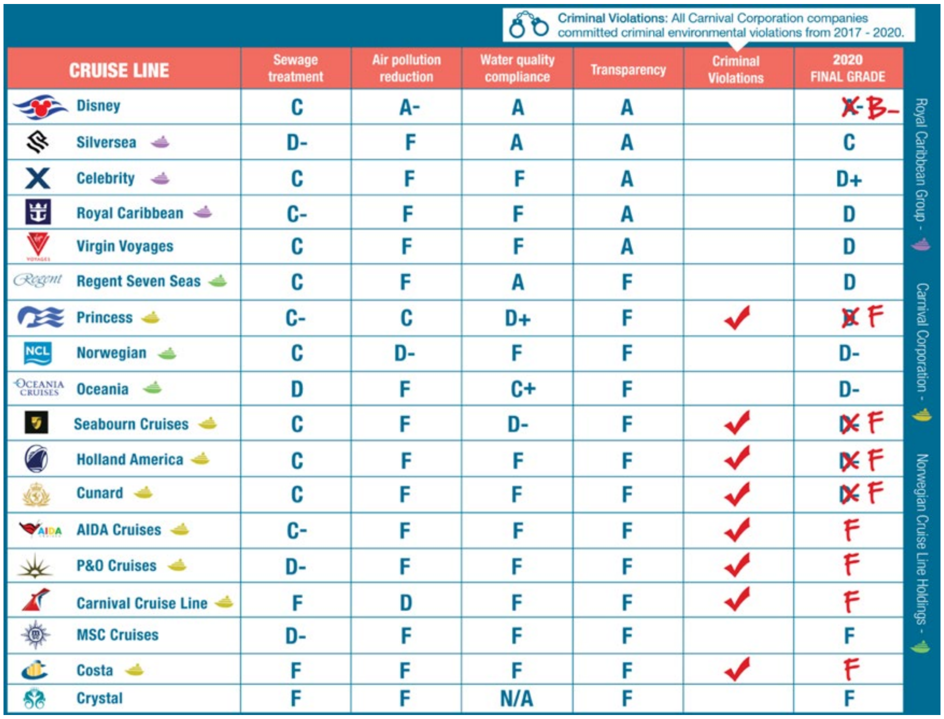


Figure 5.6 Cruise ports in the Wider Caribbean. Ports in the US and Brazil are not included (ACS Directorate for Sustainable Tourism, 2016).

In 2008, the US Environmental Protection Agency (US EPA) released its findings on cruise ship-generated waste streams including sewage, graywater, oily bilge water, solid waste and hazardous waste; including a thorough analysis of mitigating technology, and existing international and US laws that regulate shipping discharges in US territorial waters or the transport of such materials to US ports (Table 5.8). Detailed data on cruise ship operations and capacities of onboard technology for treating wastewater would be crucial in quantifying ship-based wastewater production and at-sea discharges using the published rates of wastewater production. Given the absence of industry regulations and national policies to collect and report such critical data on cruise ship operations and discharges, no systematic assessment of cruise ship nutrient waste generation has been done to date. In lieu of a formal industry or regulatory report, the Friends of the Earth (FOE), a non-governmental environmental organization, has been producing periodic report cards on cruise ships since 2010, focusing on sewage treatment, air pollution reduction, water quality compliance and transparency about environmental practices.

Table 5.8 Waste streams generated by cruise ships (US EPA 2008).

Waste Stream	Average Waste Production rate per cruise ship per day	Average Production rate per person per day	MARPOL (International Convention for the Prevention of Pollution from Ships)
Sewage (black water)	21,000 gallons	8.4 gallons	Discharge prohibited unless is discharging comminuted and disinfected sewage of more than 3 nm from nearest land; or is discharging sewage which is not comminuted or disinfected at a distance of more than 12 nm from the nearest land
Graywater (wastewater from sinks, baths, showers, laundry and galleys)	170,000 gallons	67 gallons	MARPOL Annex 4
Oily Bilge Water	2640 gallons (max for 2700-3200 passenger capacity		MARPOL Annex I, Regulations for the Prevention of Pollution by Oil
Solid waste	(Royal Caribbean Cruises, per vessel per week): 60 cubic meters of dunnage 5 cubic meters of glass 2.5 cubic meters of cans 12 cubic meters of food waste	7.7 lbs/person/day	MARPOL Annex V; also requires governments to ensure the provision of port reception facilities for solid waste
Hazardous Waste (solid waste with hazardous constituents)	(Royal Caribbean Cruises, 17 vessels): - Photo waste: 1300 gallons/week - medical waste: 80 lbs/ week - batteries: 580 lbs/ week -spent paint and thinners: 225 gallons/week		Hazardous if it appears on 4 hazardous waste lists (F-List, K-List, P-List, or U-List) or has one of four hazardous features (ignitability, corrosivity, reactivity, or toxicity); Hazardous substances are stored on board and should be disposed of in port reception facilities following port country AND MARPOL standards.



Criminal Violations: All Carnival Corporation companies committed criminal environmental violations from 2017 - 2020.

CRUISE LINE	Sewage treatment	Air pollution reduction	Water quality compliance	Transparency	Criminal Violations	2020 FINAL GRADE
Disney	C	A-	A	A		~~A-~~ B-
Silversea	D-	F	A	A		C
Celebrity	C	F	F	A		D+
Royal Caribbean	C-	F	F	A		D
Virgin Voyages	C	F	F	A		D
Regent Seven Seas	C	F	A	F		D
Princess	C-	C	D+	F	✓	~~D~~ F
Norwegian	C	D-	F	F		D-
Oceania	D	F	C+	F		D-
Seabourn Cruises	C	F	D-	F	✓	~~D~~ F
Holland America	C	F	F	F	✓	~~D~~ F
Cunard	C	F	F	F	✓	~~D~~ F
AIDA Cruises	C-	F	F	F	✓	F
P&O Cruises	D-	F	F	F	✓	F
Carnival Cruise Line	F	D	F	F	✓	F
MSC Cruises	D-	F	F	F		F
Costa	F	F	F	F	✓	F
Crystal	F	F	N/A	F		F

Figure 5.7 Year 2020 Report Card for 18 Cruise lines evaluated by the Friends of the Earth accompanied by details available at the FOE website. (Source: ***https://foe.org/projects/cruise-ships/?issue=335***)

5.3.7 Impacts of nutrient pollution: Inorganic loads, eutrophication and hypoxia

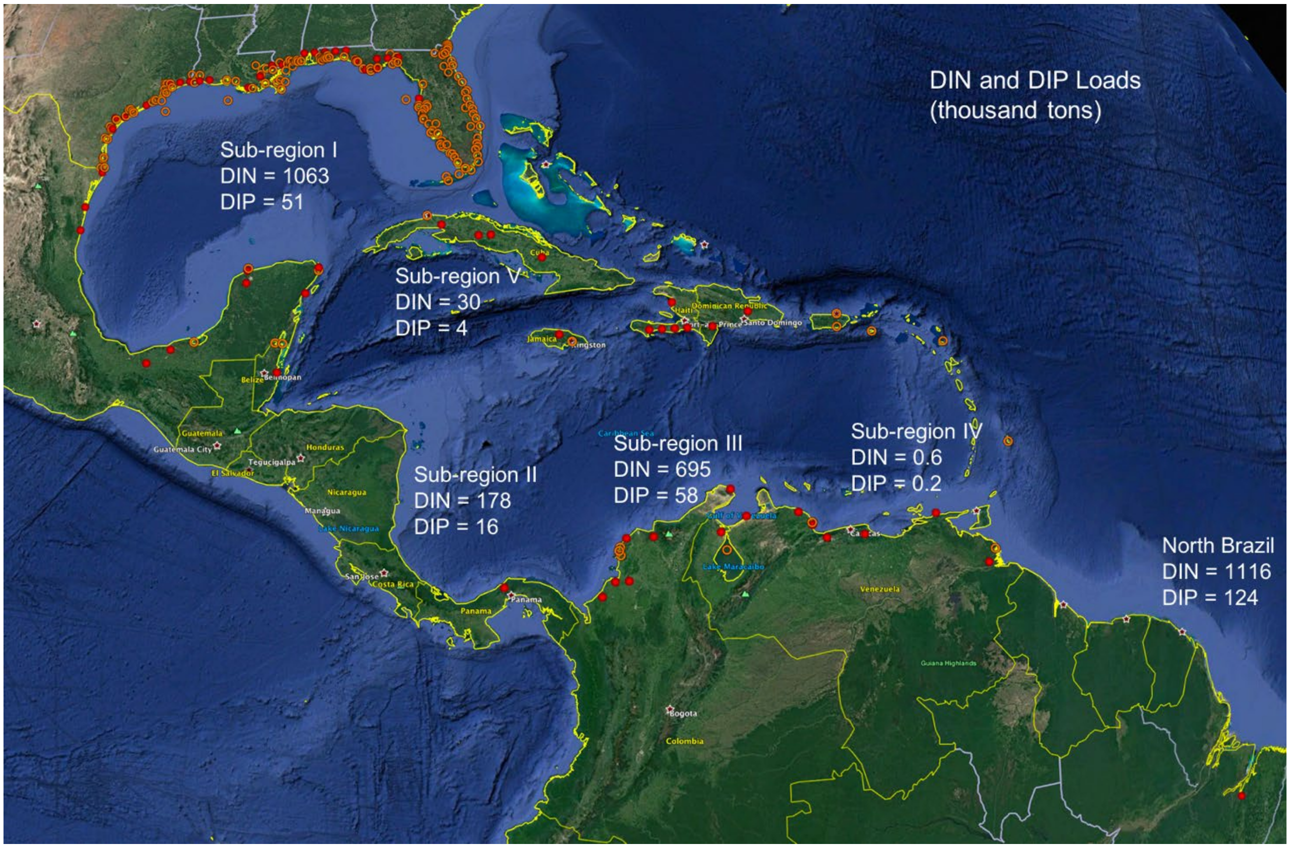


Figure 5.8 Dissolved inorganic forms of nitrogen (DIN) and phosphorus (DIP) are the most biologically reactive nutrient forms as they are used to synthesize plant biomass. Model estimates using the Global NEWS Model 2 provide watershed scale values which are aggregated here by sub-region. The orange open circles are scientifically documented eutrophic (i.e. N or P or both exceeding silica requirements of diatoms) sites that are also hypoxic (i.e. bottom dissolved oxygen equal to physiological limit of 2 mg/L of O_2) (n=164, Diaz et al. 2011), and the red filled circles are river mouths that have been assessed in this report to have a positive potential to become eutrophic.

Nutrient Indices of Coastal Eutrophication Potential. Nutrient pollution is a critical environmental issue because it triggers major ecosystem scale responses with serious impacts on livelihoods and human health, not to mention the impairment of ecosystem services that are requisite in sustaining blue economies. Using the Global NEWS2 Model data which include dissolved and particulate forms of N, P and silica (Si) for model year 2000 for 261 river basins, the N and P Indices of Coastal Eutrophication Potential (N-ICEP and P-ICEP, respectively) were assessed for all resolved basins (see Section 3.1.2). Around 63 basins were estimated to be N-ICEP positive; and 85 P-ICEP positive (Figure 5.8). Forty-three basins were positive for both nutrients. (Please see Section 3.1.2 for guidelines in data interpretation). Across river basins, N was consistently limiting except in 3 river basins following a general pattern of N limitation for coastal waters. Note that nutrient limitation can switch between N and P, and that both can be limiting at the same time. For the NEWS2 dataset, model authors determined that coastal waters were commonly N-limited. As such, sites with positive N-ICEP where nitrogen was limiting were marked with the red filled circles. A coarse validation using a compilation of scientifically documented eutrophic sites that were also hypoxic was used to see spatial proximity with sites assessed to be positive N-ICEP. As the plots show in Figure 5.8, there are coastal areas with positive N-ICEP without documented eutrophic sites. The coarse resolution of the Global NEWS is one explanatory factor as it did not resolve river mouths for small islands in Sub-region IV except for 2 systems in Trinidad and Tobago. Ideally all locations with positive ICEP should be validated empirically for the presence of harmful algal blooms (HAB) mostly composed of dinoflagellates. This microalgal functional group takes over when silica becomes limiting, and which is the nutrient preferred by siliceous diatoms that normally occur when the Redfield molar ratio of N:P is near or about 16.

Harmful algal blooms. HABs occur in response to excessive nutrients in amounts that favor algae other than diatoms. The formation of massive blooms and their subsequent decomposition imposes high oxygen demand on the water column and sediment surface. HABs in the WCR appear to be occurring with increasing intensity (Figure 5.9). Over the period of documentation from 1980 to 2018, dinoflagellates made up 80% of HABs (Figure 5.10). A major social impact of these ecological events are dinoflagellate-induced poisoning syndromes associated with the bioaccumulation of toxins. In the LAC region, Paralytic Shellfish Poisoning (PSP) accounts for 64% of reported syndromes in the region. A systematic assessment of the social and economic costs of poisoning syndromes has not been conducted for the region. This entails treating HABs poisoning syndromes as diseases that need to be tracked for their environmental and medical genesis and prognosis. As the number of cases in the region are likely to increase because of unabated nutrient pollution and global warming, it is critical that monitoring and surveillance of HABS encompass the full suite of health and oceanographic disciplines, in collaboration with the social and economic fields for an integrated programme on HABs. There are established HABs monitoring algal networks for the Caribbean and Central America (Spanish acronym ANCA) and another for South America (Spanish acronym FANSA), which collaborate to produce synthesis reports as cited here.

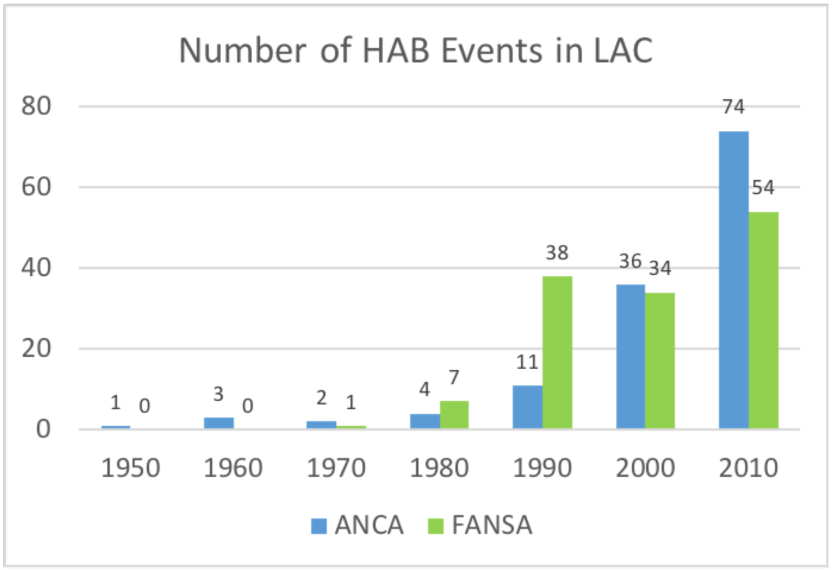


Figure 5.9 Number of HAB events in the ANCA (Caribbean and Central America) and the FANSA (South America) regions analyzed by decade. (Source: Mendez et al. 2018).

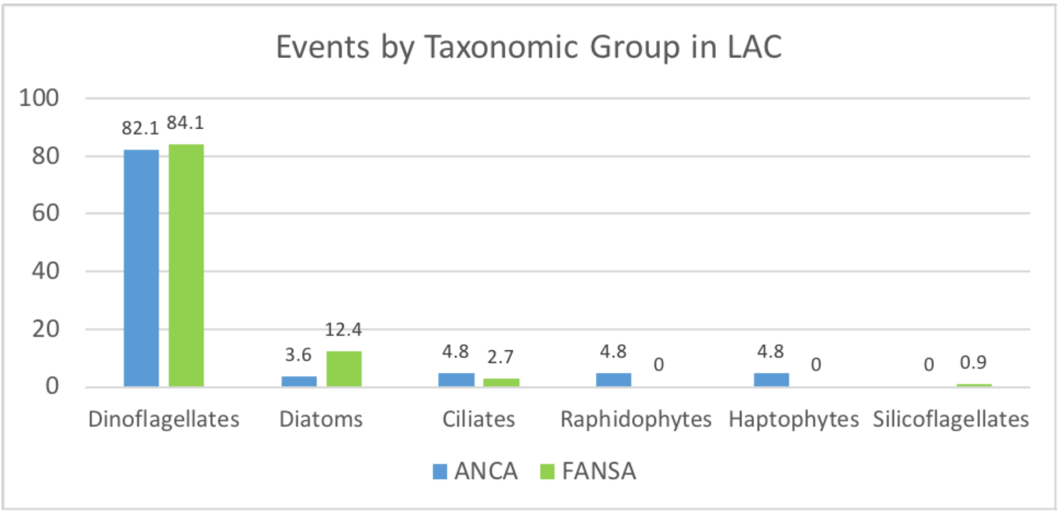


Figure 5.10 Causative organisms of HABs (Source: Mendez et al. 2018).

The economic impact of coastal HABs that occurred nationwide in the US for the period 1987–1992 has been evaluated systematically by Hoagland et al. (2002). Estimates range from a minimum of $36 million to a high of $126 million accounting for inflation-adjusted 2020 costs in public health, commercial fisheries, recreation and tourism, and monitoring and management.

Hypoxic zones and fisheries. The longevity of hypoxic conditions depends on flushing rates when oxygen can be replenished. The onset of hurricanes can shorten hypoxic events. Warming during the summer season exacerbates hypoxia. Hypoxia under conditions of minimal bottom oxygen replenishment progresses to anoxia, when dissolved oxygen dips below the physiological limit. The extent of the hypoxic zone in the Inner Gulf of Mexico has reached up to 23,000 km^2 and 140 km^3 in volume in 2017 (Figure 5.11). Undoubtedly for sessile benthos, mortality is certain, and faunal assemblages show a succession towards opportunistic and short-lived species. Mobile animals, on the other hand, can migrate to areas with less severe hypoxia. A major concern is the impact hypoxic events can have on fisheries. Because of compensatory mechanisms of nekton and the behavioral adjustments a fishing fleet can make in selecting fishing sites, measurements of economic impacts have been equivocal. Recently, bioeconomic models that use behavior-naïve parameters such as seafood price and the relationships this has on size-disaggregated target populations, have been elaborated to successfully measure economic impacts on the fisheries. It is recommended that organismic responses to oxygen be used to inform integrated models so that the oxygen impacts are captured in explicit ways.

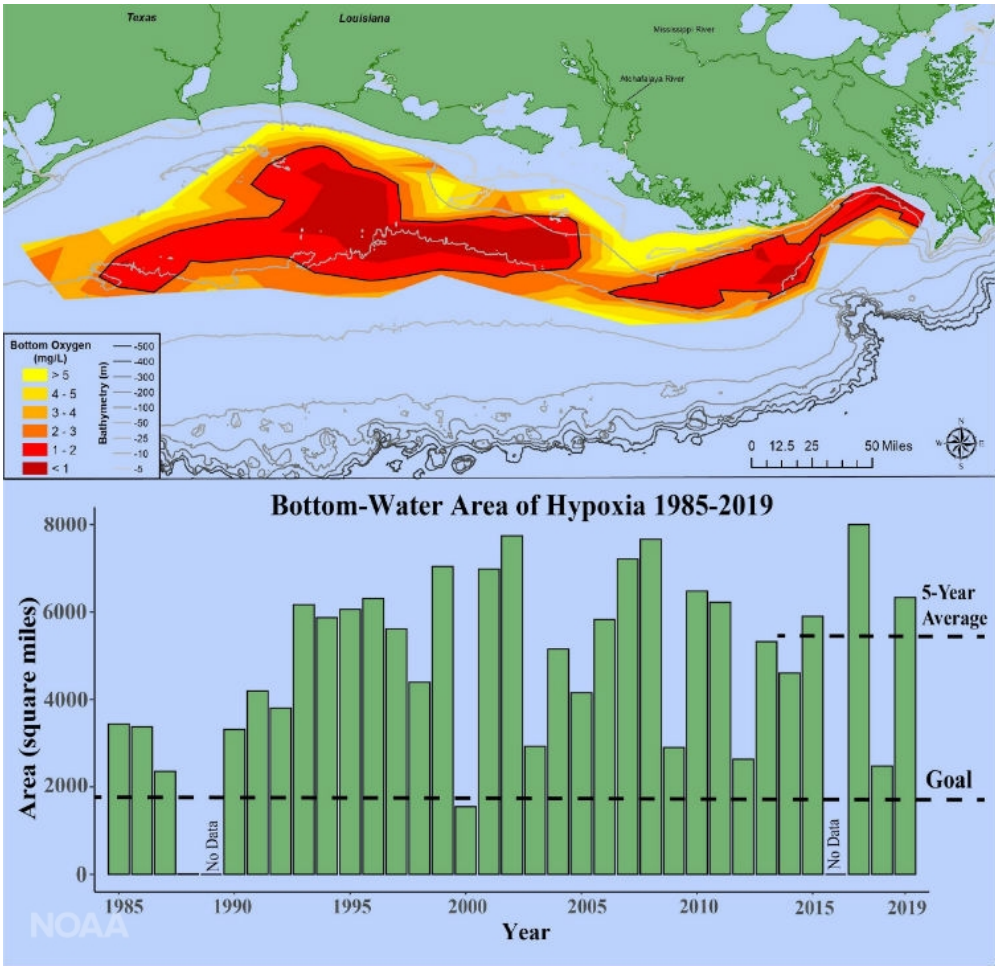


Figure 5.11 Size of the Inner Gulf of Mexico hypoxic zone from 1985 to 2019. A target is to reduce the area to less than 2000 mi^2 or 5000 km^2. (Source: https://www.noaa.gov/media-release/large-dead-zone-measured-in-gulf-of-mexico, LUMCON/LSU)

A major challenge to mitigating the Gulf of Mexico dead zone is the issue of legacy nutrients. These are nutrient pools that have built up over time in the sediments or groundwater, and which function as stored nutrients that can be biogeochemically mobilized to sustain blooms and hypoxic conditions for decades even when contemporaneous loads are reduced or banned. A disruption of the way that agriculture is practiced would need to happen such that nutrient flows can be drastically curbed at source. There is no feasible way to use or clean up legacy nutrients which can operationally constrain the extent to which contemporaneous nutrient reduction targets can be realized. More recent data for 2020 shows a lowering of the 5-year average and can be viewed here: https://www.noaa.gov/media-release/smaller-than-expected-gulf-of-mexico-dead-zone-measured.

5.3.8 Nutrient pollution and the nuisance Sargassum bloom

The pelagic *Sargassum* bloom has annually plagued the Caribbean shores in varying degrees since 2011 when it was first tracked. The hypothesized genesis of this macroalgal bloom is a climatological one – winds anomalously shifted south of the Sargasso Sea and caused an eastward dispersal of *Sargassum* in the winter of 2009-2010. The dispersing population turned south along the Canary Current and entered the tropical warm waters that get enriched with nutrients by mechanisms such as the Guinea Dome and by nutrient-laden river plumes of the Amazon and the Orinoco, the latter remaining in dispute as first-order driver for sustaining *Sargassum* blooms. Since this tipping-point journey outside the Sargasso Sea, remnants of the bloom a year prior becomes seed the following season. When *Sargassum* racks reach shore and begin to decompose within 48-72 hours, they emit H_2S that is toxic to humans when inhaled. On shallow waters, they obscure light from reaching subaquatic vegetation including seagrasses. Their decomposition causes localized eutrophication and modifies trophic dynamics of seagrass and reef inhabitants such as narrowing the diet prey availability of herbivorous sea urchin *Diadema antillarum*. Figure 5.12 shows the extent of coastline in the Mexican Caribbean that is directly impacted by the nuisance bloom, covering zones from the forereef to the mangrove areas.

Decaying seaweed racks on the beach depress tourism arrivals and impose clean-up costs on tour operators and hotels that are already compromised by travel restrictions triggered by the Covid19 pandemic. Additional costs include health expenditures, lost tourism revenues, transport costs, barrier installation and maintenance, management costs; and losses in property value, to name a few. A number of publications have explored ways to incentivize the collection of racks, such as their potential use in bioremediation as collection medium for pollutant recovery, biogas conversion, and manufacture of fertilizer, paper, beauty care products, crop and livestock feeds, and bioplastics.

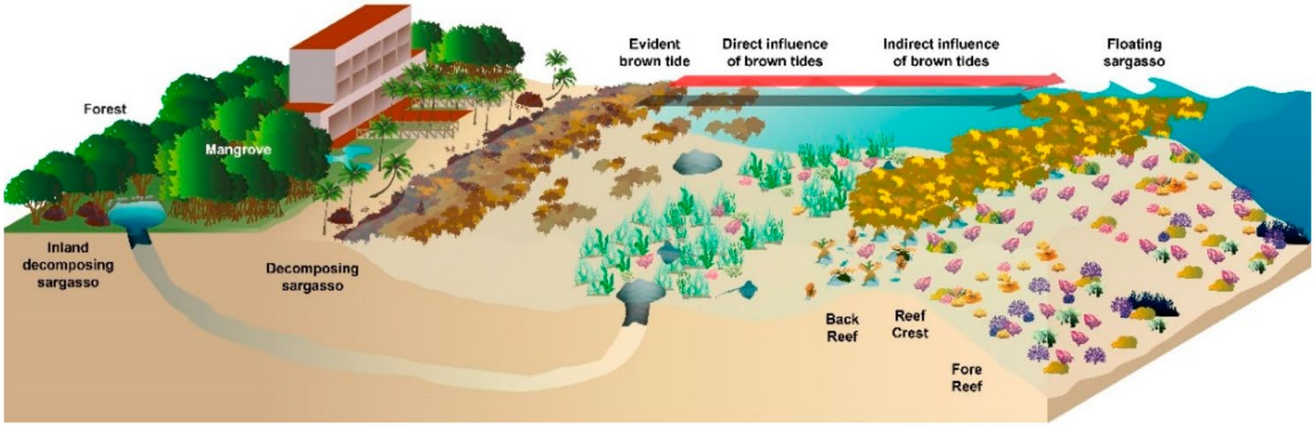


Figure 5.12 A profile of the Mexican Caribbean coast profile showing the impacted coastal zones including coral reefs, seagrass beds, mangroves and underground rivers. (Source: Chavez et al. 2020)

winds all point to the need to build resilience among human societies and ecosystems to cope with the increasing uncertainties emanating from a changing climate. Preventive measures with demonstrable success can matter a lot. Preventing local stressors such as excessive nutrient flows where they can be reduced at source is one big step. The alternative of business as usual appears just as costly or more.

5.3.9 Nutrient pollution and climate change

A number of impacts discussed in Chapter 3 include the emergence of pathogens from nutrient-enriched habitats that are spread to humans and of intermediate hosts by changing biotic interactions enhanced by warming thermal regimes. Some pioneering studies highlight that human populations most vulnerable to these pathogens include households at poverty level, and which characterize most of the farm labor in LAC. At the level of nutrient pollution, this strategy can help address the root cause, disrupting the way that agriculture has been practiced by embracing the protection of ecosystem health from land to sea, as the gold standard for policy design.

Along the same vein, the spread of coral diseases when reefs are compromised by local stressors like nutrient pollution and overfishing, and exacerbated by warming temperatures, and by acidifying and deoxygenating waters, will not be solved by a nutrient pollution reduction strategy alone. Doing so will contribute to building ecosystem resilience.

The long-range transport of micronutrients like iron and potentially pathogenic microbiomes via Sahara dust may intensify with changing climatology. This strategy, if it is able to curb local nutrient pollution, would go a long way towards mitigating added risks from transboundary stressors. Managing risks from nutrient pollution under conditions of uncertainty, and choosing strategic actions based on realistic though partial cost-benefit analysis while making tradeoffs explicit and transparent to the extent possible, is what this document hopes to achieve in the long-term.

5.4 SCOPE AND STRUCTURE OF THE RNPRSAP

5.4.1 Scope

Nutrient pollution originates from a wide diversity of sectors and sources, driven by various factors including production and societal consumption patterns and practices as well as inadequate waste management. Under the GEF project “Global foundations for reducing nutrient enrichment and oxygen depletion from land-based pollution, in support of the Global Nutrient Cycle” (GNC project), nutrient flows (losses) are attributed to two main component pathways: the agri-food pathway and the energy-transport pathway, which also incorporate societal consumption patterns (Figure 5.13). Ten key action areas are identified as being central to reducing nutrient losses from these pathways (Sutton *et al*., 2013).

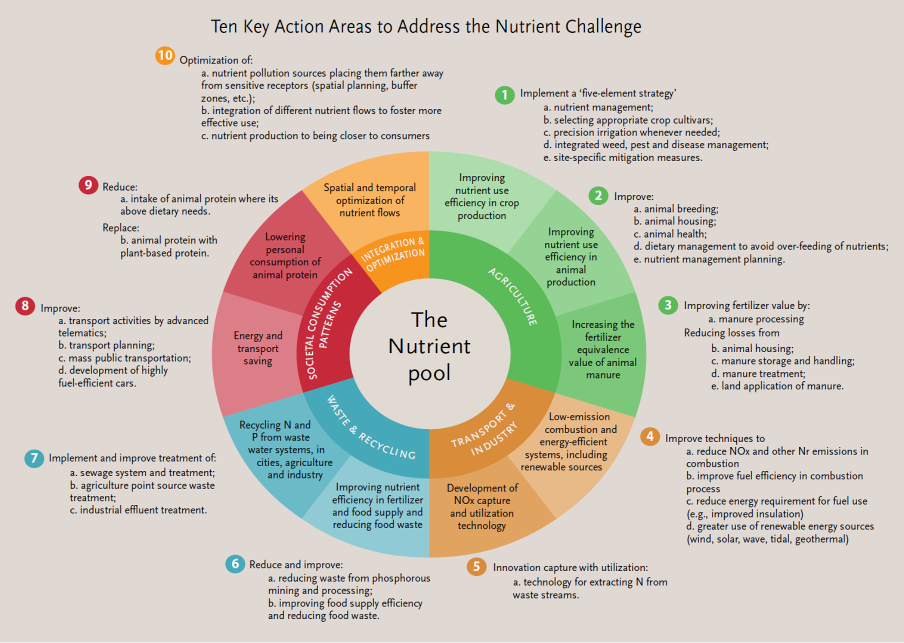


Figure 5.13 Ten key action areas to address the nutrient challenge, Sutton et al., 2013 (Prepared by GRID-Arendal for the GEF/UNEP Global Nutrient Cycle project).

The RNPRSAP builds on the findings and recommendations of the GNC project and incorporates many of the key actions to address nutrient pollution. However, the RNPRSAP scope is defined by the Cartagena Convention and its Protocols, particularly the LBS Protocol, with focus on the major land and sea-based sources of nutrient pollution of the Convention area (wider Caribbean Sea). As discussed in Chapter 2, these sources are agriculture, domestic and industrial wastewater, and wastewater from maritime activities (cruise ships, recreational vessels and cargo ships). The strategy does not address the energy and transport pathway since this is outside the Convention’s remit and is addressed under other frameworks such as the UN Framework Convention on Climate Change (UNFCCC). Societal consumption patterns (dietary choices) can be addressed in collaboration with relevant bodies such as the FAO. In view of the multi-faceted nature of the drivers, causes and impacts of nutrient pollution, it is clear that a holistic, integrated and coordinated approach is essential to ensure social, economic, and environmental benefits across the entire spectrum of the nutrient challenge. Moreover, such an approach can be potentially beneficial to efforts to address other marine pollution issues such as plastics and other chemicals (e.g., through reduction of runoff).

In addition to the Cartagena Convention and LBS Protocol, the RNPRSAP also responds to and supports the UNEP Caribbean Environment Programme (CEP) CEP Regional Strategy for the Protection and Development of the Marine Environment of the WCR, relevant UNEA Declarations particularly Declaration 4/14 on Sustainable Nitrogen Management, the 2030 Sustainable Development Agenda, Regional Seas Programmes, Small Island Developing States Accelerated Modalities of Action (SAMOA Pathway), Convention on Biological Diversity (CBD) Post-2020 Global Biodiversity Framework, and UN Convention to Combat Desertification (UNCCD), among others.

The geographic scope of the RNPRSAP is the Gulf of Mexico, Caribbean, and North Brazil Shelf LMEs, with focus on the major land and sea-based sources of nutrient pollution in these LMEs.

5.4.2 Structure

The regional nutrient reduction strategy is centred around nine Pillars, each with specific objectives and associated targets and indicators. There are 14 main objectives as well as eight sub-objectives under Pillar 9 on enabling conditions. An overview of the Pillars and associated Objectives is given in Figure 5.14.

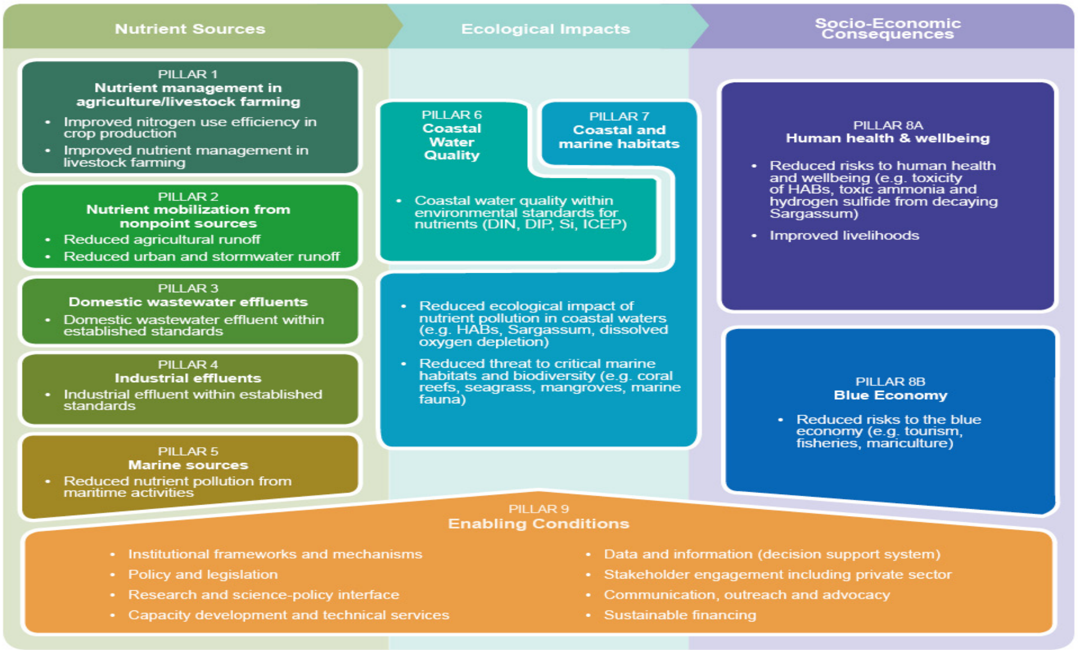


Figure 5.14 Structure of the WCR nutrient pollution reduction strategy showing the nine Pillars and associated objectives. See text for details.

Pillars 1-8 cover the entire continuum of the nutrient challenge, from nutrient inputs from land and sea-based sectors, to their loss through major point and nonpoint sources to aquatic systems, and associated ecological impacts in coastal waters and consequences for human wellbeing and economies. Pillar 9 provides for the establishment of enabling conditions that are necessary for successful implementation of the strategy. Also considered are the benefits of optimal fertilizer use (Pillar 1) in terms of increasing crop yields and cost savings from more efficient fertilizer use as well as benefits from nutrient recovery and waste recycling and reuse.

Emerging issues such as climate change impacts on nutrient pollution and the response of aquatic ecosystems to interaction among multiple stressors should be considered when implementing the strategy. Coastal and marine ecosystems that are already degraded are less resilient to climate change impacts such as coral bleaching. An important consideration will be climate change impacts on agricultural production and on processes (e.g., rainfall patterns and soil erosion) that influence the delivery of nutrients to aquatic systems including coastal waters in the WCR. Assessment of how climate change specifically affects nutrient discharge and impacts at regional and even national scales is important. Therefore, an integrated and holistic approach to implementing this strategy could also be seen as a climate change adaptation measure.

A brief generic description of the type of strategies and BMPs to achieve each objective is included. Details of major strategies and BMPs are given in the BMP Compendium in Annex 5.2, the GPNM BMP database (http://nutrientchallenge.org/bmp-database), and other publications (Annex 5.2). Most of the interventions (stress reduction) are appropriate at the national/local level where nutrient pollution originates, while others are appropriate at the sub-regional and regional levels. The latter relates primarily to the transboundary dimensions and Pillar 9 (enabling conditions at the regional level). All the Pillars and Objectives (or the appropriate combination thereof) should be incorporated into national action plans to reduce nutrient pollution through more sustainable agriculture and waste management practices (see the Action Framework in Section 5.7).

Together with Figure 5.14, Table 5.9 provides an overview of the structure of the regional strategy in terms of the SDG Targets associated with specific Objectives. Most of the Targets are aligned with the SDGs (particularly SDG 6 and 14) and Targets, and the LBS Protocol. Other relevant Targets are from the CBD Post-2020 Global Biodiversity Framework and the UNCCD. Global targets and indicators may need to be adapted to the appropriate scale (local, national, sub-regional, regional) for implementation of the strategy. Furthermore, targets and measures for reducing nutrient pollution should be in synergy with existing and nationally approved regulations and guidelines, while recognizing the need for harmonization at the regional level, as appropriate.

Table 5.9. Objectives and SDG Targets for Pillars 1-8

	PILLARS		OBJECTIVES	2.4	3.9	6.3	6.6	11.6	11.7	12.3	12.4	12.5	14.1	14.2	15.2	15.3
1	Nutrient management in agriculture/ livestock farming	1.1	Improved nitrogen use efficiency in crop production (Halve nitrogen waste by 50%)	✓						✓			✓			
		1.2	Improved nutrient management in livestock farming													
2	Nutrient mobilization from nonpoint sources	2.1	Reduced agricultural runoff	✓											✓	✓
		2.2	Reduced urban and stormwater runoff					✓	✓							
3	Domestic wastewater effluents	3.1	Domestic wastewater effluent within established standards (LBS Annex III limits for TSS)			✓										
4	Industrial effluents	4.1	Industrial effluent within established standards			✓					✓	✓				
5	Marine sources	5.1	Reduced nutrient pollution from maritime activities													
6	Coastal water quality	6.1	Coastal water quality within environmental standards for nutrients			✓							✓			

7	Coastal and marine habitats	7.1	Reduced ecological impact of nutrient pollution in coastal waters			✓	✓						✓	✓		
		7.2	Reduced threat to critical marine habitats and biodiversity			✓	✓						✓	✓		
8a	Human health and wellbeing	8.1	Reduced risks to human health and wellbeing		✓											
		8.2	Improved livelihoods													
8b	Blue economy	8.3	Reduced risks to the blue economy													

A description follows of the nine Pillars and corresponding Objectives, Targets, and Indicators.

5.5 PILLARS, OBJECTIVES, TARGETS, AND INDICATORS

5.5.1 Pillar 1: Sustainable nutrient management in crop production and livestock farming

Annex IV of the LBS Protocol of the Cartagena Convention identifies "Agricultural nonpoint sources of pollution" as pollution originating from the cultivation of crops and rearing of domesticated animals, excluding intensive animal rearing operations that would otherwise be defined as point sources. This Annex requires each Contracting Party to formulate policies, plans, legal mechanisms, and programmes to mitigate pollution of the Convention Area from agricultural nonpoint sources of pollution, particularly if these sources contain nutrients (nitrogen and phosphorus) and sediments, among other pollutants that may adversely affect the Convention area.

Objective 1.1. Improved nitrogen (nutrient) use efficiency in crop production (halve nitrogen waste from all sources by 2030).

Improvements in nitrogen (or nutrient) use efficiency (NUE) in crop production, that is, the fraction of N input harvested as product, are critical for addressing the triple challenges of food security, environmental degradation, and climate change (Zhang *et al*., 2015). Improving NUE in crop production is a 'win-win' strategy, as it aims at increasing crop production, thereby contributing to food security, while minimizing nutrient losses and ultimately eutrophication and its impacts (Sutton *et al*., 2013; Davidson *et al*., 2015). Estimates of NUE, including a 2008 baseline, for individual WCR countries are given in Sutton *et al*. (2013) (Annex 5.3). N budget and NUE in crop production for Brazil and LAC (without Brazil) are shown in Table 5.10.

Table 5.10 N budget and NUE in crop production for Brazil and LAC (without Brazil) in 2010 and projected for 2050 (Zhang *et al*. 2015).

Country/region	2010				2050			
	Harvest N (Tg N yr^{-1})	Input N (Tg N yr^{-1})	**NUE**	Surplus N (Tg N yr^{-1})	Projected harvest N* (Tg N yr^{-1})	**Target NUE**	Required input N (Tg N yr^{-1})	Resulting surplus N (Tg N yr^{-1})
LAC minus Brazil	7	12	**0.52**	6	10	**0.70**	15	4
Brazil**	6	11	**0.53**	5	10	**0.70**	15	4

** The Brazil report (University of Para, 2020) on Agrochemical Runoff in the Amazon Hydrographic Basin states that in 2019, about 9.7 million tons of fertilizers (mainly NPK) were used in the basin, of which about 96,655 tons are lost to the environment (assuming that approximately 1% is lost by runoff). Ammonia and potassium chloride are the main residual in soils and water in this basin.

An analysis of NUE trends in several WCR countries showed that NUE decreased with increasing total N inputs in all the countries (Lassaletta *et al*., 2014; Chapter 2). As discussed in Chapter 2, this decreasing NUE results in increasing surplus N, which is the potential nutrient pollutant load. Further, even though a significant improvement in NUE occurred in many of the countries after the 1980s, a further increase of nitrogen fertilization would result in a disproportionately low increase of crop production with further environmental alterations, unless the efficiency of cropping systems is substantially improved.

In addition to excessive fertilizer use, agricultural pesticides such as organophosphate pesticides may be another source of nutrient pollution. However, information is unavailable on the contribution of pesticides to nutrient pollution of aquatic systems in the WCR, which needs to be assessed. Nevertheless, reducing agricultural pesticide use should be incorporated into a holistic approach to more sustainable agriculture, due to its adverse impacts on soil health, which ultimately underpins cropland productivity, and its toxicity to humans and other biota (see Chapter 2).

Targets and indicators related to NUE

The Colombo Declaration calls for countries to 'Halve nitrogen waste by 2030', which complements the target of reduction by countries of their respective NUEs by 20 percent by 2020. Estimated Crop NUE and Full-chain NUE for WCR countries for 2008 (baseline) as compared with an aspirational target for 2020, based on a 20 percent relative improvement from the 2008 values are shown in Annex 5.3 (Sutton *et al.*, 2013). WCR countries are below the long-term target values for eventual Crop NUE of 70 percent and Full-chain NUE of 50 percent. Countries already exceeding these thresholds are estimated to be suffering from significant soil nutrient mining, low levels of crop productivity and food insecurity.

Global targets and indicators that are relevant to nutrient management are given in Table 5.11. Three are SDG Targets and indicators. A proposed Target (Target 17) under the CBD Post-2020 Global Biodiversity Framework (expected to be adopted at the CBD Conference of Parties 15 in 2021) relates to eliminating environmentally harmful subsidies in various sectors including agriculture. Other targets and indicators should be established for the socio-economic benefits derived from improving NUE, such as increase in crop yields and associated income, economic costs, and livelihoods.

Table 5.11 Targets and indicators related to nutrient management.

Target	Indicator
SDG Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality. Sustainable Nitrogen Management Index (SNMI): Long-term objective is a value of 0 by 2030.	Sub-indicator of SDG 2.4.1: Proportion of agricultural area under productive and sustainable agriculture. Indicator: Sustainable Nitrogen Management Index, which combines two efficiency measures in crop production: NUE and land use efficiency (crop yield) (Zhang and Davidson 2019). The SDG dashboard (2020) shows that none of the countries in LAC (for which data are available) had achieved the target of zero for this indicator in 2015 (https://dashboards.sdgindex.org/explorer/sdg2_snmi)
SDG 2.3.1. At least four specific nutrient management measures taken to mitigate environmental risks (FAO 2020).	UNECLAC complementary indicator (UNECLAC 2018): Intensity of fertilizer use (apparent consumption by cultivated area) Management of fertilizers (Fertilizer pollution risk; related sub-indicator on Soil health).
SDG 12. Production-based nitrogen emissions: Long-term objective is a value of 2 by 2030.	Production-based nitrogen emissions: Reactive nitrogen emitted during the production of commodities, which are then either exported or consumed domestically. Corresponds to emissions of

	ammonia, nitrogen oxides and nitrous oxide to the atmosphere, and of reactive nitrogen potentially exportable to water bodies.
Colombo Declaration on Sustainable Nutrient Management: Halve nitrogen waste from all sources by 2030.	A goal to reduce nitrogen waste by a standard amount offers a more equitable approach, whereby countries currently wasting more nitrogen would need to take more ambitious steps. For example, in a country wasting 80%, halving nitrogen waste across the economy would need to reduce total nitrogen losses from all sources to 40% of inputs (absolute reduction of 40%). By contrast, a country wasting only 50% would require an absolute reduction of 25% (Sutton *et al*., 2013).
GPNM: Each country aims to improve its Crop NUE and Full chain NUE by 20% as a step towards achieving an eventual Crop NUE target of at least 70% and a Full chain NUE of 50% relative to its baseline, by 2020 (See Annex 5.3 with NUE for WCR countries). Note: 2020 timeframe to be revised	Crop NUE: the nutrients in harvested crops in a country as a percentage of the total nutrient input to that country (sum of mineral fertilizer input plus crop biological nitrogen fixation). Full-chain NUE: the nutrients in food available for human consumption in a country as a % of the total nutrient inputs to that country (sum of fertilizer inputs, BNF in crops and grass, import in fertilizer, feed and food).
Target 17 (Post-2020 Global Biodiversity Framework): By 2030, redirect, repurpose, reform or eliminate incentives harmful for biodiversity, including [X] reduction in the most harmful subsidies, ensuring that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity	17.0.2 Potentially harmful elements of government support to agriculture (environmentally harmful subsidies) as a percentage of GDP.
Socio-economic targets (improvements in crop yield, income, cost saving, etc.)	Crop yield, income, costs (annual)

Additional targets and milestones can be added as new nutrient reduction goals are set for downstream waters or as new research and policies inform planning and decision making.

Strategies and best management practices for optimizing NUE

Achieving NUE targets while also increasing yields requires implementation of technologies and management practices that optimize NUE at the farm scale. The goal is to match nutrient supply with crop requirements and to minimize nutrient losses from the field. Available approaches to improve crop NUE are outlined in the BMP Compendium (Annex 5.2) and the GPNM best management practices (BMP) database (http://nutrientchallenge.org/bmp-database). Some common principles include the '4Rs' Nutrient Management Stewardship approach of applying the right fertilizer, the right rate, the right time of application, and the right placement. The technologies and management practices related to the '4Rs' vary regionally and depend on the local cropping systems, farming scale, soil types, climate and socio-economic conditions, among others. Other conservation and agronomic practices such as no-till farming and use of cover crops support the '4Rs' nutrient stewardship. Training of small-scale and large-scale farmers in the '4Rs' approach and other BMPs will be vital to improve nutrient efficiency and optimize crop production while reducing nutrient losses to the environment. This also implies strong collaboration between UNEP CEP and FAO, consistent with Annex IV of the LBS Protocol. Other options to reduce nonpoint pollution emanating from the release of N and P from fertilizers (and wastewater) include recovery and recycling of nutrients, for which a range of technologies are available (see Ahmed *et al.*, 2019 for a review).

Objective 1.2. Improved nutrient management in livestock farming.

ANNEX I of the LBS Protocol (Source Categories, Activities and Associated Pollutants of Concern) identifies Intensive Animal Rearing Operations as among the Priority Source Categories and Activities Affecting the Convention area. However, it does not specify the contaminants to be addressed. The LBS Monitoring and Assessment Working Group considered intensive animal rearing operations (in small islands) to be of medium priority for the SOCAR.

Most of the water used for livestock drinking and servicing returns to the environment in the form of liquid manure, slurry, grey water and wastewater, with animal manure a primary source of N and P flows into surface and groundwater (US EPA, 2017). Use of animal manure to fertilize crops is another major nonpoint source of nutrients. Latin America has the second biggest contribution rate of manure to fertilization of crops (73%) after Africa (84%) (FAO, 2018). Estimates of annual losses of N and P to freshwater courses from animal manure in croplands and pasture in Central and South America (Table 5.12) amount to 720,000 tons of N and 102,000 tons of P (FAO and IWMI, 2018). It should be noted that these estimates do not distinguish freshwater courses that discharge into the WCR.

Table 5.12 Losses of N and P to freshwater courses from animal manure in croplands and pasture, in thousands of tons (rounded values) (FAO and IWMI, 2018).

Sub-region	**Crop**		**Pasture**		**Losses to freshwater courses**	
	N	P	N	P	N	P
Central America	351	192	351	22	176	26
South America	1,052	577	1,051	59	526	76
Total					**702**	**102**

Targets and indicators

There are no national and regional targets explicitly for livestock. However, some of the targets for Objectives 1.1 and 1.2 are relevant to this objective.

Strategies and best management practices to minimize nutrient losses from livestock farming.

Dietary (keeping excess N and P out of feeds to reduce the levels in manures) and grazing management (silvopasture), manure and waste management in combination with nutrient management, and integrated farming are among the measures to reduce nutrient emissions from livestock operations. Traditional techniques such as restoring degraded pasturelands and better managing animal diets and feed additives are needed, while efforts should be strengthened in new nutrient recycling techniques and technologies, such as farm waste biodigesters. When closely integrated into the farming system, biodigesters not only reduce nutrient pollution but have added value such as providing clean fuel for cooking and lighting (thereby reducing the need for fuelwood and its associated environmental and human health impacts, the latter of which is particularly important for women and children), reduced emission of methane (a greenhouse gas) to the atmosphere, production of bioslurry (a liquid organic fertilizer), lower farm production costs, and increased farmers' productivity (World Bank, 2019).

See the BMP Compendium (Annex 5.2) and the GPNM BMP database and case studies (e.g., Case study #2: Manure management).

5.5.2 Pillar 2. Nutrient mobilization from nonpoint sources.

This Pillar addresses the mobilization of nutrients from nonpoint land-based sources (agriculture and urban/storm runoff) to aquatic systems (rivers, groundwater, and coastal waters). Typical pathways for nutrient pollution from nonpoint sources are: i) from soil solution to deep percolation and groundwater recharge; ii) from natural or human induced soil erosion; and iii) from runoff, drainage water and floods to streams, rivers and estuaries.

Objective 2.1. Reduced agricultural runoff

Crops and pasturelands alone are responsible for the mobilization of significant amounts of sediment every year, much of which ends up in water bodies (FAO, 2018). Sediment discharges to the WCR are associated with the erosion of lands within watersheds due to deforestation, urbanization, and agricultural activities such as land clearing and incorrect use of cultivation techniques (UNEP-CEP, 2010). In addition, overgrazing of livestock has led to significant soil erosion and general land degradation in the region (CCA and IRF, 1991). While rivers are generally considered to be the main entry point for the introduction of nutrients to coastal waters (see Chapter 2), nitrogen inputs from groundwater from agricultural land dominates in all the sub-regions except sub-region II, where agricultural surface run-off dominates. The predominantly karstic nature of some coastal groundwater aquifers, which discharge directly into coastal waters, likely contributes to the contamination of coastal waters.

Targets and indicators

While WCR countries have adopted nutrient (nitrate and phosphate) standards for drinking water (due to the risk to human health) and coastal water quality (recreational waters), there are no regional criteria, standards, and permissible limits for nutrient loads discharged from point and nonpoint sources. It is important to ensure that management targets are consistent between countries and water categories, especially for management of transboundary water bodies. The total allowable N and P loads of each priority basin must be determined in order to estimate the target reduction load for the basin. Further, permissible loads from point and nonpoint sources must be linked with ambient water quality criteria as part of an integrated watershed management strategy (based on predictive modeling, for which capacity needs to be strengthened). Importantly, discharge limits should be linked with marine water quality standards that are relevant to the ecological thresholds of the receiving marine ecosystems (Tosic *et al.*, 2019 and references therein). Various science-based methods have been developed to link water quality objectives for land-based discharges and marine waters.

The US Clean Water Act uses Total Maximum Daily Loads (TMDL), which are calculations of the load reductions of a pollutant needed so that the waterbody will meet and continue to meet water quality standards for that particular pollutant (https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls). A TMDL determines a pollutant reduction target and allocates load reductions necessary to the point and nonpoint sources of the pollutant. It is important to note that the federal program of the US does not regulate nonpoint source dischargers.

Several targets and indicators have been adopted that are relevant to processes such as deforestation and land degradation that can promote nutrient transport to aquatic systems (Table 5.13). Two of these are SDG Targets that relate to protection of forests, which is important for reducing soil erosion and runoff. Other relevant SDG Targets are 6.3, 6.6, 14.1, and 14.2, which are addressed under other Pillars. Complementing the SDG Targets are Strategic Objectives (SO) and Expected Impacts of the UNCCD, particularly SO 1 (To improve the condition of affected ecosystems, combat desertification/land degradation, promote sustainable land management and contribute to land degradation neutrality) and its four Expected Impacts (Land productivity and related ecosystems services are maintained or enhanced; The vulnerability of affected ecosystems is reduced and the resilience of ecosystems is increased; National voluntary land degradation neutrality targets are set and adopted by countries wishing to do so, related measures are identified and implemented, and necessary monitoring systems are established; and Measures for sustainable land management and the combating of desertification/land degradation are shared, promoted and implemented).

Table 5.13 Targets and indicators related to processes that promote the transmission of nutrients to aquatic systems from nonpoint sources.

Target	Indicator
SDG Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	Sub-indicator of 2.4.1: Prevalence of soil degradation: The combined area affected by any of the four selected threats (soil erosion, reduction in soil fertility, salinization of irrigated land, waterlogging to soil health) is negligible (less than 10 percent of the total agriculture area of the farm) (FAO 2020).
SDG Target 15.2: By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally. Note: 2020 timeframe to be revised	Indicator: 15.2.1 Progress towards sustainable forest management (preventing erosion and loss of nutrients).
SDG Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.	Indicator 15.3.1: Proportion of land that is degraded over total land area (supplementary indicator, UNECLAC 2018)
UNFCCC SO 1: Improve the condition of affected ecosystems, combat desertification/land degradation, promote sustainable land management and contribute to land degradation neutrality.	SO 1-1: Trends in land cover. SO 1-2: Trends in land productivity or functioning of the land. SO 1-3: Trends in carbon stocks above and below ground.
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Strategies and best management practices for reducing mobilization of nutrients to aquatic systems.
Proper land use and water management are critical in minimizing groundwater seepage and runoff from agriculture by reducing land degradation/erosion and sediment production. Best environmental practices (BEPs)* (GPNM) and BMPs that result in moderate to substantial improvement include:

- Nature-based solutions/ green engineering: e.g., wetland restoration/creation*; forest and grass riparian buffers* (vegetated and unfertilized buffer zones alongside watercourses).
- Controlling soil loss: tillage management - avoid conventional tillage (plowing) operations including on hillsides; conservation tillage* (planting, growing and harvesting of crops with minimal disturbance to the soil surface through the use of minimum tillage, mulch tillage, ridge tillage, or no-till; vegetative cover including cover crops*; livestock grazing management*; sediment basin.

Some of these measures provide opportunities for additional income generation/food production, for example, growing of other crops as cover among the main crops. Another win-win strategy is payment for ecosystem services (PES) programmes in which incentives are given to farmers to produce a mix of ecosystem services by adopting more sustainable practices (FAO, 2007). Such programmes can also potentially contribute to poverty reduction and food security in rural areas.

Policy instruments to reduce nutrient pollution from agricultural nonpoint sources include water quality trading. However, Stephenson and Shabman (2017) argue that economists need to more clearly articulate the limitations of current and proposed water quality trading programmes and suggest that a new generation of market-based incentive policies will be necessary to make significant progress in reducing agricultural nonpoint source loads.

See the BMP compendium in Annex 5.2, the GEF GNC project case studies (e.g., Manila Bay), the GPNM BMP database, UNEP CEP Technical Reports 32 (sediment control in the insular Caribbean) and 41 (best management practices for agricultural non-point sources of pollution).

Objective 2.2. Reduced urban and stormwater runoff

Another nonpoint source of nutrients and other pollutants is urban/storm runoff, although the nutrient input from this source has not been quantified for the region. 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 (UNEP CEP, 2019). Another concern related to urban and stormwater runoff is the emission of domestic waste and sewage from open sewers, pit latrines and septic tanks during floods or in low lying areas with high water tables.

Changes in precipitation patterns with climate change, especially increase in annual rainfall (including extreme rainfall events) in some areas, will exacerbate runoff in the absence of adequate measures to curb runoff. On the other hand, in some countries and territories, reduced rainfall is leading to increased nutrient concentration in rivers, enhancing conditions for algal growth, poor water quality, and in extreme cases, fish kills (IMA, 2020).

Targets and indicators

Two SDG Targets under SDG 11 relate to urban areas although they do not explicitly address nutrients in urban/storm runoff (Table 5.14). Appropriate targets and indicators that relate to nutrients in urban/storm runoff should be developed for the RNPRSAP, under the LBS Protocol.

Table 5.14 Targets and indicators related to urban/ storm runoff.

Target	Indicator
SDG Target 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.	11.6.1. Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities. 11.6.2. Annual mean levels of fine particulate matter in cities (population weighted).
SDG Target 11.7. By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.	SDG Indicator 11.7.1. Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities. Other: Proportion of built up and green areas

Strategies and best management practices for reducing urban/storm runoff

Among the solutions to address runoff from paved surfaces are techniques such as 'green infrastructure', for example, urban storm water park ('sponge cities'), green rooftops and walls, roadside plantings, landscaped parks, permeable pavements, pixilated parking, urban farming, and other swatches of vegetation buffers placed inside urban areas. Retention and detention of runoff include capture of runoff in lagoons and other structures for reuse/recycle for irrigation and other uses. These techniques can be costly initially, but in the longer term 'going green' can be a far more cost-effective solution (see WWAP/UN-Water, 2018). Development and urban planners and those responsible for managing urban and suburban areas should identify and implement pollution prevention strategies and examine source control opportunities. The US National Pollutant Discharge Elimination System (NPDES) stormwater programme regulates stormwater discharges from three potential sources: municipal separate storm sewer systems, construction activities, and industrial activities (https://www.epa.gov/npdes/npdes-stormwater-program). Information on management measures to control nonpoint source pollution from urban areas is available from the US EPA (https://www.epa.gov/sites/production/files/2015-09/documents/urban_guidance_0.pdf).

5.5.3 Pillar 3: Domestic wastewater effluent

After agricultural sources, inadequately treated domestic wastewater is the second most important anthropogenic source of excessive nutrient loads in the WCR (UNEP CEP, 2019). About 869,000 tons of TN and155,000 tons of TP are estimated to be likely released in untreated sewage by the WCR population in 2010. These estimates are conservative since they exclude contributions from partially treated sewage that is discharged at point sources such as sewage outfalls.

Objective 3.1. Domestic wastewater effluent within established standards for nutrients

LBS Protocol Annex III (Domestic Wastewater[7]) established regional limitations for domestic sewage, but not specifically for nutrients. In sub-regional reports prepared for the RNPRSAP, most of the countries

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[7] For the purposes of this Annex: "Domestic wastewater" means all discharges from households, commercial facilities, hotels, septage and any other entity whose discharge includes the following: (a) Toilet flushing; (b) Discharges from showers, wash basins, kitchens and laundries; or (c) Discharges from small industries, provided their composition and quantity are compatible with treatment in a domestic wastewater system.

identified domestic and municipal wastewater as the main source of nutrient pollution of the marine environment and considered this source to be of high priority. Septic system failures (due to inadequate construction, improper siting, and poor operations and maintenance, among others) have caused pollution of groundwater, rivers and streams (GEF CReW, 2016b). Discharge of septic tank effluent and its dispersal into the environment through floodwater is a serious problem in certain areas. In some countries in the insular Caribbean, wastewater is disposed into the subsurface through what are locally known as "suck wells." Because the soil in many of these islands are predominantly karstic, discharges to the subsurface can be transmitted with little assimilation into the marine environment (Nurse *et al*., 2012).

Targets and indicators related to domestic wastewater

Currently, there are no regional nutrient (N and P) discharge criteria and limits for domestic wastewater under the LBS Protocol[8], a gap that needs to be addressed urgently. Annex II of the LBS Protocol provides a list of factors to be considered in determining effluent and emission source controls and management practices when developing sub-regional and regional source-specific effluent and emission limitations and management practices. Establishing regional criteria, standards and limits and harmonizing them across the countries will be critical in identifying numeric nutrient reduction targets for the priority watersheds.

CARICOM proposed a limit for total nitrogen (inorganic and organic) of 5 mgl^{-1} and total phosphorous (inorganic and organic) of 1 mgl^{-1} (based on 50:1 dilution with nutrient removal). However, these were preliminary limits and have not been finalized and adopted by CARICOM. At the national level, many countries have adopted maximum permissible limits for N and P concentrations in wastewater discharges, according to the designated uses of the receiving water bodies (see the sub-regional reports). These limits are in terms of concentration and not of actual loads, and there is a wide divergence among the national standards and maximum permissible limits for the different forms of N and P, even for similar designated uses of the receiving water bodies across the countries. Some countries have regulations that provide for the establishment of water quality standards, but they have not implemented such standards. Standards for nitrate limits in groundwater vary considerably in the region, although many are more stringent than the World Health Organization guidelines (50 mgl^{-1}). For example, the US EPA has set the maximum contaminant level for nitrate-nitrogen in drinking water at 10 mgl^{-1}. National standards exist for pathogenic bacteria (*E. coli* and *Enterococcus* sp.) in domestic wastewater effluent due to the associated public health risk.

While SDG Target 6.3 calls for a 50 percent reduction in the proportion of untreated wastewater by 2030, it does not specify the level of treatment or contaminants to be removed (Table 5.15). The Regional Wastewater Management Policy Template and Toolkit prepared by the GEF Caribbean Regional Fund for Wastewater Management (CReW) Project sets out the key issues and principles that should constitute wastewater management policy. Among these are:

- Treatment of wastewater shall be targeted towards producing an effluent fit for reuse in irrigation in accordance with Annex III of the LBS Protocol as a minimum. Reuse of treated wastewater for other purposes shall be subject to appropriate specifications (GEF CReW, 2016b).

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[8] LBS Protocol Annex III sets effluent limits for total suspended solids, Biochemical Oxygen Demand (BOD5), pH, Fats, Oil and Grease, and Floatables.

- Specifications and minimum standards shall be issued by the wastewater utility for the use of septic tanks in rural areas. Particular attention shall be paid to the protection of underlying aquifers (GEF CReW, 2016b).

Estimation of the empirical annual N and P loads in domestic wastewater (baseline) and determination of the ultimate nutrient reduction desired for coastal water quality improvement, expressed as a percent reduction in load required and the associated timeframe to achieve the limit for N and P, will be a priority task in implementing the strategy. Establishing the link between the level of reduction needed to achieve the desired improvement in water quality will require appropriate research and monitoring of nitrogen and phosphorus loads in both the effluent discharge and downstream, to document nutrient load reductions and associated instream effects.

Table 5.15 Targets and indicators related to domestic wastewater.

Target	Indicator
Regional criteria and limits for N and P in domestic wastewater effluent, and associated target(s) to be established under the LBS Protocol, in consultation with member states (note: Annex IIIC of the LBS Protocol specifies timeframes for achieving effluent limitations for total suspended solids, biological oxygen demand, etc. but not for nutrients, in domestic wastewater that discharges into the Convention area).	% discharge compliant with N and P effluent standards for domestic wastewater, by municipal and industrial source. N and P loads and concentrations in wastewater effluent.
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.	6.3.1: Proportion of domestic and industrial wastewater flows safely treated. The long-term objective for this indicator is a value of 100 (% of wastewater treated). 6.3.2: Proportion of bodies of water with good ambient water quality.
LBS Protocol, Annex III: Effluent limit for discharge of Total Suspended Solids (TSS) in domestic wastewater into Class I waters of 30 mg l^{-1}, and Class II waters of 150 mg l^{-1}. The Target should be 100% of discharge meeting these limits.	Proportion of domestic wastewater discharged that meets the concentration limits established by the LBS Protocol.

Strategies and best management practices for reducing nutrient inputs from domestic wastewater.
The inclusion of wastewater management based on the concept of minimizing generation, adequately treating and reusing/discharges of wastewater on a collective or individual basis should be an essential component of national water policies and strategies (GEF CReW, 2016b). The organizational polluter-pays principle and defining the optimal role of the public and the private sectors in providing, monitoring and regulating wastewater services should also be included in the strategy.

Although continuously evolving, many nutrient removal technologies in wastewater treatment are available, which should be assessed and incorporated into existing and new treatment plants as appropriate. Green or soft engineering in combination with hard engineering has been proven to be effective in treating domestic wastewater. Other measures are recovery of nitrogen, phosphorus, and potassium from domestic wastewater and reuse of treated sanitation waste for fertilizer, irrigation, and biogas production. Today, several technologies are in use to properly treat and process sewage sludge, yielding safe, nutrient-rich organic materials that can improve and maintain productive soils and stimulate plant growth (UNEP, 2017). Many WCR countries have legislative, regulatory, and policy frameworks for wastewater and sludge reuse (Peters, 2015; GEF CReW, 2016). Various GEF projects demonstrate solutions for wastewater treatment and management in the region (e.g., IWCAM, IWEco, CReW+). However, the extent to which these solutions address nutrients needs to be assessed and the solutions adequately shared with the various national stakeholders. In addition, analysis of the economic feasibility and cost/benefit analysis of possible solutions will be necessary for replicating and upscaling the experiences from projects and programmes as well as for implementing other BMPs for nutrient pollution.

Some WCR countries have installed submarine outfalls for domestic wastewater (and in some cases, industrial wastewater) as alternative municipal treatment options. Careful siting and design of submarine outfalls to minimize the effects of nutrient inputs as well as removal of nutrients, pathogens and other harmful substances from the discharged water will be important. The private sector dimension related to wastewater treatment and reduction of nutrient loads must be also considered in addressing nutrient pollution. Several hotels use on-site wastewater treatment plants, but in many cases these facilities do not work effectively, and treatment is inconsistent.

See the BMP compendium (Annex 5.2), GEF-GNC BMP database, and GEF CReW Regional Wastewater Management Policy Template and Toolkit (GEF CReW, 2015). UNEP (2017) showcases some innovative approaches being used and provides guidance on how communities can put their wastewater to purposeful reuse.

5.5.4 Pillar 4: Industrial effluent

Estimates of industrial nutrient loads in the WCR for the period 1997 - 2008 are 28,000 tons of TN and 5,000 tons of TP per year (UNEP CEP, 2010). Ammonia fluxes from industrial point sources (hotspots) in the WCR for 2008 – 2018 have been estimated at 23,879 tons per year (Chapter 2). Industries include NH3-based fertilizer plants and nickel-cobalt mines as in Cuba. Improved assessment and quantification of industrial contribution to nutrient pollution is urgently needed for the region.

Objective 4.1. Industrial effluent within established standards for nutrients

ANNEX I of the LBS Protocol (Source Categories, Activities and Associated Pollutants of Concern) identifies Priority Source Categories and Activities Affecting the Convention Area, among which are chemical industries, extractive industries and mining, food processing operations, manufacture of liquor and soft drinks, oil refineries, pulp and paper factories, and sugar factories and distilleries. Annex III calls on each Contracting Party to endeavour, in keeping with its economic capabilities, to develop and implement industrial pre-treatment programmes to ensure that industrial discharges into new and existing domestic wastewater treatment systems, and within the scope of its capabilities to promote appropriate industrial wastewater management, such as the use of recirculation and closed loop systems, to eliminate or minimize wastewater discharges to domestic wastewater systems. Although the LBS Protocol calls for pre-treatment of industrial waste that is discharged into a domestic wastewater treatment system, it does not specify the components of industrial discharges. In most cases, however, due to various factors, pre-treatment of industrial waste may be non-existent and needs to be urgently addressed.

The LBS Protocol Monitoring and Assessment Working Group arranged the following industries according to high, medium, and low priority:

High	Medium	Low
● Chemical industries	● Oil refineries ● Resource extraction industries ● Sugar factories and distilleries	● Food processing ● Pulp and paper factories

To improve prioritization of industries for further action, it is necessary to determine their relative contributions to nutrient pollution. Industrial wastewater was not identified as a high priority source of nutrient pollution by the English-speaking countries and French-speaking territories, with only Trinidad and Tobago considering ammonia pollution emanating from ammonia-producing industries in Point Lisas a hotspot, and Antigua and Barbuda considering it a priority issue (IMA, 2020). The US EPA has established national standards for industrial wastewater discharges from different industry categories to surface waters and publicly owned treatment works (municipal sewage treatment plants) under the Clean Water Act. These standards are technology-based (i.e., based on the performance of treatment and control technologies) and not on risk or impacts on receiving waters. Among the relevant listed industries is fertilizer manufacturing, with regulations for discharges of various forms of nitrogen and phosphorus compounds (https://www.epa.gov/eg/fertilizer-manufacturing-effluent-guidelines#pollutants). It is important for countries to development effluent standards for industrial wastewater.

Another industrial source of N and P is atmospheric deposition (from burning of fossil fuel and other processes). Atmospheric deposition of nutrients from dust clouds and storms (e.g., Sahara dust, which is a seasonal problem in the WCR and implicated in the *Sargassum* outbreak in the region) is also of concern in the region. Mitigating atmospheric deposition of nutrients across national boundaries requires collaboration at regional and even global levels (which is outside the scope of this strategy).

Targets and indicators related to industrial discharge

There are no regional standards and permissible limits for N and P in industrial discharge. However, some countries have maximum permissible limits for nutrients in wastewater discharge or regulations for discharges from different sources (domestic, municipal, industrial, livestock, and agricultural) into land or marine receiving water bodies, but not for discharges into sewers. The discharge standards include the maximum permissible nutrients limits in terms of concentration and not of pollutant load (flow multiplied by concentration). Therefore, the flow factor is not taken into account when assessing the impact of substances or compounds that can cause damage to the receptor body, although in general, the need to measure discharge flow is recognized in most of the standards. Relevant SDG Targets are shown in Table 5.16. However, these do not explicitly address nutrients but can be adapted for nutrients.

Table 5.16 Targets and indicators related to industrial wastewater.

Target	Indicator
Regional criteria and limits for N and P in industrial effluent to be established under the LBS Protocol	To be established

National criteria and limits to be established, harmonized with regional target (see the US EPA national standards for industrial discharges of N and P compounds)	To be established, harmonized with regional indicator(s)
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.	6.3.1: Proportion of domestic and industrial wastewater flows safely treated. The long-term objective for this indicator is a value of 100 (% of wastewater treated). 6.3.2: Proportion of bodies of water with good ambient water quality.
SDG Target 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. Note: 2020 timeframe to be revised	Indicator 12.4.1. Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement.
SDG Target 12.5. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1: National recycling rate, tons of material recycled. Proxy indicator of 12.5.1. Proportion of recycled waste in relation to total collected waste (UNECLAC, 2018). Other indicator(s) to be developed.

Strategies and best management practices to reduce nutrient pollution from industrial wastewater

Strategies and BMPs for industrial wastewater are dependent on the type of industry. Many technologies are available including for recycling of industrial effluents. An Industrial Wastewater Treatment Technology Database was developed by the US EPA and is available at https://watersgeo.epa.gov/iwtt/guided-search. See also the GEF CReW (2016b) Wastewater Policy Toolkit, which addresses industrial wastewater discharges from small industries only, since the composition and quantity are compatible with treatment in domestic wastewater systems. It is recommended that an online database of technologies be developed by UNEP-CEP, adapting the US EPA database as appropriate.

5.5.5 Pillar 5: Marine sources of nutrients

While the LBS Protocol focuses on land-based sources and activities, the Cartagena Convention on the whole covers pollution of the marine environment from both land and marine-based sources. Pillar 5 focuses on the unregulated disposal of wastewater and food waste in marine waters from the maritime sector including merchant ships, cruise ships and recreational vessels such as yachts. The Wider Caribbean Sea serves as a major hub for the global shipping industry (with the Panama Canal being one of the world's major shipping route for global trade) and cruise ship tourism. Given the scope and intensity of shipping in the region and the sensitive nature the Caribbean Sea itself, ship-generated waste presents a significant threat to the WCR marine ecosystems and dependent economic sectors. In addition to untreated sewage and food waste, the emission of nitrogen oxide from ship exhausts is another potential source of nutrient pollution of the marine environment due to atmospheric deposition. Empirical estimates of the contribution of nutrient pollution from maritime activities is lacking. However, modeled estimates of the concentrations of components found in biosolids generated by cruise ships indicate substantial nutrient (nitrates, nitrites, and ammonia) content (see Chapter 2).

Objective 5.1. Reduced nutrient pollution from maritime sources and activities

(MARPOL is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. MARPOL Annex IV on Prevention of Pollution by Sewage from Ships prohibits the discharge of sewage into the sea, except when the ship has an approved sewage treatment plant in operation or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land. Sewage that is not comminuted or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land. In addition, Annex IV requires governments to ensure the provision of adequate reception facilities at ports and terminals for the reception of sewage, without causing delay to ships. In the case of yachts, there is a loophole with respect to MARPOL provisions, as these types of vessels generally fall outside of the provisions. MARPOL Annex VI on Prevention of Air Pollution from Ships sets limits on nitrogen oxide emissions from ship exhausts, among others. MARPOL Annexes IV and VI are optional and must be ratified separately from the Convention.

Targets and indicators related to marine sources

For sewage that is deposited into port reception facilities, domestic wastewater effluents standards will be applicable (see Pillar 3). MARPOL Annex IV specifies maximum permissible discharge rates at sea for sewage according to the speed and draft of the vessel. There are no specific targets and indicators for nutrients under Annex IV, except under the amendment to Annex IV, which introduced, inter alia, a definition for Special Area as well as relevant requirements for the discharge of sewage from passenger ships in Special Areas and for port reception facilities. Under this amendment, nitrogen and phosphorus removal standards are established for the sewage treatment plant installed on a passenger ship intending to discharge sewage effluent in Special Areas (resolution MEPC.227(64), section 4.2). Currently, the Baltic Sea area is the only Special Area under Annex IV. Designation of the Wider Caribbean Sea as a Special Area under Annex IV (and also Annex I) should be pursued by UNEP CEP. This calls for continued close collaboration between the International Maritime Organization (IMO) and UNEP including through the work of the Regional Marine Pollution Emergency Information and Training Center for the Wider Caribbean (RAC/REMPEITC) and linking with meetings of the IMO Marine Environment Protection Committee and Senior Maritime Officers in the region.

Strategies and best management practices to reduce nutrient pollution from maritime activities

MARPOL Annex IV requires ships to be equipped with either an approved sewage treatment plant or an approved sewage comminuting and disinfecting system or a sewage holding tank, and the provision of adequate port reception facilities for sewage. However, some of the requirements have to be translated into national legislation and implementation. While reception facilities have gained regional attention, issues such as availability, adequacy, and fee structures have hindered their widespread adoption. Most WCR countries, in particular the island nations, lack adequate port reception facilities for ship-generated waste (IMO, 2016). The IMO has developed an Action Plan to tackle the alleged inadequacy of port reception facilities, which includes guidelines and good practices on port reception facility for providers and users.

Existing treatment technologies available to cruise lines include traditional Type II Marine Sanitation Devices and Advanced Wastewater Treatment Systems (AWTS) (see Chapter 2). Folbert (2020) estimated that in 2019, 64 percent of the cruise ships operating in the Caribbean use AWTS for the treatment of wastewater streams. These systems are becoming the standard in the cruise industry and newbuilds are typically fitted with such systems. However, these and other onboard systems are not primarily designed to remove nutrients, but to treat effluents to remove pathogens, suspended solids, BOD, etc. Once the sewage is deposited in the reception facilities, strategies and BMPs that are relevant to domestic wastewater effluents will be applicable to ship-generated waste (Pillar 3).

Other strategies to support management of nutrient pollution from ships include process-based systems such as ISO 14001 for environmental management systems. For example, ISO 14001:2015 specifies the requirements for an environmental management system to enhance environmental performance and is intended for use by an organization seeking to manage its environmental responsibilities in a systematic manner that contributes to the environmental pillar of sustainability.

Eco-certification and ecolabeling are other tools that are relevant to maritime sectors particularly the cruise ship industry. In fact, these tools can be used across other sectors to encourage more sustainable practices and meeting a set of established standards.

5.5.6 Pillar 6: Coastal water quality

Objective 6.1. Coastal water quality within environmental standards (for ecological function and designated human uses).

Annex III (Domestic wastewater) and Annex IV (Agricultural non-point sources of pollution) of the LBS Protocol explicitly call on the Contracting Parties to take measures to protect the Convention Area from nutrient (N and P) pollution. Annex III of the LBS Protocol recognizes the sensitivity of marine habitats to domestic wastewater in defining two Classes (I and II) of waters based on specific characteristics:

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. Class I waters include but are not limited to: (a) waters containing coral reefs, seagrass beds, or mangroves; (b) critical breeding, nursery or forage areas for aquatic and terrestrial life; (c) areas that provide habitat for species protected under the Protocol Concerning Specially Protected Areas and Wildlife to the Convention (SPAW Protocol); (d) protected areas listed in the SPAW Protocol; and (e) waters used for recreation.

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.

The constituents of domestic wastewater for which limits are established for Class I and Class II waters do not include nutrients. Most of the Contracting Parties have not yet classified their waters, which should be a priority moving forward. An assessment of nutrient pollution in the Cartagena Convention area presented in the SOCAR report shows a high proportion of sampling sites that exceeded the water quality limits for DIN and DIP, which are the forms of nutrients that are directly utilizable by marine plants and hence of most relevance to eutrophication. These figures may indicate the presence of nutrient pollution hotspots that are associated with areas influenced by riverine discharge and urban centres (UNEP CEP, 2019). Further investigation and monitoring will be necessary to link observed coastal water quality with nutrient inputs in watersheds and nutrient loads to coastal waters from point and nonpoint sources.

Targets and indicators for coastal water quality

Appropriate nutrient criteria are vital for the management of eutrophication of surface waters to achieve good ecological status. Criteria for good, fair, and poor conditions for the coastal water quality indicators DIN, DIP, Chlorophyl a (Chl a) and Dissolved Oxygen (DO) have been adopted by the LBS Monitoring and Assessment Working Group for the SOCAR, based on the US EPA guidelines (Tables 5.17 and 5.18). Different thresholds are applied for continental and island environments because of differences in their natural characteristics and ecological vulnerability. Regional thresholds, however, must be negotiated and agreed by all the countries. At the national level, some countries have established maximum permissible limits for N and P in discharges to coastal waters as well as coastal water quality standards for designated uses of the receiving water body (see CIMAB, 2020 and IMA, 2020). These include criteria and standards established under the US Clean Water Act and, for the French territories, the European Water Framework Directive (Poikane *et al*., 2019).

Table 5.17 Water quality criteria for DIN and DIP for continental and island environments (UNEP CEP, 2019).

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

Table 5.18 Water quality limits for Chlorophyll a (Chl a) for continental and island environments and for bottom Dissolved oxygen (DO).

Chl a		
Status	**Continental µg l^{-1}**	**Island µg l^{-1}**
Good	<5.0	<0.5
Fair	5.0 to 20.0	0.5 to 1.0
Poor	>20.0	>1.0
Bottom DO (continental and island)		
Good	> 5 mg.l^{-1}	
Fair	5-2 mg.l^{-1}	
Poor	< 2 mg.l^{-1}	

At the global level, SDG 14.1 and the CBD Post-2020 Global Biodiversity Framework Target 6 explicitly address nutrient pollution of the marine environment (Table 5.19). Capacity building will be required for monitoring and estimating the SDG 14.1 indicator (ICEP) in the countries. Other indicators are given in Annex 5.4 (Monitoring framework).

Table 5.19 Targets and indicators for coastal water quality.

Target	Indicator
Regional targets to be established: Coastal waters (Class I and nutrient hotspots) restored to 'good' status (or natural levels of N and P?) by 2030. Note: Criteria and standards for 'good'	Concentration of DIN, DIP, Chl a, Total suspended solids (TSS), DO (bottom water); DIN, DIP, Si loads at river mouths (NEWS model);

status to be developed and approved by member states (to be facilitated by UNEP-CEP)	Proportion of marine area meeting standards (see also SDG Indicator 6.3.1).
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	6.3.1. Proportion (%) of bodies of water (rivers, groundwater and coastal waters) with good ambient water quality.
SDG 14.1. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including **nutrient pollution**	Indicator 14.1.1: (a) Index of coastal eutrophication potential (ICEP); and (b) % Chl a deviations (from remote sensing).
CBD Post-2020 Global Biodiversity Framework Target 6: By 2030, reduce pollution from all sources, including reducing excess nutrients [by x%] to levels that are not harmful to biodiversity and ecosystem functions and human health. • 6.1. Reduction of pollution from excess nutrients	6.0.1. Proportion of water with good ambient water quality (freshwater and marine) • 6.1.1. Nitrogen balance (in rivers from SDG indicator 6.3.2 and in oceans from SDG indicator 14.1.1) • 6.1.2. Phosphate balance (in rivers from SDG indicator 6.3.2 and in oceans from SDG indicator 14.1.1) • 6.1.3. Fertilizer use 6.1.1.1. Trends in Loss of Reactive Nitrogen to the Environment.

Strategies and best management practices to restore and maintain coastal water quality

Protecting coastal waters from nutrient discharges from land-based sources and activities calls for ecosystem-based approaches such as integrated watershed and coastal area management and integrated coastal zone management. Among the most effective measures (which should be implemented in combination with other appropriate BMPs related to the above objectives) are reducing erosion and runoff (see above) and establishing vegetative buffer zones along water courses and along the coast (the latter in the form of coastal vegetation such as mangrove forests, salt marshes and seagrass beds). Therefore, restoration and protection of coastal vegetation will be essential in reducing inputs of nutrients to coastal waters from land-based sources and activities. This must be accompanied by measures to address marine sources such as shipping, tourism and the oil and gas industry, as well as atmospheric deposition of nutrients to the ocean. For marine sources, ecosystem-based management tools and approaches such as Marine Spatial Planning and Integrated Coastal Zone Management will need to be implemented.

See the BMP compendium and the GEF-GNC BMP database for appropriate BMPs.

5.5.7 Pillar 7: Productive coastal and marine habitats

Objective 7.1. Reduced ecological impact of nutrient pollution in coastal waters

Objective 7.2. Reduced threat to critical marine habitats and biodiversity from nutrient pollution *(link to Regional Habitats Strategy)*

While Objectives 6.1, 7.1, and 7.2 are closely linked, they represent different levels of impacts of nutrients on the marine environment. Nutrient pollution provokes a cascade of changes in the marine environment, manifested by different phenomena, which may or may not be obvious. Objective 6.1 deals with coastal water quality, which is critical in addressing the resulting habitat-scale impacts and monitoring the level of N, P, and Si to enable detection of the likelihood (as shown by the ICEP) for provoking certain responses. Objective 7.1. deals with the biological responses provoked by excessive nutrient loads in coastal waters, reflected in phenomena such as algal proliferation (including HABs and *Sargassum*) and oxygen depletion in bottom waters. Objective 7.2. deals with the direct impacts of nutrient enrichment on marine biodiversity and the quality of critical marine habitats. This approach allows the three distinct impacts of nutrients in the marine environment to be monitored to inform management and mitigatory responses.

The UNDP/GEF CLME+ Project supported the development of a Regional Strategy and Action Plan for the Valuation, Protection and/or Restoration of Key Marine Habitats in the Wider Caribbean (2021 – 2030) (UNEP CEP, 2020) for the UNEP CEP SPAW Sub-Programme (hereinafter referred to as the Habitats Strategy). There are important synergies between the two strategies, and close coordination in their implementation will be critical. Relevant goals and objectives of the Habitats Strategy include Goal 1. Improve ecosystem health, biodiversity and resilience; Objective 5 (Pillar 2): Reduce threats to the habitats from coastal/marine-based sectors and development activities that impact coral reefs, mangroves and seagrasses, with a targeted percentage reduction in the area of degraded habitats by 2030. In addition, the Strategy of the UN Decade on Ecosystem Restoration (2021-2030) describes three pathways with associated activities to be implemented to prevent, halt and reverse the degradation of ecosystems worldwide (https://www.decadeonrestoration.org/).

A challenge for researchers will be to determine the degree to which the different threats (nutrients, sedimentation, climate change, physical destruction, etc.) affect marine habitats, how they interact and the cumulative impact of these interactions as well as how these habitats may have developed resistance and resilience to multiple stressors.

Targets and indicators for coastal habitats

In addition to the targets for Objective 6.1, two other SDG Targets are relevant to Pillar 7 (Table 5.20). Other indicators are given in Annex 5.4 (Monitoring framework).

Table 5.20 Targets and indicators for coastal and marine habitats

Target (*year to be revised)	Indicator
SDG 6.6. By 2020*, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	SDG 6.6.1. Change in the extent of water-related ecosystems over time. Area of mangroves: Complementary UNECLAC indicator for SDG 14.2 (UNECLAC, 2018)
SDG 14.2. By 2020*, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	SDG 14.2.1 Number of countries using ecosystem-based approaches to managing marine areas.

Regional targets to be established under the LBS Protocol: Reduction in the incidence of algal blooms, HABS, *Sargassum* outbreaks, fish kills, etc. by 2030	Number of incidents per year, areal extent, weight/volume/density of *Sargassum* on shorelines
Other relevant targets and indicators are given in the CLME+ Regional Strategy and Action Plan for the Valuation, Protection and/or Restoration of Key Marine Habitats in the Wider Caribbean (mentioned above).	

Strategies and best management practices to reduce the impacts of nutrients on coastal habitats

See BMPs for Objectives 6.1 and the Habitats Strategy. Consideration of climate change impacts on marine habitats will be key in developing measures to achieve this objective.

5.5.8 Pillar 8: Human wellbeing and the blue economy

Objective 8.1. Reduced risks to human health and wellbeing from nutrient pollution
Objective 8.2. Improved livelihoods
Objective 8.3. Reduced risks to the blue economy from nutrient pollution (economic losses)

These three objectives address the socio-economic consequences of nutrient pollution of coastal waters in the Cartagena Convention area. There are few estimates of the incidence of human illnesses, loss of livelihoods, and economic costs associated with the impacts of nutrient pollution in the region (Chapter 3). However, the available information indicates that the impacts can be substantial. Improving monitoring programmes, identification of socio-economic impacts that are directly linked to nutrient pollution, and estimation of the associated costs in terms of human health, livelihoods and economies will be of vital importance in implementing an ecosystem-based approach to management of nutrients. Direct attribution of changes in human health, livelihoods and economies to nutrient pollution will be a challenge and will require timely and coordinated data collection and investigations.

Targets and indicators related to human wellbeing and the blue economy

SDG Target 3.9. explicitly addresses the impacts of pollution on human health – By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination (Table 5.21). Targets for the other objectives need to be established.

Table 5.21 Targets and indicators related to the impacts of pollution on human health.

Objective	Target	Indicator
Objective 8.1. Reduce risks to human health and wellbeing from nutrient pollution.	SDG 3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.	SDG 3.9.2. Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene SDG 3.9.3 Mortality rate attributed to unintentional poisoning Others:

		Number of persons affected and type of illnesses per year. Annual economic cost of addressing human health impacts (medical treatment, etc.). Number of advisories for polluted water per year. Number of shellfish beds and fisheries closures per year.
Objective 8.2. Reduce loss of livelihoods linked to nutrient pollution of coastal waters.	To be determined	Number of persons affected per year. Average loss in income (USD) per year.
Objective 8.3. Reduce risks to the blue economy from nutrient pollution.	To be determined	(Note: losses and changes are those that can be attributed to nutrient pollution, which may be difficult to identify) Economic losses per year (USD) by sector (caused by nutrient pollution). Job losses per year by sector. Change in GDP contribution by sector. Job opportunities created. Annual economic cost of mitigating nutrient pollution and addressing its impacts.

Strategies and best management practices for reducing risks to human wellbeing, livelihoods, and economies.

Clearly, the best strategy to achieve these objectives (and all the other objectives) is addressing the problem at its source, that is, preventing the excessive inputs of nutrients from point and nonpoint sources to the environment. One of the barriers is the scarcity of quantitative data and information on the social and economic impacts of nutrients and the links between observed impacts with nutrient pollution. A monitoring, forecasting and early warning system employing traditional (e.g., water samples and direct observation) and modern technology (e.g., satellite imagery) and with the involvement of all relevant sectors including the public health sector is essential. The US National Oceanic and Atmospheric Administration (NOAA) HABs Observing System (https://habsos.noaa.gov/#) and HABs Operational Forecast System and Red Tide Forecasts (https://tidesandcurrents.noaa.gov/hab/gomx.html) are examples of existing systems in this region for HABs and red tides. The Harmful Algae Event Data Base (HAEDAT) hosted by the UNESCO Intergovernmental Oceanographic Commission (IOC) International Oceanographic Data Exchange Programme contains regularly updated information on HAB events by countries worldwide (http://haedat.iode.org/). IOC Regional HAB Networks include the ANCA and the FANSA).

Regular monitoring of the level of toxins and their sources in fish and shellfish should be included in nutrient monitoring programmes. Another strategy for mitigating the impact of HAB toxins on human health is to process harvested fish and shellfish to reduce toxicity to an acceptable level, for example, removal of viscera before marketing or consuming.

5.5.9 Pillar 9. Enabling effective implementation of the WCR NPRSAP

Objective 9.1. Establish enabling conditions for addressing nutrient pollution and its impacts in the WCR. Implementing the WCR NPRSAP will require a range of enabling conditions to be established at local/national, sub-regional and regional scales. The LBS Protocol contains provisions for participation; education and awareness; reporting; institutional mechanisms; scientific, technical and advisory committee; operational procedures; and funding. These provisions, along with others, are incorporated under Pillar 9.

Targets and indicators

Specific targets should be identified at different scales (local, national, regional). The following are Targets for Pillar 9:

- Enhance institutional frameworks and mechanisms at all levels and strengthen linkages (horizontal and vertical) among them (multiscale governance framework). This includes efforts of UNEP CEP to develop more integrated projects for pollution prevention and habitat degradation/restoration under the LBS and SPAW Protocol;
- Promote policy and legislative reforms that support an integrated approach to addressing nutrient pollution in the Cartagena Convention area;
- Improve the data and knowledge base and decision support system, and strengthen knowledge sharing and exchange;
- Improve science-based policy and decision-making for management of nutrient pollution (science-policy interface);
- Strengthen knowledge and capacity across all necessary disciplines and skills for nutrient pollution management, including on BMPs for nutrient pollution reduction;
- Increase involvement, buy-in and awareness of stakeholders at all levels;
- Promote development of sustainable financing mechanisms and leveraging adequate and sustained financial resources for implementing the strategy and action plan.

Indicators will be primarily process indicators related to the targets (preferably numeric targets). Indicators are to be identified for Pillar 9.

For process indicators, see, for example, Duda (2002), Heileman and Walling (2008), GEF/UNDP/UNEP (n.d.), and GEF LME:LEARN (2019).

Institutional framework

The WCR has a rich network of relevant actors and institutions at different levels, from local and national to sub-regional/ regional and international, that serve various purposes but seldom intersect effectively (Fanning *et al*., 2007, Mahon *et al*., 2013). Changes in the institutional framework will be required to enhance the institutional mechanisms that link watershed-level interventions to relevant national, regional and global policies and to facilitate the implementation of an integrated ridge to reef (watershed) approach. A major barrier is the sectoral (silo) approach that still prevails in many countries and the absence of or weak links among the different actors. The institutional/governance framework can be examined in the context of the five stages of a generic policy cycle: data and information, synthesis and provision of advice, decision-making, implementation, and review and evaluation, each requiring different inputs and actors (although there is some overlap).

Under the previous GEF Caribbean LME (CLME) Project, a multi-scale LME governance framework was proposed by Fanning *et al*. (2007) consisting of a set of nested and laterally linked governmental and non-governmental actors and institutions (Figure 5.15). This framework provides for the processes and linkages at the multiple geographic and organizational scales that are characteristic of the diversity and complexity inherent in the Caribbean. The proposed LME governance framework comprises complete policy cycles at multiple jurisdictional levels that are networked through both vertical and lateral linkages.

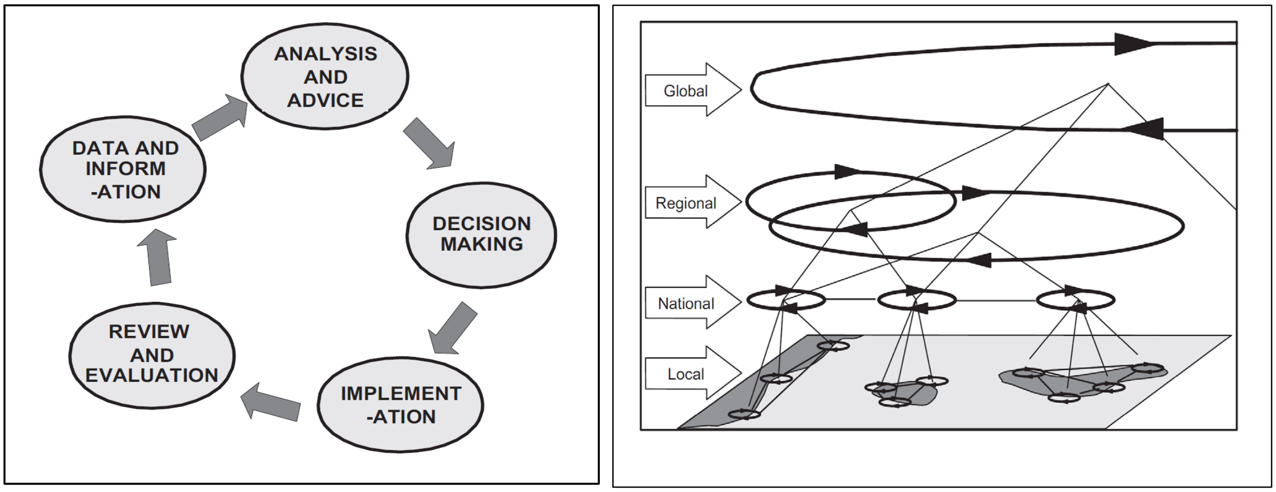

Figure 5.15 A generic policy cycle (left) and the multi-scale component (right) of the proposed governance framework with vertical and horizontal linkages among the different policy cycles (Fanning et al., 2007)

The kinds of stakeholders and activities that may be associated with the policy cycle stages are illustrated in Figure 5.16 (from Fanning *et al*., 2007). This framework accommodates the diversity of policy cycles arrangements and types of linkage that are required to achieve the goals and objectives of the regional strategy. Based on an analysis of existing policy cycles to identify their strengths and weaknesses, the multi-scale cycles and linkages will need to be established and/or enhanced.

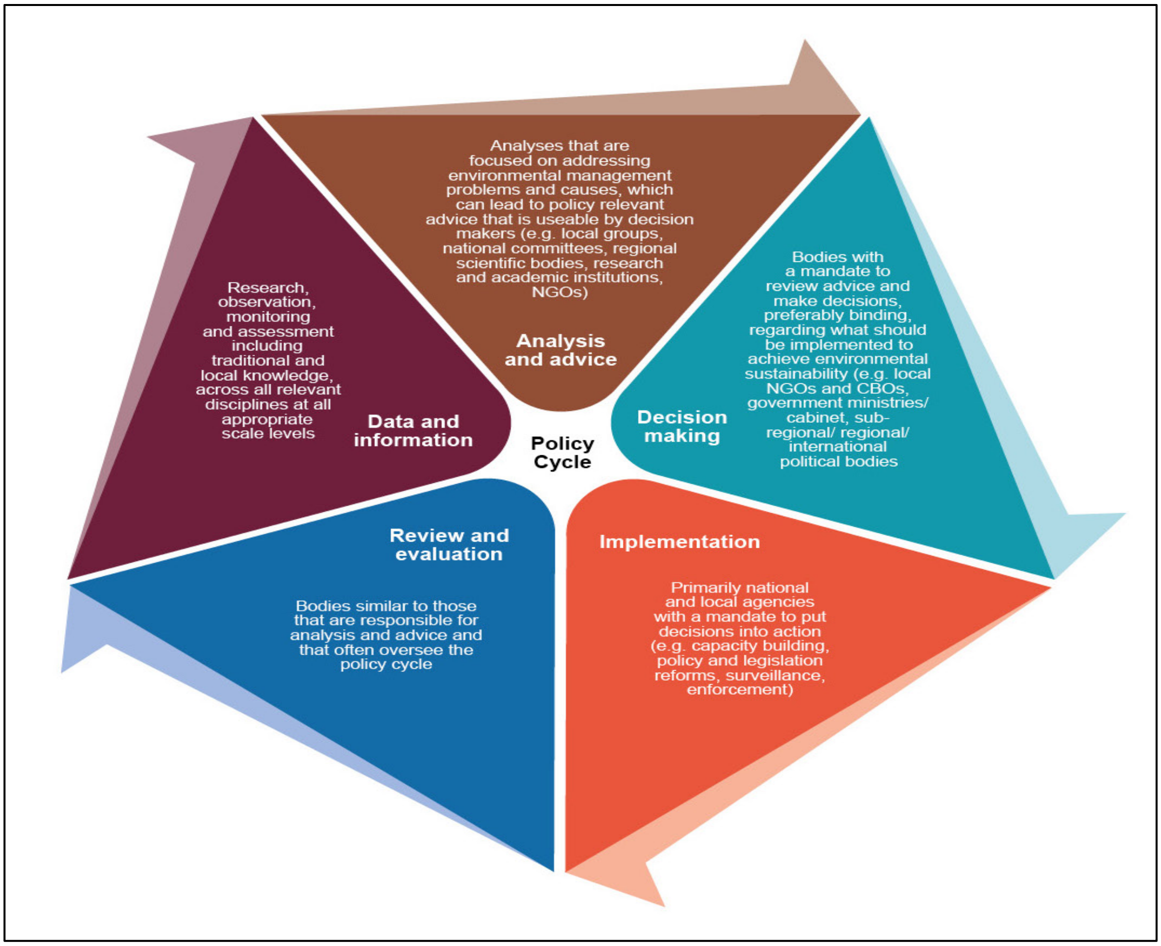

Figure 5.16 The diversity of stakeholders and activities associated with each policy cycle stage (adapted from Fanning et al., 2007)

UNEP CEP (as the Secretariat for the LBS Protocol) has been actively promoting national, sub-regional and regional initiatives to address LBS pollution on multiple spatial scales. UNEP CEP also facilitates vertical linkages between the national, sub-regional and global (e.g., Global Programme of Action for the Protection of the Marine Environment from Land-based Activities -GPA, GPNM) levels and horizontal linkages across policy cycle stages (e.g., analysis and advice/decision making; see science-policy interface below). The policy cycle for LBS pollution can be considered to be complete in the sense that there is scope for all five policy stages under UNEP CEP in connection with the LBS Protocol (Mahon *et al*., 2013). However, not all WCR countries are parties to the Convention and the LBS Protocol. To date, only 16 countries have ratified the LBS Protocol. Because of the transboundary nature of nutrient pollution and the high inter-connectedness among the countries' EEZs, it is imperative that all countries ratify and implement the Protocol in a timely manner.

Complete policy cycles for nutrient management are needed also at the national level. These should be set within an integrated watershed management framework. Creation of a national intersectoral institutional framework (e.g., national intersectoral committee or inter-ministerial committee) for nutrient management should be encouraged and supported, which is then linked to the sub-regional/regional level. Among the sectors/stakeholders that should be involved are the relevant public agencies (environment, agriculture, tourism, fisheries, health, planning and development, water/sanitation, etc.), those producing, marketing and using nutrients as well as private sectors that are impacted by nutrient pollution (e.g., tourism, fisheries). Such mechanisms can be facilitated, for example, under GEF projects, many of which have the establishment of national inter-ministerial committees as an activity or expected output.

Cooperation among countries sharing transboundary rivers and aquifers

The presence of major transboundary rivers and groundwater aquifers in the region requires cooperation among the relevant countries in implementing measures to address nutrient pollution. Such cooperation is called for by SDG Target 6.5 (By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate, with the associated indicator 6.5.2: Proportion of transboundary basin area with an operational arrangement for water cooperation). This will require the establishment or strengthening of multi-country policy and institutional mechanisms (for example, the Amazon Cooperation Treaty among Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela; joint institutional coordination framework for the Río Motagua watershed proposed under the UNDP/GEF Project Integrated Environmental Management of the Río Motagua Watershed between Guatemala and Honduras) and 'Common River Basin Management Plans' between the countries to tackle nutrient pollution at the appropriate scale. The WCR NPRSAP will provide another mechanism to facilitate transboundary cooperative arrangements. Transboundary cooperation could be also facilitated through the UNEP Regional Seas Programme and LME projects.

Policy and legislative framework

Effective implementation of the RNPRSAP must be underpinned by appropriate policy, legislation and regulations at the relevant scales, as well as effective enforcement. A review of existing policies and legislation will be necessary to identify gaps and weaknesses related to nutrient management. Based on this evaluation, regional/sub-regional policies and national sectoral policies, legislation and regulations may need to be reformed and harmonized and new ones developed to support the implementation of nutrient pollution reduction activities. As discussed in Chapter 4, in general, existing national policies are not specific enough for addressing nutrient pollution.

The LBS Protocol is the regional policy framework related to point and nonpoint sources of pollution, including nutrients. However, the Protocol may need to be amended to explicitly cover nutrients and links between the state of the Convention Area coastal waters with upstream sector activities and practices (ridge to reef approach). Several past and ongoing GEF projects in the region include a component on policy and legislation review and reforms for integrated natural resources management (for example, IWCAM, IWEco, CReW+). These may lay the foundation for a framework that can be adapted for integrated nutrient management. The GEF IWCAM Project produced a Toolkit for institutional, policy, and legislative improvements in support of the IWCAM approach in Caribbean SIDS. At the national level, there is need to move from compartmentalized, sectoral efforts to full integration of policies and legislation for agriculture, forestry, environment, fisheries, water, land, planning, poverty reduction, etc. that take into account upstream−downstream linkages within a watershed management perspective (FAO, 2006b). In general, watershed-based planning that is mainstreamed in physical development planning is not done in most of the countries, although there has been some progress.

Criteria and standards

Environmental criteria and standards are critical for attaining water quality goals. The LBS Protocol does not specify standards and limits for discharge from point sources (domestic wastewater discharges) and water quality related to nutrients. However, as mentioned above, Annex II provides guidance for developing source-specific effluent and emission limitations and management practices. As mentioned previously, for the SOCAR report, DIN, DIP, Chl a and DO criteria and limits for coastal water quality were adopted from the US EPA, but these have not been agreed or adopted by all the member states. As discussed in the sub-regional reports, the policy and legislative frameworks related to nutrients vary among the countries. Several countries have discharge limits for N and P in domestic and industrial wastewater (point sources), while others place more emphasis on microbiological indicators (faecal pathogens) in domestic wastewater effluent and coastal water quality for designated uses such as recreation and fishing. This reflects concerns over the impacts of poor water quality on human health, which takes precedence over impacts on coastal and marine ecosystems and the goods and services they provide. This further highlights the need for more integrated assessments, for example, using the Driver-Pressure-State-Impact-Response (DPSIR) framework including of the value of ecosystem goods and services and the direct and indirect social and economic costs of marine pollution.

Determining the permissible discharge load of nutrients required to meet water quality/ecological criteria and standards is core to the strategy, but very challenging due to data and knowledge gaps as well as inherent uncertainties. Various science-based methods are available that link marine water quality objectives with nutrient discharge loads. The US EPA (under the US Clean Water Act) establishes TMDL for pollutants entering a waterbody so that it meets the associated water quality standards (https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls).

See UNEP CEP (1992) for a discussion of environmental quality criteria for coastal zones in the WCR.

Policy instruments, compliance, and enforcement

A diverse range of policy instruments are available for addressing nutrient pollution. See, for example, GEF GNC project Nutrient Management Policy Framework, GPNM policy database (http://www.nutrientchallenge.org/policy-database), US EPA, USDA, EU Water Framework Directive. The appropriate mix of policy instruments to be implemented for point and nonpoint sources will be dependent on the local/national context, objectives, targets, etc. Necessary policy and legislative reforms will need to be identified and implemented. The US regulatory framework for example includes states which have unique approaches to nutrient management that are not part of the federal program.

Mechanisms must be in place to ensure that regulatory requirements are met, with appropriate compliance monitoring. These mechanisms include monitoring of the discharges of regulated sources such as municipal and industrial wastewater treatment plants in order to determine compliance and effective enforcement mechanisms in cases of non-compliance. Watershed nutrient pollution loading caps and enforceable discharge allocations to sources will be necessary. As discussed in Chapter 4, countries face capacity constraints for surveillance and enforcement, and employ different mechanisms such as having a regulatory authority do the monitoring; use by the regulatory authority of a third party with the required capacity (such as CARPHA); and regulations that place the burden on industry to do routine monitoring, with verification of the results and occasional spot checks (such as Jamaica NEPA). A market-based tool for controlling nutrient pollution from point and nonpoint sources is water quality credit trading. This approach, however, requires the establishment of numeric criteria and quantitative limits on nutrient pollution and other data and information which may not be readily available.

Policy instruments for controlling agricultural nonpoint source pollution include financial and technical assistance to farmers for the implementation of best management practices and environmental protection; taxes and fees; water quality credit trading; and PES programmes in which farmers and landowners are paid to preserve or restore ecosystems on their lands. Related to the latter are 'conservation easements', which can be an effective tool to protect land and are legally binding agreements between a landowner and a land trust or government agency.

Monitoring and data collection

An essential component of a sound, science-based strategy is a monitoring system to collect relevant data, with the objectives of characterizing baselines, detecting trends, and informing adaptive management and appropriate policy responses including decisions on future investment opportunities. Moreover, a high proportion of the targets and indicators in the strategy are covered by the SDGs and proposed in the CBD Post-2020 Global Biodiversity Framework, which countries should be engaged in monitoring. Therefore, monitoring programmes for these frameworks and for nutrient pollution (including the ICEP) will be mutually supportive and potential synergies should be strengthened. In addition, the collection of empirical data is required to ground-truth the results of the analytical models used in development of the strategy. The general poor monitoring capacity, data (including geo-referenced data) and information on nutrient pollution, its sources and environmental impacts and socio-economic consequences is one of the major barriers towards nutrient management in the region.

The multi-faceted nature of the nutrient challenge calls for a coordinated, holistic, and integrated monitoring programme across all the Pillars. A streamlined monitoring programme that is harmonized and linked across scales (from national to sub-regional and regional) is necessary, but currently, such a monitoring programme does not exist in the region. At the national level, nitrogen and phosphorus in coastal waters are monitored by a significant number of countries. However, in general monitoring is sporadic and uncoordinated among the pertinent sectors, and with focus on water quality monitoring. Among the WCR countries with well-established, long term monitoring programmes, there is a wide disparity in the indicators (species of N and P) monitored as well as in the sampling protocols and analytical techniques used (as revealed during development of the SOCAR, and in the sub-regional reports).

The SOCAR provides a series of recommendations for establishing monitoring programmes. In addition, the CLME+ Pollution Research Agenda (Acosta *et al.*, 2020) identifies priority topics related to monitoring (https://clmeplus.org/a-research-agenda-for-the-wider-caribbean-region/), including developing regional standards and criteria for nutrient discharges; identifying regional indicators for monitoring nutrient discharges into the marine environment; and enhancing science-based monitoring in response to management goals and objectives.

A monitoring programme should involve all relevant sectors and agencies and incorporate 'citizen science' as a cost-effective approach to collecting certain kinds of data and information. Essential requirements for a robust monitoring programme are adequate trained personnel and monitoring, sampling and analytical laboratory capacity as well as data analysis capability. Several national environmental laboratories exist in the region, but their capability may need to be enhanced for work on nutrients. Current capacity building efforts through various externally funded projects should be continued but linked with a commitment to also institutionalize national monitoring and assessment programmes and to generate national environmental data and information to support decision making and policy setting. An essential requirement regarding data collection will be quality assurance/ quality control of data.

To optimize monitoring, it will be necessary to classify marine waters (Class I and Class II) and to determine the eutrophication status of different marine areas (e.g., problem areas or hotspots, potential problem areas, and areas without eutrophication problems). Based on this screening, the appropriate level of monitoring effort can be implemented in the different areas (see for example, the OSPAR Eutrophication Monitoring Programme https://mcc.jrc.ec.europa.eu/documents/OSPAR/CEMP_guidelines_fo%20coordinatedmonitoring_foreutrophication_CAMPandRID.pdf).

Analytical tools and frameworks

Managers and decision makers need to be better equipped with tools to help guide cost-effective nutrient reduction planning in the watersheds, ultimately leading to the reduction of excess nutrients in the coastal and marine environment. These include predictive water quality and loading models to predict pollution inputs to the receiving water body from point and nonpoint sources and the response of the water body to those inputs, and to estimate the maximum allowable nutrient load and required load reduction.

An analytical framework developed under the GEF-GNC project is described in Box 5.1.

Box 5.1.
The GEF-GNC Project developed an analytical framework called a Pollution Reduction Opportunity Analysis (PROA) that can serve as a decision-support tool in the setting of allocations. The PROA is designed to help identify the most cost-effective solutions for pollution reduction in a holistic manner. The methodology involves the following steps: 1. All sources of the pollutant of concern are identified; 2. Pollutant loadings from each source and/or sector are estimated; 3. Methods of reducing the discharged loads from each source and/or sector are identified; 4. The load reduction potential of each source/ sector is identified; 5. The cost of achieving load reductions for each source/sector is estimated on a per mass unit basis (kg per year); 6. The results are graphed in a manner that clearly shows the reduction potential and cost effectiveness for each method and sector (WRI, 2017). The PROA was tested for the Philippines (see http://www.nutrientchallenge.org/sites/default/files/documents/GNC-Publications/D2-2-2_Pollution%20reduction%20analyses.pdf)

Data management and decision support system

Data management and decision support systems at the national level linked to a regional system (and possibly sub-regional systems of the OECS and SICA/CCAD as well as Brazil and the French Territories) will be critical. Existing or planned systems such as the decision support system being developed by UNEP CEP under the GEF IWEco and CReW+ Projects should be assessed for incorporating data and information to serve the purposes of the RNPRSAP. The GPNM-Caribbean, currently facilitated through the Cartagena Convention Secretariat and the LBS Protocol Regional Activity Centres (RAC), will play a major role in knowledge sharing. Such a platform will also be used to facilitate knowledge exchange and transfer on best practices and case studies relating to nutrients and sediments management among managers and stakeholders (see the GPNM online platform at http://nutrientchallenge.org/).

Research

Watershed management policies must be grounded on the best available scientific evidence while also taking account of local and traditional knowledge. Efforts will be required to identify, compile, and assess local and traditional knowledge of relevance to nutrient pollution. A Pollution Research Agenda for the CLME+ region focusing on one of the overarching CLME+ Strategic Action Programme (SAP) goals (Expand the knowledge base required for the efficient and cost-effective reduction of LBS pollution in the CLME+) was developed by the Gulf and Caribbean Fisheries Institute (GCFI) and regional experts (Acosta *et al*., 2020). This report identifies challenges to developing, obtaining, and using the best available scientific evidence as ranging from low capacity to produce or access relevant scientific evidence, to poor communication of science to decision makers, and governance processes that are inadequately structured for the uptake of scientific advice.

Based on a survey among regional decision makers, the CLME+ Pollution Research Agenda identifies a range of research topics under five research themes: Pollution science, Monitoring, Governance, Economic and Communications Research Themes. While many of the research topics are relevant to nutrients, several of the topics explicitly address nutrients (https://clmeplus.org/a-research-agenda-for-the-wider-caribbean-region/). One of the two topics that ranked highest for the pollution research priorities is ‘Develop effective advocacy approaches (e.g., lobbying, influencing decision makers) that result in decreased impacts of marine pollution on the environment and society’, under the Communication/Goal (Create or enable policies and legislation that contribute to the reduction in marine pollution). Another area is engagement of the academic and research community in building capacity for monitoring as well as developing/innovating technology for nutrient recovery.

A coordinated and harmonized framework for policy-relevant research, data collection and information-sharing to support scientific and decision-making processes in the region is a necessary step to ensuring adequate national and regional capacity to produce relevant knowledge and information for nutrient management. The UN Decade of Ocean Science for Sustainable Development (2021-2030) will present opportunities to support research and capacity building in the region (https://oceandecade.org/). One of the objectives of the UN Decade is to provide a common framework to ensure that ocean science can fully support countries to achieve the 2030 Agenda for Sustainable Development. Outcome 1 of the UN Decade is: A clean ocean where sources of pollution are identified, reduced or removed. Among the challenges identified by participants of the UN Decade Western Tropical Atlantic (WTA) Regional Workshop (Mexico,28–29 April 2020) is ‘significant gaps in data and research regarding the types, sources, concentrations and channels of marine pollutants in the WTA’, with the corresponding action to ‘improve understanding, through a harmonized, region-wide data collection, analysis and research programme, of the flow and impacts of all pollutants in the WTA, transforming decision making, facilitating targeted pollution prevention measures, to sustain and catalyse more sustainable use of our coastal and marine resources.’ The IOC-UNESCO has been tasked by the UN General Assembly to design the Decade of Ocean Science. The UN Decade on Ecosystem Restoration (2021-2030) will also provide opportunities to strengthen capacity, with one of the three Pathways for its implementation (Pathway III) aiming to building technical capacity for deploying science and technology in ecosystem restoration, and catalysing and accelerating action on the ground.

Science-policy interface

Linkages between the analysis and decision-making stages of policy cycle (see above) are critical for effective management. Yet, these stages are often the weakest in marine resource management. Constraints on the use of science in policy and decision making include low capacity, science not being provided in policy-relevant format, not having easy access to databases, and low policy demand for science (McConney *et al*., 2016). Efforts should focus on establishing or enhancing mechanisms for analysis and provision of advice on a regular and timely basis and ensuring that it is considered by decision-makers in the appropriate fora (Fanning *et al*., 2007).

A regional mechanism for facilitating the science-policy interface exists under the LBS Protocol, consisting of the STAC that provides advice and recommendations for decisions to the Conference of Parties. The STAC receives inputs from the LBS Monitoring and Assessment Working Group, which is composed of national focal points and relevant national and regional experts. A vital element of this mechanism is the LBS RACs (Institute of Marine Affairs- IMA, and the Center for Research and Environmental Management of Transport -CIMAB), and the Regional Activity Network (RAN) of technical institutions and individuals (including governmental, intergovernmental, non-governmental and academic and scientific) that provide input, peer review, and expertise through the relevant RACs. At the sub-regional level, SICA/CCAD and the OECS Commission have their respective mechanisms for facilitating the uptake of science into policy, which should be linked to the regional mechanism. The LBS Protocol mechanism should be strengthened to generate scientific knowledge and provide advice on nutrient management, for example, by explicitly including work on nutrients in the terms of reference of the various bodies and establishing a regional technical working group on nutrients. At the national level, various mechanisms exist across the countries to enable the science-policy interface. The GPA and the GPNM-Caribbean are two other important mechanisms. It is crucial that all these elements are linked to enable an operational and effective science-policy interface.

Assessment and reporting are essential tools to communicate science to policy makers and other stakeholders. In this regard, state of environment reports such as the regional UNEP CEP SOCAR and CLME+ State of the Marine Environment and Associated Economies (SOMEE) and the SOMEE assessment and reporting mechanism (being established under the CLME+ Project) need to be supported and sustained. Interim products such as ecosystem health report cards (e.g., GNC ecosystem health report card) focusing on nutrients should be considered.

Stakeholder outreach and engagement/public awareness and education

Stakeholder outreach and engagement and public awareness and education programmes directed at key stakeholders and the wider public are necessary to raise public awareness about the impacts of nutrients in WCR waters and to garner support and buy-in for the strategy. Annex IV of the LBS Protocol calls for education, training and awareness programmes to be established. The development of public-private partnerships will be critical to support implementation of BMPs in the targeted areas.

Education programmes for farmers on the impacts of farming on the local and downstream rivers, groundwater, and coastal waters are critical to encourage voluntary change. Education and technical assistance programmes for farmers will be also necessary, not only for managing nutrients but to demonstrate to farmers how they stand to benefit from improved soil quality, increased yields, and cost savings. Providing greater technical assistance around nutrient management and other agricultural BMPs in developing countries is an excellent way to cost-effectively manage nutrients while also supporting improved livelihoods including for women. Technical assistance programmes should include demonstration projects on the most effective BMPs as well as a strategy for replication and upscaling and associated financial plans that enable sustainability. In developing education and technical assistance programmes for farmers, ensuring that women and indigenous groups are adequately represented will be essential.

Documenting and communicating the outcomes of nutrient management initiatives to stakeholders will be important. The results, including quantitative costs and benefits, need to be analyzed and documented for each management practice and watershed. These results should be presented so they convey clear, concise, and understandable messages to stakeholders, regulatory agencies, and participating organizations.

Capacity building/knowledge transfer

Strengthened capacity across a range of technical and soft skills among watershed and water resources management professionals, government agencies, water and wastewater utilities, farmers and other stakeholders are important conditions for the implementation of a successful nutrient reduction strategy. Capacity building programmes should be developed based on an assessment of capacity needs at the local, national and regional levels. They should include training programmes on best management practices; technology transfer and information exchange; strengthening agricultural extension services and technical assistance programmes for farmers; environmental and socio-economic monitoring and data management; assessments; strengthening laboratory capability; analytical modeling including downscaling of global models (see the Global NEWS model calculator in the GPNM Global Nutrient Management Toolbox); use of satellite remote sensing data; and strengthening country capacity to access funding. Of critical importance will be capacity for planning and scenario assessment of implementation of practices to control nutrient pollution, and the forecasted desired outcomes to guide decision making. Demonstration projects on BMPs and other relevant themes, with strategies for replication and upscaling and dissemination of lessons, are an important component of capacity strengthening. Results and lessons from relevant completed and ongoing projects (e.g., RepCar, IWCAM, CReW, IWEco, CReW+ and case studies in the GPNM Toolkit) are valuable resources to inform nutrient management interventions in the WCR. An easily accessible and user-friendly platform for knowledge exchange/transfer on best practices and case studies relating to nutrients and sediments management, linked to other platforms such as the GPNM platform and the GEF International Waters Learning Exchange and Resource Network (IWLEARN), will be critical for promoting transformational change. See SOCAR for capacity building recommendations and the CLME+ Pollution Research Agenda.

Financial resources

The development of innovative financial mechanisms and affordable financing to assist countries to address land-based pollution is of high priority in the region (UNEP CEP 2019). One of the priorities in the CLME+ Pollution Research Agenda is the development of an investment plan that outlines and costs priority actions to reduce pollution sources that cause substantial impacts on ecosystem goods and services of critical importance for human well-being and sustained socio-economic development. A financial strategy/plan should be developed, with consideration of the following:

- Leveraging funds from multiple sources and mechanisms (e.g., public sector financing, private sector investment, development banks, international donors and mechanisms including GEF Small Grants Programme, trust funds, revolving funds).
- Economic and non-economic incentive programmes and innovative market-based solutions.
- Economic instruments (taxes, fees, bonds, debt-for-nature swaps, etc).
- Cost-benefit analysis of specific interventions.
- Potential investment opportunities.
- Opportunities for collaborating with or building on completed and ongoing initiatives that support nutrient management (including implementation of the regional Habitats Strategy).
- Valuation of ecosystem goods and services likely to be affected by nutrient pollution.
- Quantification of economic losses caused by nutrient pollution.

The GEF CReW Project developed and tested an economic valuation resource guide (Grey *et al*., 2015) to assist countries in making a stronger case for investments in wastewater treatment (https://www.gefcrew.org/index.php/resources#resources6). This guide can 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). Several other GEF CReW products provide information that is relevant to financing for waste treatment in the region (https://www.gefcrew.org/index.php/publications).

With financial support under the UNDP/GEF CLME+ Project, the Ocean Foundation is supporting the Cartagena Convention Secretariat with the development of an integrated habitat restoration and pollution reduction investment plan for the CLME+ region.

5.6 IMPLEMENTATION OF THE STRATEGY

The RRPRSAP is a tool that guides national, sub-regional, and regional implementation of actions to address nutrient pollution of the Cartagena Convention area. It will be implemented primarily through actions at the national level, with the support of international, regional and sub-regional institutions and partners. Alignment of the strategy with the 2030 Sustainable Development Agenda, the CBD Post-2020 Global Biodiversity Framework, the Colombo Declaration and UNEA Declarations as well as with the Cartagena Convention LBS Protocol and other relevant MEAs means that its implementation will support, more cost-effectively, the achievement of the targets and objectives of these frameworks and vice versa. Further, the 2021-2030 timeframe for implementation of this strategy aligns with the UN Decade of Ocean Science for Sustainable Development, the UN Decade on Ecosystem Restoration, and the Regional Habitats Strategy. Coordination across all levels and strategic partnerships will be essential for cost-effective and efficient implementation of the strategy.

This section proposes an institutional framework, including major potential roles and responsibilities of the various stakeholders, in implementation of the strategy. This is followed by an action framework (Section 5.7) to achieve the objectives and targets of the strategy at the regional, sub-regional, and national levels.

5.6.1 Institutional Implementation Framework

Implementation of the RNPRSAP will require a multiscale institutional framework, as described under Pillar 9 (enabling conditions). This will involve participation by stakeholders representing all stages of the policy cycle at all levels from local/national to sub-regional and regional to global (relevant government ministries and agencies, private sector, national and regional technical institutions, academia, sub-regional political integration bodies, transboundary basin governance arrangements, and regional and international organizations, among others). An essential role for the global, regional and sub-regional bodies will be to contribute to development of the enabling conditions for implementation of the strategy. Among the key players are:

Global level: UNEP, FAO, IMO, GPA, GPNM, United Nations Development Programme (UNDP), Pan American Health Organization (PAHO), and World Health Organization (WHO).

Regional level: UNEP CAR/RCU Cartagena Convention Secretariat (responsible for coordinating the implementation of the RNPRSAP supported by the LBS RACs and RAN, LBS Protocol STAC and Monitoring and Assessment Working Group), GPNM-Caribbean.

Sub-regional level: CARICOM, SICA/CCAD, OECS, and ACTO - Support implementation of the strategy among member states, by integrating the strategy and action plan into their relevant programmes; and facilitating stakeholder engagement and awareness raising.

National level: Cartagena Convention and LBS Protocol Contracting Parties and non-contracting countries) will be responsible for implementing the required actions at the national and local levels. This will involve creating the enabling conditions at the national level. Increased ratification of the Convention and Protocol will greatly contribute to achieving the objectives of the strategy.

Partnerships: Partnerships with technical and programmatic stakeholders from civil society, the private sector and academia, among others, and engagement with financial institutions will be critical to support roll out of the strategy and action plan.

5.7 ACTION FRAMEWORK

An action framework for implementation of the RNPRSAP is presented below. This consists of activities at the regional and sub-regional levels as well as at the national level that are required to achieve the objectives and targets of the strategy (and other targets that may be identified by stakeholders). Ultimate success in addressing nutrient pollution while deriving socio-economic benefits depends on actions at the national and local levels, linked to and supported by actions at the regional and global level. Actions must be prioritized, targeted, and measurable to ensure that limited resources are allocated where they are most needed. As far as is feasible, multiple activities should be executed in parallel, rather than sequentially.

It is emphasized that the regional strategy and action framework must be adapted as appropriate for the local/national contexts including the main source(s) of nutrient pollution and priority watersheds or coastal areas. The local/national context will help to guide the selection of the management measures and BMPs to be implemented, and the timeframe.

The timeframe for implementation of the strategy (2021-2030) is aligned with the timeframe for global Targets (SDGs, Post-2020 Global Biodiversity Framework, and Colombo Declaration), although the response time of the system to nutrient reduction interventions is unknown at this time. Hence, the timeframe for the strategy is divided into two blocks of 5 years each, with the first time period focusing primarily on establishing enabling conditions and preparations, and the second on on-the-ground implementation. However, provisions must be made for differences in capacity, institutional and policy frameworks, etc. among the countries, with some countries requiring more time to implement the strategy than others. Capacity strengthening, strategic partnerships, and sustainable financing will be vital to support implementation.

Please see also the monitoring framework in Annex 5.4.

ACTION FRAMEWORK (2021-2030)

LINE OF ACTION/ MILESTONE	**ACTIVITIES**	**INDICATIVE TIMEFRAME**
REGIONAL LEVEL (UNEP CAR/RCU, Cartagena Convention Secretariat)		
Adoption of the RNPRSAP	● Review of the RNPRSAP by the LBS STAC and adoption by the LBS COP ● Develop a M & E framework to track and assess progress in implementation of the strategy.	2021
Policy and institutional framework	● Promote ratification of the Convention and LBS Protocol among non-member countries. ● Recommend and facilitate necessary amendments to the LBS Protocol to explicitly cover nutrients and links between the state of the Convention Area coastal waters with upstream sector activities and practices. This may include consideration of a new Annex dedicated to Nutrients. ● Facilitate operationalization of GPNM-Caribbean. ● Identify opportunities for strengthening the LBS M & E Working Group and LBS RACs for nutrient management. ● Facilitate coordination in implementation of the RNPRSAP and Habitats Strategy by member states. ● Establish/strengthen strategic partnerships with regional and international organizations, academic institutions, among others, including through the CLME+ partnership arrangement. ● Collaborate with the IMO to strengthen mechanisms to address nutrient pollution from marine sources. ● Engage with sub-regional political integration mechanisms (CARICOM, OECS, SICA/CCAD) and ACTO to mainstream management of nutrient pollution in their respective programmes and to support downscaling and implementation of the RNPRSAP in member states (through the CLME+ Interim Coordination Mechanism/long-term Coordination Mechanism). ● Strengthen the multi-level regional governance framework.	2021-2025 2021-2025 2021-2025 2021-2025 2021-2030 2021-2025 2021-2025 2021-2025 2021-2025
Financial resources	● Develop/implement investment plans for pollution reduction in the CLME+ region (based on the integrated habitat restoration and pollution reduction investment plan for the CLME+ region developed by the Cartagena Convention Secretariat with support from the Ocean Foundation). The plan should outline and cost high-priority actions to reduce nutrient pollution sources that cause substantial impacts on ecosystem goods and services of critical importance for human well-being and sustained socio-economic development. ● Identify opportunities for financial support and investments through projects (e.g., follow on to the CLME+ Project), partnership with financial institutions (e.g., Caribbean Development Bank, Agricultural Development	2021-2030 2021-2025

	Bank, World Bank, Interamerican Development Bank) and bilateral and multilateral donors, among others. ● Leverage financial resources for implementation of the strategy.	2021-2030
Capacity building and technical assistance to member states	● Facilitate capacity building for member states (regional capacity building programmes, pilot projects and strategy for replicating and upscaling, compilation and dissemination of lessons and experiences, facilitation of partnerships with countries that have nutrient pollution reduction strategies in place, etc.). ● Facilitate transfer of technologies to member states and promote the development and/or adaptation of technologies specific to the region. ● Facilitate access by member states to tools, data and information, including through production of a Regional Toolbox (similar to the GEF-GNC Toolbox). ● Establish a dedicated regional action/expert group for nutrient pollution. ● Provide technical and other support to member states through the expert group and LBS RAN/RACs for delivery of activities in support of the implementation of the RNPRSAP at national and where appropriate local levels. ● Support countries in developing national programmes of action for implementation of the RNPRSAP at national and local levels, and implementation of the LBS Protocol and other relevant MEAs that contribute to reduction of nutrient pollution (e.g., through the ACP MEA project) to achieve multiple environmental and socio-economic objectives including the SDGs, in a coordinated, streamlined, and cost-effective manner. ● Catalyze adoption by member states of an integrated, watershed management approach that links coastal water quality with activities and practices in watersheds.	2021-2030 2025-2030 2021-2025 2021-2025 2021-2030 2021-2025 2021-2030
Regional monitoring, assessment and reporting, communication	● Recommend regional criteria, standards and limits for nutrients in domestic and industrial wastewater effluents for endorsement by the LBS COP. ● Identify a set of priority monitoring sites covering the WCR and develop a detailed nutrient monitoring protocol. ● Identify and recommend a suite of region-specific targets and indicators (to complement the SDG, Post-2020 Global Biodiversity Framework, and other relevant global targets and indicators) for endorsement by the LBS COP and facilitate development of a harmonized regional monitoring programme to be implemented by member states. ● Quantitative and qualitative identification and mapping of land-based and marine sources of nutrients through multidisciplinary approaches (field sampling, fixed monitoring stations, remote sensing). ● Identify and map the most affected ecosystems and most important socio-economic impacts. ● Facilitate periodic regional assessment and reporting on nutrient pollution, with production and dissemination of innovative knowledge products such as report cards (with inputs from member states). ● Identify and keep track of emerging issues related to nutrient pollution. ● Establish a regional data management and decision support system for nutrient management (building on planned or existing system under other programmes).	2021-2025 2025-2030 2021-2025 2021-2030 2021-2025 2021-2030 2021-2030 2025-2030 2021-2030

	- Engage the regional network of accredited environmental laboratories to support regional monitoring.	2021-2025
	- Assist member states in classifying their marine waters (Class I and Class II) and in determining the eutrophication status of the WCR marine waters.	
NATIONAL LEVEL		
Institutional frameworks and mechanisms	- Designate an appropriate agency or mechanism to coordinate activities for the integrated management of nutrients using a watershed, ridge to reef approach.	2021-2025
	- Support the establishment of or strengthen existing national inter-sectoral or inter-ministerial committees to address nutrient pollution.	2021-2025
	- Review existing institutional framework to identify gaps and weaknesses related to nutrient management.	2021-2025
	- Initiate process of reform and harmonization to ensure an appropriate institutional framework for nutrient management. This should include an intersectoral body, public-private partnerships, etc. and facilitate local/national/regional linkages.	2021-2025
	- For transboundary watersheds and groundwater aquifers, establish and operationalize a framework for cooperation among the concerned states.	2025-2030
Management of transboundary river basins and groundwater aquifers	- Establish or strengthen agreement and mechanism of cooperation for transboundary (shared) river basins and groundwater aquifers.	2025-2030
	- Develop ‘Common River Basin Management Plans’ between the relevant countries.	2025-2030
Stakeholder engagement and communication/ public awareness	- Identify key stakeholders at national and local levels and develop/implement a strategy for stakeholder engagement and awareness campaign on nutrients, linked to regional strategy; elevate the nutrient issue on the national agenda.	2021-2025
	- Enhance mechanisms for communication among relevant sectors and between watershed scientists and policy-makers (consider establishing an intersectoral mechanism that is linked to the sub-regional/regional level).	2021-2025
	- Establish strategic partnerships including public-private partnerships.	2021-2030
Policy, legislation, and regulatory frameworks	- Review policy and legislative frameworks to identify gaps, weaknesses and barriers to effective implementation of the strategy.	2021-2025
	- Accede to and implement the Cartagena Convention and LBS Protocol (as appropriate).	2021-2025
	- Mainstream the RNPRSAP into national planning and development frameworks; initiate process of reform and harmonization to ensure a coherent policy and legislative framework that links downstream water quality with upstream practices in the domestic wastewater, agriculture, and industrial sectors; and promotes compliance with national guidelines, standards and limits.	2021-2030
	- Establish N and P standards and limits for domestic and industrial effluent, and water quality for designated uses.	2025-2030
	- Mainstream nutrient management goals and targets into policy and legislation.	2025-2030
	- Strengthen mechanisms for compensation to affected persons for losses, and for compliance and enforcement.	2025-2030
	- Strengthen implementation of MEAs and other commitments (SDGs) that are relevant to nutrient management.	2021-2030
Characterize and prioritize watersheds	- Identify priority watersheds that individually or collectively account for a substantial portion of nutrient loads (e.g., more than 75%). Criteria to be determined by the countries.	2021-2025

	● Identify major sources of nutrient loads in priority watersheds (e.g., domestic wastewater, agriculture/livestock, industries). ● Collect baseline data in priority watersheds including land use, fertilizer use, nitrogen use efficiency, N and P sources and magnitude, environmental impacts, socio-economics, etc. ● Downscale and validate models: Use best available information to estimate N and P loadings delivered to aquatic systems from each major source/sector in all major watersheds. See GEF GNC Toolbox.	2021-2025 2021-2025 2021-2025
Screen and classify coastal waters	● Determine the eutrophication status of coastal areas. ● Identify coastal nutrient hotspots and associated major sources of excess nutrients. ● Classify receiving waters in accordance with the obligations of the LBS Protocol (Class 1 and Class 2 of equivalent classification system).	2021-2025 2021-2025 2021-2025
Monitoring, data collection, assessment and reporting	● Based on the above screening and classification, develop or strengthen existing monitoring programmes for the different classes and eutrophication status of identified areas. Monitoring should include N, P and Si sources and magnitudes, estimation of ICEP, environmental impacts, socio-economic data, etc. using indicators that are harmonized with regional and global indicators. Monitoring should include citizen science, and traditional and modern approaches. ● Develop national data management system linked to a regional data management system. ● Develop or strengthen mechanism for periodic assessment and reporting and informing adaptive management, policy responses and decision-making. This should include preparation of knowledge products such as report cards.	2025-2030 2025-2030 2025-2030
Capacity building	● Assess capacity gaps at local and national levels and across all relevant disciplines. ● Develop and implement capacity building programmes to address identified gaps, including technical assistance for farmers and agricultural extension officers and those involved in the health, water and wastewater sectors, and estimation of ICEP. ● Identify opportunities for learning and sharing of experiences with other countries. ● Promote use of available resources (GEF-GNC Global Nutrient Management Toolbox, UNEP-CEP technical reports on best management practices for wastewater and erosion, US nutrient reduction strategies and action plans- Gulf of Mexico states)	2021-2025 2021-2025 2021-2030 2021-2030
Incentive programmes	Develop incentive programmes for farmers and other sectors (to promote nutrient management, wastewater treatment and treated wastewater reuse). This should include assessing economic policy instruments for financial incentives and identifying opportunities for recovery and reuse of nutrients, increasing production and income generation for farmers (e.g., from cover crops), payment to farmers and landowners for ecosystem services.	2025-2030
Financial resources	Develop a sustainable financing plan and identify funding sources and opportunities (Public sector financing, private sector investment, development banks, international donors and mechanisms including GEF Small Grants Programme, trust funds, PES, fiscal measures such taxes, market-based financing mechanisms, etc.) for implementation of nutrient management programme (see below).	2025-2030

Scientific research	● Identify policy-relevant research priorities and facilitate the conduct of research including through partnerships with academic institutions and creation of opportunities for scientists. See the CLME+ Pollution Research Agenda. ● Strengthen the science-policy interface to facilitate uptake of science in policy setting.	2021-2025 2021-2030
Nutrient reduction targets and allocation of allowable pollution loads	● Establish quantitative nutrient reduction targets by source in each priority watershed in accordance with waterbody designated uses and to protect/ improve ecosystem services. ● Estimate current nitrogen use efficiency (NUE) and determine required reduction to achieve NUE targets. ● Identify and evaluate management practices (see the BPM Compendium and the GNC database) to achieve the reduction targets and loads. ● Allocate the allowable pollution loads to the various sources.	2025-2030 2021-2025 2021-2025 2025-2030
National nutrient pollution reduction strategy and national/watershed action plans	• In consultation with all key stakeholders and based on the RNPRSAP, develop a national nutrient pollution reduction strategy and action plan(s) for priority watersheds to achieve the reduction targets as well as other targets identified, appropriate mix of BMPs*, cost-benefit analysis of BMPs based on the local context, financial mechanism and incentives, M&E plan, strategy for dissemination of lessons, replication and upscaling, etc. National strategy and action plan should be aligned with national 2030 Sustainable Development Agendas and incorporate consideration of climate change impacts on sediment and nutrient mobilization, and crop production. • Implementation of the programme could be incremental, starting with the highest priority watershed(s) and hotspots. As far as possible, implementation should be coordinated with that of the Regional Habitats Strategy to multiply benefits. The appropriate mix of experts across various disciplines (including economists, agronomists, environmental specialists, etc.) will be necessary in developing and implementing the programme. *Innovative and market-based management practices should be identified. A range of practices beyond the traditional point and nonpoint source management practices can be used to reduce nutrient loads. These include programmes for engaging industries, businesses, and agricultural enterprises for voluntary pollution prevention; regulations for emission of nitrogen gases; basin or watershed-based nutrient trading programmes; and water and input management practices.	2021-2030 2021-2030 2021-2030
Implement watershed action plan(s)	Implement action plan(s) for priority watershed(s)	2025 -2030
Port reception facilities	Establish/improve port reception and treatment facilities for wastewater from ships.	2025 -2030
Monitoring and adaptive management	● At regular intervals, monitor and evaluate progress towards achievement of targets using established indicators (process, stress reduction, socio-economic and environmental state indicators) and impacts of the implemented solutions. This will include reporting every two years by Member States to the LBS Protocol Conference of Parties. ● Adapt management actions based on results and incorporating any new scientific data and information, and emerging issues. ● Document and communicate results and lessons.	2030 and beyond

5.8 RECOMMENDATIONS/ NEXT STEPS FOR ROLLING OUT THE RNPRSAP

Recommendations for addressing nutrient pollution are given throughout the preceding chapters, particularly chapter 5. The following recommendations/next steps address preparations for the roll out of the RNPRSAP, and include:

1. Preparation of a plan by UNEP CEP for (incrementally) rolling out the strategy, in collaboration with Member States, LBS RACs, and sub-regional bodies (CARICOM, SICA/CCAD, OECS, and ACTO). This should include assigning the LBS Monitoring and Assessment Working Group (or a new or sub-group on nutrients- see below) to address some key tasks for facilitating implementation of the Strategy;
2. Establishment of a regional, multi-disciplinary advisory group (including relevant technical experts) focusing on nutrient pollution, possibly under the LBS Working Group (terms of reference and membership/technical expertise to be identified by UNEP CEP and the LBS Working Group and approved by the STAC/COP);
3. Facilitate sharing of experiences among Parties of the Convention, e.g., USA on nutrient pollution action plans for the Gulf of Mexico; and Colombia/INVEMAR on coastal monitoring; and with other Regional Seas Programmes including work done under the European Water Framework Directive for setting ecological objectives;
4. Full integration of the RNPRSAP into the UNEP CEP Strategy and identification of synergies with other relevant strategies and frameworks including the Regional Habitats Strategy and the UNEP CEP Regional Integrated Water Resource Management Framework, and modalities for their implementation using a more programmatic and less project-focused approach.
5. Prioritization of needs and actions at the national, sub-regional, and regional levels to accelerate implementation of the strategy and finalization of the timeframe for actions (adapt the 2030 timeframe as necessary) including addressing data and capacity gaps and adapting the targets and indicators according to the existing context in the countries;
6. Strengthening of efforts to operationalize the GPNM-Caribbean;
7. Identification of sites (nutrient pollution hotspots) and opportunities to develop and execute pilot projects on implementation of the strategy, for example, through ongoing and planned projects such as IWEco, CReW+, and the ACP MEA initiative (and potentially Procaribe, the follow-up to the CLME+ Project). This should consider the pollution reduction and habitat restoration investment plans developed by the Secretariat with support of the CLME+ project.
8. Mainstreaming of the RNPRSAP into countries' national planning and development frameworks and preparation by countries of National Action Plans for Nutrient Pollution Reduction, based on the RNPRSAP and in alignment with their national 2030 Sustainable Development Agendas;
9. Estimation of the cost of implementing elements of the strategy and identification of funding opportunities for implementation including though the private sector in particular the tourism and agricultural sectors, and development banks;
10. Identification of opportunities through the Decade of Ocean Science and UN Decade on Ecosystem Restoration to establish/strengthen enabling conditions (strengthen capacity, fill data/ knowledge gaps, etc.);
11. Consider the development of a communication strategy for the RNPRSAP and utilize existing platforms for communication;
12. Promotion of the RNPRSAP through advocacy and stakeholder engagement (including private sector, civil society, and sub-regional and regional partners) to obtain buy-in and facilitate collaboration as well as uptake and effective implementation of the strategy.

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ANNEXES

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Annex 1.1. Main international frameworks and resolutions related to pollution

- Cartagena Convention and its LBS and Oil Spill 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 re-use 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 re-use.
- 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.
- The second session of the UN Environment Assembly (UNEA2) Resolution 2/12 in 2016 on sustainable coral reefs management, which calls on countries to, among others, undertake the priority actions to achieve Aichi Target 10 in CBD decision XII/23. This includes implementation of *watershed management policies encompassing reforestation; erosion control; runoff reduction; sustainable agriculture and mining; reduction of pesticides, herbicides, fertilizer and other agrochemical use; and wastewater management and treatment.*
- The UNEA3 Resolution on water pollution to protect and restore water-related ecosystems EA.3/L.27, invites Member States, in collaboration with relevant stakeholders, private sector, industry, academia, civil society, and the Global Programme of Action, including through encouraging platforms for wastewater and management of nutrients, to *help prevent and mitigate water pollution and to protect and restore water-related ecosystems in order to minimize adverse impacts on human health and the environment.*
- The UNEA4 Resolution on protection of the environment from land-based activities EA.4/11 calls for mainstreaming the protection of coastal and marine ecosystems in policies, particularly those addressing environmental threats caused by marine litter, nutrients, and wastewater.
- Our Ocean, Our Future: *Call for Action,* which emerged from the United Nations Conference to Support the Implementation of SDG 14, held in New York in June 2017, called on stakeholders to *take urgent actions to develop and implement effective adaptation and mitigation measures that will enhance resilience of ecosystems including coral reefs to effects of climate change, and accelerate actions to prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities.*

Annex 2.1 Land use and cover in the Wider Caribbean Region

A. Agricultural land use and forest land (10^3 ha) in WCR Sub-regions I and III , 1990 to 2018 (every 5th year).

B. Agricultural land use and forest land (10^3 ha) in WCR Sub-region II,1990 to 2018 (every 5th year).

Graphs showing cropland, pastures and forest land every 5th year (input data: FAOSTAT). Panel A tracks land use in continental countries of WCR Sub-regions I and III; Panel B, land use in Sub-region II; and Panels C and D, land use in island states and territories of Sub-regions IV and V. Country names are in the UN 3-letter iso-code format: Sub-region I: MEX (Mexico), USA (United States of America), Sub-region III: BRA (Brazil), COL (Colombia), GUY (Guyana), SUR (Suriname), GUY (French Guiana), VEN (Venezuela); Sub-region II: BLZ (Belize), CRI (Costa Rica), GTM (Guatemala), HND (Honduras), NIC (Nicaragua), PAN (Panama); Sub-region IV: ATG (Antigua and Barbuda), BRB (Barbados), DMA (Dominica), GRD (Grenada), GLP (Guadeloupe), MSR (Monserrat), MTQ (Martinique), KNA (Saint Kitts and Nevis), LCA (Saint Lucia), SVG (Saint Vincent and the Grenadines), TTO (Trinidad and Tobago),VGB (British Virgin Islands), VIR (U.S. Virgin Islands); Sub-region V: BHS (The Bahamas), CUB (Cuba), DOM (Dominican Republic), HTI (Haiti), JAM (Jamaica), PRI (Puerto Rico).

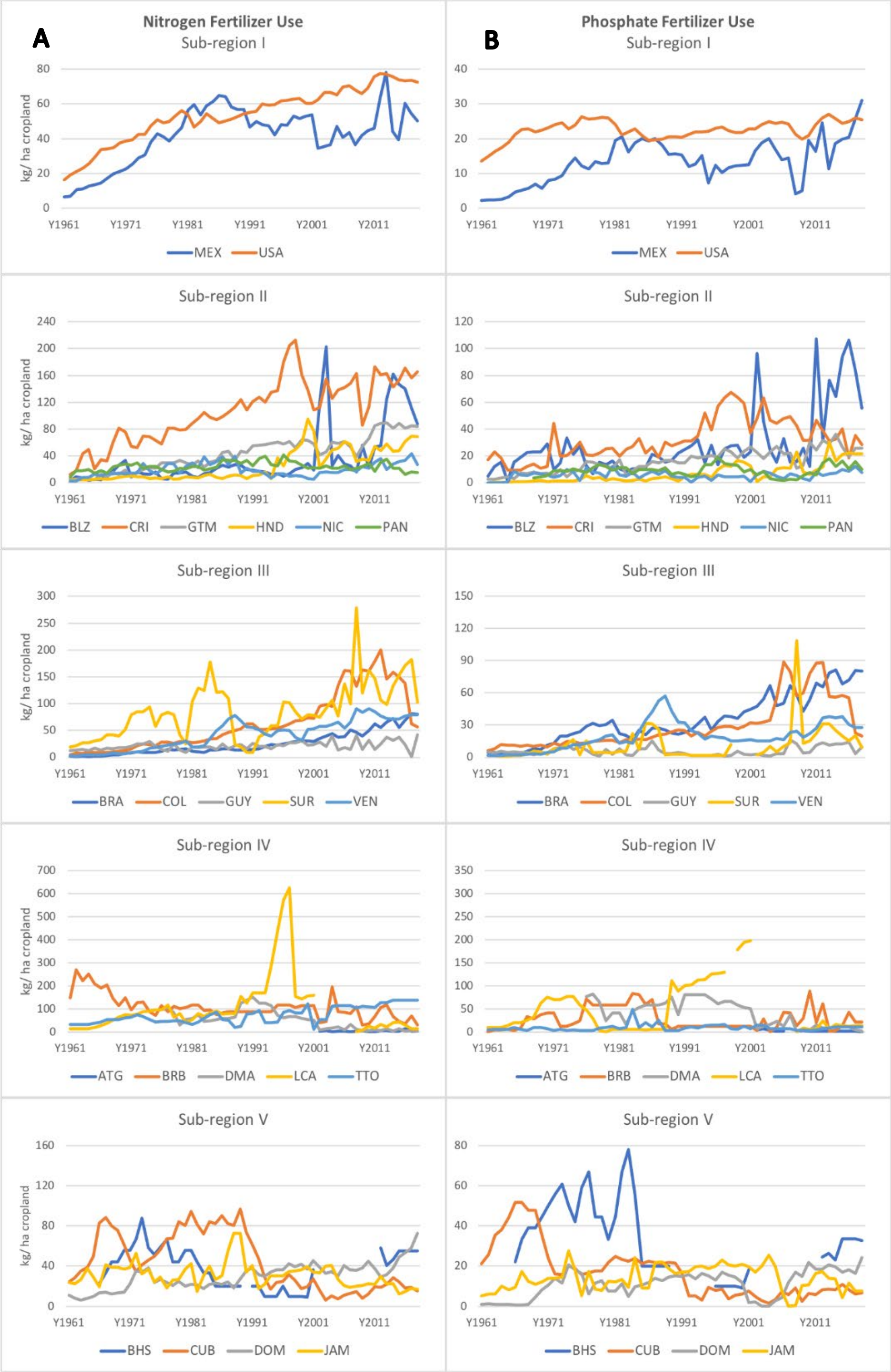
C. Agricultural land use and forest land (10^3 ha) in WCR Sub-region IV, 1990 to 2018, (every 5th year).

Country names are in the UN 3-letter iso-code format: Sub-region I: MEX (Mexico), USA (United States of America), Sub-region III: BRA (Brazil), COL (Colombia), GUY (Guyana), SUR (Suriname), GUY (French Guiana), VEN (Venezuela); Sub-region II: BLZ (Belize), CRI (Costa Rica), GTM (Guatemala), HND (Honduras), NIC (Nicaragua), PAN (Panama); Sub-region IV: ATG (Antigua and Barbuda), BRB (Barbados), DMA (Dominica), GRD (Grenada), GLP (Guadeloupe), MSR (Monserrat), MTQ (Martinique), KNA (Saint Kitts and Nevis), LCA (Saint Lucia), SVG (Saint Vincent and the Grenadines), TTO (Trinidad and Tobago),VGB (British Virgin Islands), VIR (U.S. Virgin Islands); Sub-region V: BHS (The Bahamas), CUB (Cuba), DOM (Dominican Republic), HTI (Haiti), JAM (Jamaica), PRI (Puerto Rico).

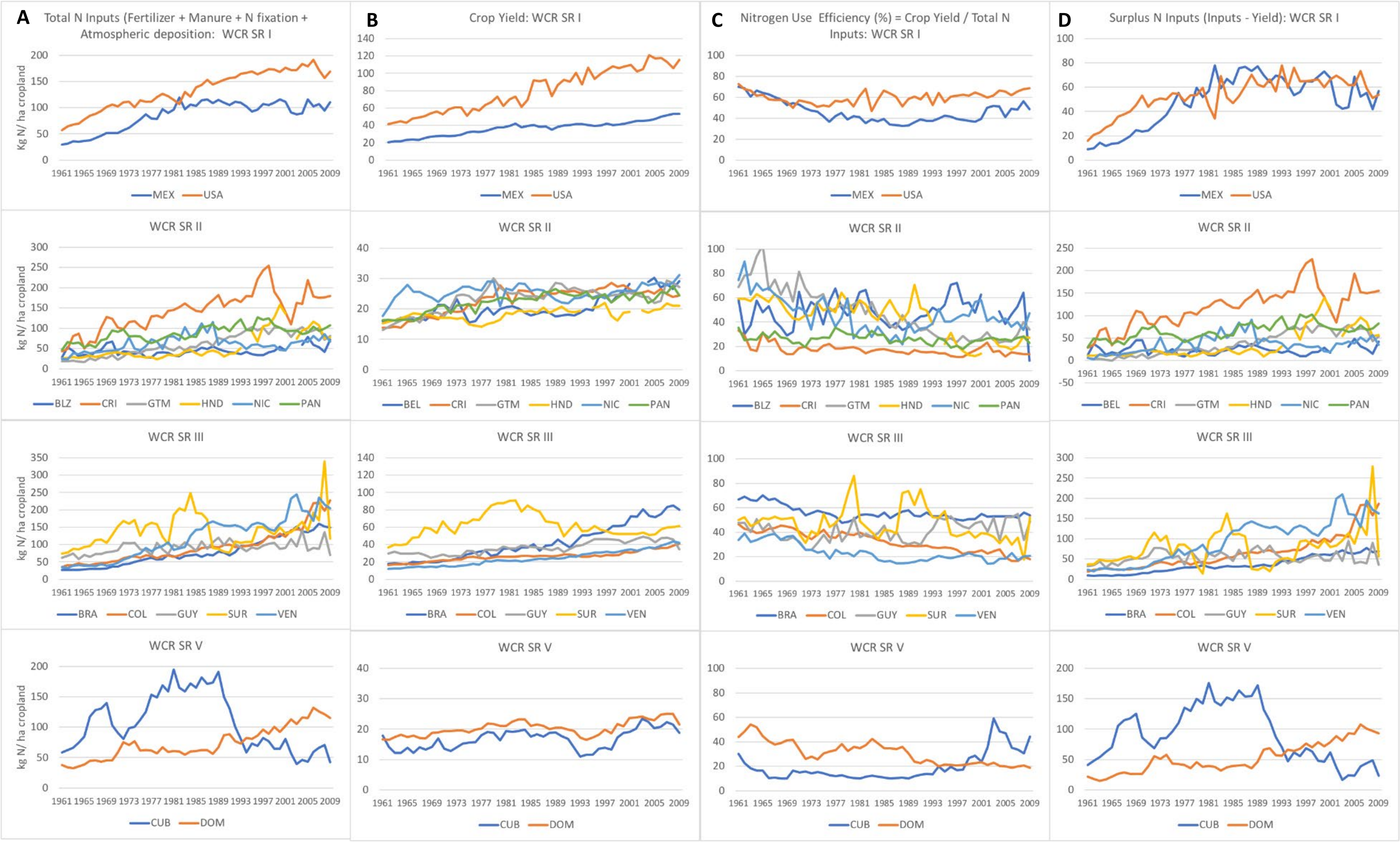
D. Agricultural land use and forest land (10^3 ha) in WCR Sub-region V, 1990 to 2018 (every 5th year).

Country names are in the UN 3-letter iso-code format: Sub-region V: BHS (The Bahamas), CUB (Cuba), DOM (Dominican Republic), HTI (Haiti), JAM (Jamaica), PRI (Puerto Rico).

Annex 2.2. Synthetic fertilizer application rates in the Wider Caribbean Region.



Annex 2.2. Nitrogen (N) (Panel A) and Phosphate (P) (Panel B) fertilizer application per ha cropland in WCR sub-regions (SR) I to V for the period 1961 to 2018 (input data from FAOSTAT). While variable across countries and time, continental countries show an increasing trend in fertilizer application. Among island states and territories, patterns are highly variable. In the case of island states of Sub-region IV, applications rates for both N and P fertilizers exceeded those of continental states.



Annex 2.3 Analysis of Nitrogen Use Efficiency , 1961 to 2009 in the (input data from Luis Lassaletta et al. 2014). Panel A: Total N inputs to croplands which includes fertilizer, manure, N_2 fixation and atmospheric N deposition. Crop yield (Panel B) is the production of crops in response to these N inputs, expressed in terms of kg N incorporated as plant biomass per ha cropland. Nitrogen use efficiency (Panel C) is Crop Yield divided by N inputs, and is expressed as a percentage. Surplus N (Panel D) is the difference between Inputs and Crop Yield, and represents excess nitrogen. Country names use ISO CODE abbreviations.

Annex 2.4. Total P runoff computed based on Phosphorus Use Efficiency (PUE) and Surplus Cropland N for Model year 2000 scaled to agricultural land in WCR draining watersheds. (Input data: Lassaletta et al 2014, Lun et al. 2018).

Model year 2000	Country/Territory Iso-Code	Cropland, km2	Pastures, km2	Cropland P runoff, tons	Pasture P runoff, tons	Total P runoff, 10^3 tons	Cropland Surplus N, 10^3 tons
Mexico	MEX	224,409	367,115	53,414.62	13,933.37	67.3	1,638
United States of America	USA	1,409,823	1,373,055	419,869.66	21,858.32	447	8,340
Sub-region I		**1,634,232**	**1,740,170**	**473,284.28**	**35,791.69**	**514**	**9,978**
Belize	BLZ	1,218	554	315.23	7.52	0.3	3
Costa Rica	CRI	1,352	10,050	506.49	580.77	1.1	19
Guatemala	GTM	11,834	20,095	3,011.73	1,469.34	4.5	91
Honduras	HND	10,471	10,788	1,841.69	571.04	2.4	146
Nicaragua	NIC	21,080	49,600	3,101.78	3,136.22	6.2	42
Panama	PAN	512	4,443	96.48	265.67	0.4	4
Sub-region II		**46,466**	**95,529**	**8,873**	**6,031**	**15**	**305**
Brazil	BRA	67,858	510,668	25,357.64	28,141.87	53.5	413
Amazon basins in non- WCR countries[1]	Combined	51,655	333,868	10.19	10.40	20.59	264
Colombia	COL	25,991	207,992	10,901.18	9,769.88	20.7	261
French Guiana	GUF	93	47	9.03	0.05	0.0	No data
Guyana	GUY	5,120	12,505	1,101.90	60.26	1.2	24
Suriname	SUR	641	215	190.04	0.51	0.2	6
Venezuela	VEN	34,392	192,707	12,370.98	7,058.84	19.4	436
Aruba	ABW	2	26	0.15	0.00	0.0	No data
Sub-region III		**185,751**	**1,258,028**	**49,941**	**45,042**	**116**	**1,405**

[1] These include Bolivia, Ecuador and Peru. Land use areas and nutrient flows from agriculture and domestic sewage from these Amazon River watersheds even if they are located outside of the delineated WCR region.

Annex 2.4 (continued)

Model year 2000	Country/Territory Iso-Code	Cropland, km2	Pastures, km2	Cropland P runoff, tons	Pasture P runoff, tons	Total P runoff, 10^3 tons	Cropland Surplus N, 10^3 tons
Anguilla	AIA	10	118	2.68	26.98	0.0	No data
Antigua and Barbuda	ATG	37	9	13.91	21.18	0.0	No data
Barbados	BRB	9	107	22.73	6.66	0.0	No data
British Virgin Islands	VGB	24	8	2.54	15.08	0.0	No data
Dominica	DMA	75	14	4.94	10.75	0.0	No data
Grenada	GRD	37	386	3.24	77.58	0.1	No data
Guadeloupe	GLP	37	12	2.85	28.24	0.0	No data
Martinique	MTQ	2	26	0.72	10.64	0.0	No data
Montserrat	MSR	6	69	1.57	6.81	0.0	No data
Saint Kitts and Nevis	KNA	20	7	3.28	20.75	0.0	No data
Saint Lucia	LCA	16	5	0.90	12.14	0.0	No data
Saint Vincent and the Grenadines	SVG	1,416	131	1,050.56	14.10	1.1	No data
Trinidad and Tobago	TTO	861	3,331	394.46	92.31	0.5	No data
Sub-region IV		**2,549**	**4,223**	**1,504**	**343**	**2**	**No data**

Annex 2.4 (continued)

Model year 2000	Country/Territory Iso-Code	Cropland, km2	Pastures, km2	Cropland P runoff, tons	Pasture P runoff, tons	Total P runoff, 10^3 tons	Cropland Surplus N, 10^3 tons
Bahamas	BHS	43	42	22.58	0.70	0.0	No data
Cayman Islands	CYM	44,584	28,003	6,245.75	2,852.98	9.1	No data
Cuba	CUB	16,166	20,873	4,873.60	3,295.06	8.2	206
Dominican Republic	DOM	11,705	5,208	840.19	767.42	1.6	115
Haiti	HTI	2,931	2,374	821.01	313.91	1.1	No data
Jamaica	JAM	894	1,815	369.38	167.60	0.5	No data
Puerto Rico	PRI	109	421	0.39	0.00	0.0	No data
Turks and Caicos Islands	TCA	0	100	2.68	0.00	0.0	No data
Sub-region V		**76,431**	**58,836**	**13,176**	**7,398**	**21**	**321**

Annex 2.5. Assessment of industrial point sources of pollution by country (CEP 2010).

Countries and territories	**Industrial pollutant load discharged in WCR (t / yr)**				
	BOD	**COD**	**TSS**	**TN**	**TP**
United States of America	112,600	198,410	295,340	6,060	974
Mexico	83,649	175,662	209, 122	7,350	1,470
Sub-region I	**196,249**	**374,072**	**504,462**	**13,410**	**2,444**
Belize	870	1, 827	218	290	80
Guatemala	7,362	15, 460	2, 408	24	5
Honduras	410	856	100	115	70
Nicaragua	312	733	39	78	36
Costa Rica	801	2 ,034	1, 305	135	62
Panama	199	897	1, 913	17	10
Sub-region II	**9, 954**	**21,807**	**5,983**	**659**	**263**
Colombia	4, 000	6, 000	80, 000	1, 000	100
Venezuela	28, 559	59, 974	6 ,155	9, 605	475
Guyana	87	183	26	8	5
French Guiana	51	214	28	10	6
Suriname	102	214	28	10	6
Aruba	NA	0	0	0	0
Netherlands Antilles	1, 489	3, 127	438	145	88
Sub-region III	**34,288**	**69,498**	**86,647**	**10,768**	**674**

Annex 2.5 (continued)

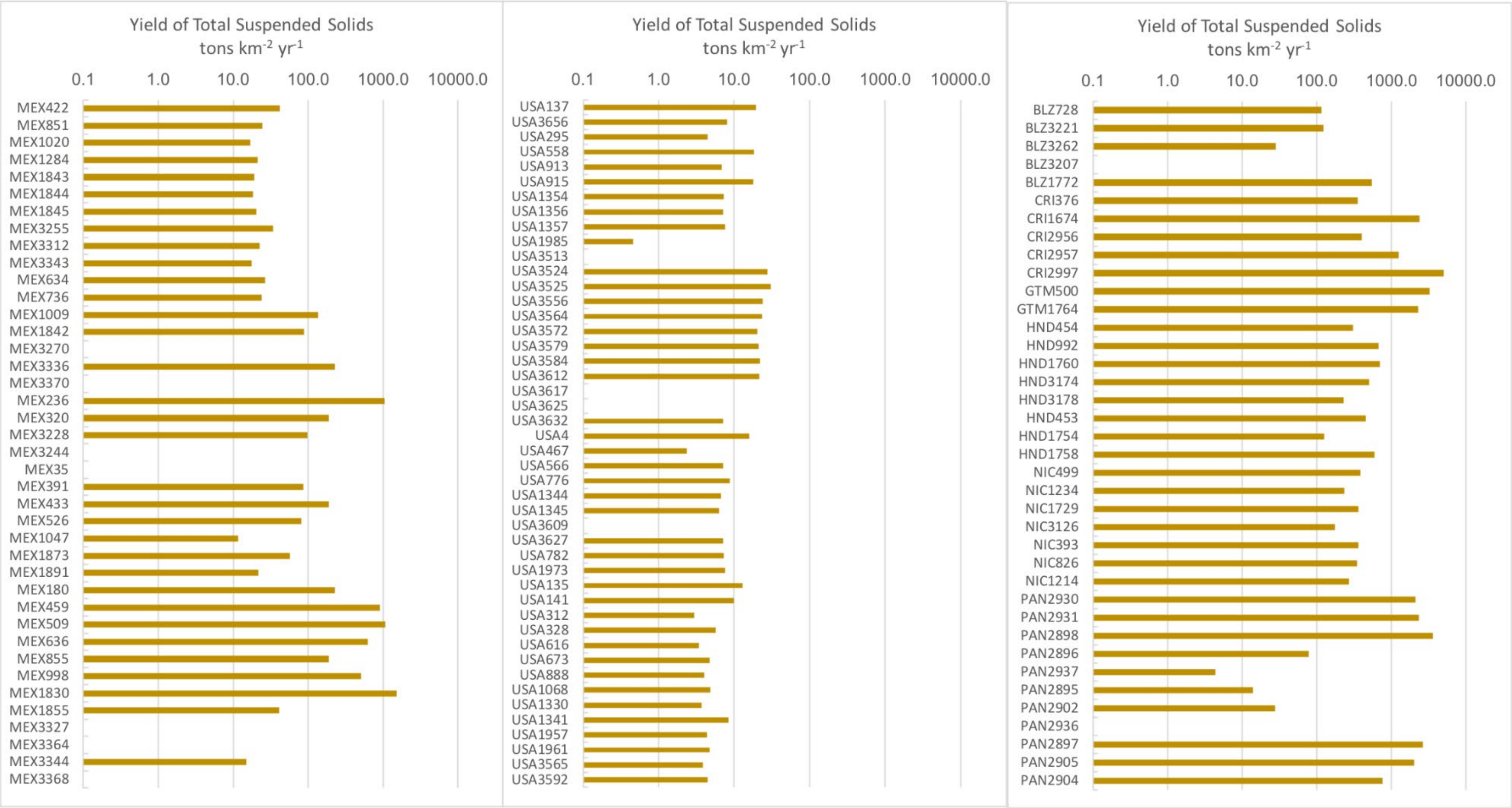
Countries and territories	Industrial pollutant load discharged in WCR (t / yr)				
	BOD	COD	TSS	TN	TP
Anguilla	NA	0	0	0	0
Antigua and Barbuda	45	95	9	4	2
Barbados	1, 650	4, 116	15	58	7
British Virgin Islands	5	11	2	1	1
Dominica	636	1, 336	120	24	18
Grenada	365	767	185	21	17
Guadeloupe	538	1, 026	123	32	18
Martinique	734	2, 378	770	NA	NA
Montserrat	NA	0	0	0	0
St. Lucia	190	399	895	38	34
St. Martin	NA	0	0	0	0
St. Bartholomi	NA	0	0	0	0
St. Kitts and Nevis	183	384	100	8	5
US Virgin Islands	44	2, 331	800	6	2
Trinidad & Tobago	192, 337	340, 336	39, 138	1, 125	523
S.V. and the Grenadines	335	704	225	9	4
Sub-region IV	**197,062**	**353, 883**	**42,382**	**1,326**	**631**
Bahamas	NA	0	0	0	0
Cayman Islands	NA	0	0	0	0
Cuba	44, 340	93, 083	NA	1, 697	1, 194
Dominican Republic	587	1, 190	69	32	14
Haiti	521	1, 051	58	27	12
Puerto Rico	1, 491	3, 131	5, 610	1	5
Jamaica	5, 178	10, 873	2, 788	158	62
Turks and Caicos Islands	NA	0	0	0	0
Sub-region V	**52, 117**	**109, 328**	**8,525**	**1, 915**	**1,287**
Total	**489,000**	**928,000**	**648,000**	**28,000**	**5,000**

Annex 2.6 Ammonia hotspots in the WCR (data from Van Damme et al. 2018).

LAT	LON	NAME	STATE	COUNTRY	SOURCE	IASI (kg/s)	EDGAR IND (kg/s)	EDGAR AGR (kg/s)	AREA (km²)	IASI (kg/ha/yr)
7.05	-73.12	Santander Dept - Bucaramanga		Colombia	Agriculture	5.55E-02	1.17E-02	1.51E-02	4.42E+03	3.96E+00
20.78	-102.9	Acatic		Mexico	Agriculture	2.75E-02	0.00E+00	1.40E-02	1.04E+03	8.34E+00
22.02	-102.31	Aguascalientes		Mexico	Agriculture	1.04E-01	6.35E-05	3.59E-02	4.13E+03	7.95E+00
28.2	-105.42	Delicias		Mexico	Agriculture	6.21E-02	1.14E-03	1.25E-02	6.97E+03	2.81E+00
20.68	-99.91	Ezequiel Montes		Mexico	Agriculture	1.70E-01	2.15E-05	8.14E-02	1.16E+04	4.63E+00
21.26	-102.38	Jalostotitlan - San Juan de Los Lagos		Mexico	Agriculture	2.80E-01	3.86E-07	7.70E-02	7.37E+03	1.20E+01
32.46	-116.7	La Presa		Mexico	Agriculture	3.90E-02	2.44E-04	9.49E-03	3.76E+03	3.27E+00
18.44	-97.33	Tehuacan		Mexico	Agriculture	8.89E-02	5.74E-05	2.80E-02	4.22E+03	6.64E+00
18.84	-97.8	Tochtepec		Mexico	Agriculture	5.31E-02	1.15E-06	2.50E-02	2.93E+03	5.72E+00
25.69	-103.51	Torreon		Mexico	Agriculture	4.71E-01	2.38E-04	7.80E-02	1.11E+04	1.33E+01
20.26	-102.45	Vista Hermosa de Negrete - Los Charcos		Mexico	Agriculture	5.44E-02	0.00E+00	3.35E-02	2.90E+03	5.92E+00
32.9	-112	Stanfield	AZ	USA	Agriculture	1.38E-01	9.80E-11	8.67E-03	6.64E+03	6.55E+00
32.67	-114.07	Wellton	AZ	USA	Agriculture	4.50E-02	1.67E-10	1.99E-03	5.10E+03	2.78E+00
40.14	-102.57	Eckley - Yuma	CO	USA	Agriculture	7.70E-02	2.01E-11	1.26E-02	4.63E+03	5.24E+00
40.38	-104.55	Greeley	CO	USA	Agriculture	1.93E-01	4.36E-04	3.01E-02	9.42E+03	6.46E+00
34.29	-83.11	Royston	GA	USA	Agriculture	7.04E-02	1.59E-06	1.75E-01	6.54E+03	3.40E+00
43.15	-96.3	Sioux	IA	USA	Agriculture	1.29E-01	9.79E-07	1.16E-01	9.02E+03	4.51E+00
42.75	-114.57	Jerome - Wendell	ID	USA	Agriculture	1.40E-01	6.91E-06	3.80E-02	5.81E+03	7.60E+00
42.3	-113.92	Oakley	ID	USA	Agriculture	1.12E-01	8.06E-11	7.98E-03	3.29E+03	1.07E+01

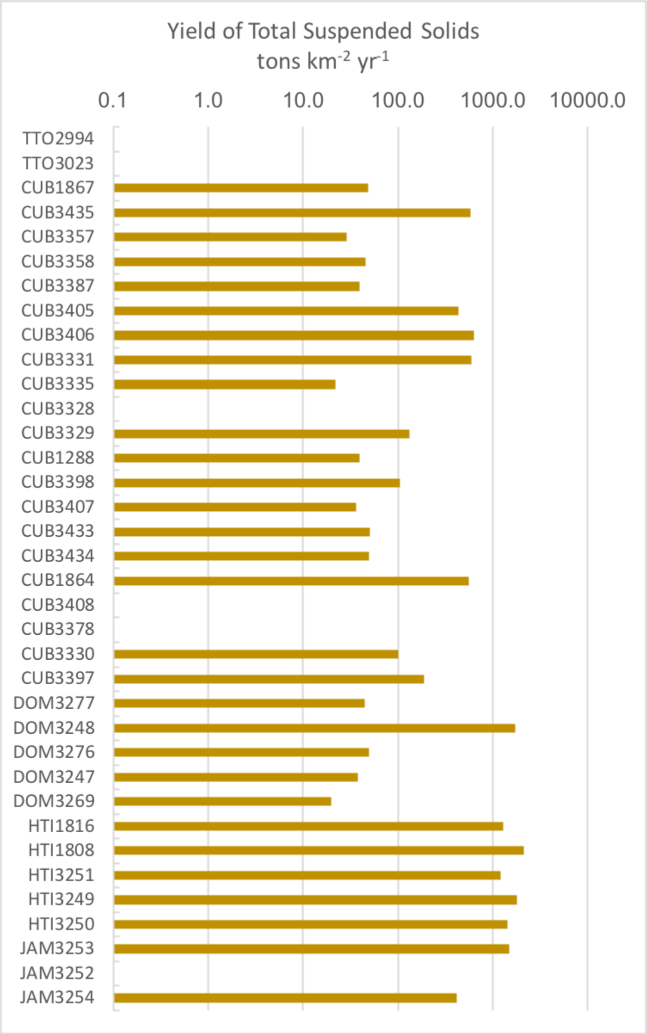
LAT	LON	NAME	STATE	COUNTRY	SOURCE	IASI (kg/s)	EDGAR IND (kg/s)	EDGAR AGR (kg/s)	AREA (km²)	IASI (kg/ha/yr)
37.81	-100.84	Garden City	KS	USA	Agriculture	1.04E-01	3.35E-04	3.15E-02	6.25E+03	5.25E+00
41.37	-99.63	Broken Bow	NE	USA	Agriculture	3.35E-02	9.60E-09	9.63E-03	3.34E+03	3.16E+00
41.97	-96.93	Wisner	NE	USA	Agriculture	8.41E-02	1.13E-06	3.79E-02	5.88E+03	4.51E+00
33.29	-104.43	Dexter - Rosswell	NM	USA	Agriculture	1.21E-01	4.57E-05	1.65E-02	1.03E+04	3.69E+00
32.59	-107.28	Hatch	NM	USA	Agriculture	4.16E-02	6.43E-11	8.00E-03	6.67E+03	1.97E+00
32.12	-106.63	Vado	NM	USA	Agriculture	4.17E-02	4.90E-05	1.06E-02	6.70E+03	1.96E+00
39.4	-118.76	Fallon	NV	USA	Agriculture	2.84E-02	1.37E-05	7.42E-03	6.11E+03	1.46E+00
34.81	-102.38	Hereford	TX	USA	Agriculture	2.36E-01	5.63E-06	3.60E-02	6.50E+03	1.15E+01
39.37	-112.51	Delta	UT	USA	Agriculture	3.63E-02	1.56E-05	5.35E-03	6.12E+03	1.87E+00
38.23	-113.14	Milford	UT	USA	Agriculture	4.74E-02	9.64E-10	7.84E-03	6.22E+03	2.40E+00
10.05	-68.09	Tocuyito - Barrerita		Venezuela	Agriculture	7.31E-02	4.57E-03	4.39E-02	4.38E+03	5.26E+00
10.32	-75.52	Cartagena - Mamonal		Colombia	Fertilizer Plant	1.35E-01	7.85E-03	6.51E-03	4.38E+03	9.72E+00
20.53	-101.11	Salamanca - Villagran		Mexico	Fertilizer Plant	1.71E-01	5.62E-03	5.26E-02	1.16E+04	4.66E+00
10.43	-61.52	Point Lisas		Trinidad and Tobago	Fertilizer Plant	3.20E-02	4.64E-03	8.00E-04	3.04E+03	3.32E+00
30.05	-90.98	Donaldsonville	LA	USA	Fertilizer Plant	4.87E-02	1.66E-03	2.70E-03	3.85E+03	3.99E+00
47.31	-101.79	Beulah	ND	USA	Fertilizer Plant	2.90E-02	1.12E-03	5.29E-03	3.02E+03	3.03E+00
33.43	-81.9	Beech Island	SC	USA	Fertilizer Plant	3.79E-02	4.39E-03	9.42E-03	5.06E+03	2.36E+00
10.09	-64.86	El Jose		Venezuela	Fertilizer Plant	1.03E-01	2.74E-04	2.20E-03	5.96E+03	5.45E+00
10.5	-68.2	Moron		Venezuela	Fertilizer Plant	4.50E-02	5.37E-03	1.14E-02	3.04E+03	4.67E+00

LAT	LON	NAME	STATE	COUNTRY	SOURCE	IASI (kg/s)	EDGAR IND (kg/s)	EDGAR AGR (kg/s)	AREA (km²)	IASI (kg/ha/yr)
19.42	-99.05	Mexico City		Mexico	Non-determined	2.02E-01	1.94E-02	1.98E-02	1.17E+04	5.46E+00
20.62	-74.92	Moa		Cuba	Open pit Industrial	8.08E-02	4.17E-04	3.26E-03	7.41E+03	3.44E+00
20.68	-75.6	Nicaro		Cuba	Open pit Industrial	5.16E-02	4.88E-03	9.02E-03	4.16E+03	3.91E+00
25.75	-100.56	Garcia		Mexico	Open pit Industrial	7.43E-02	1.75E-03	3.40E-02	7.13E+03	3.29E+00
26.88	-101.43	Monclova		Mexico	Open pit Industrial	2.27E-02	1.59E-05	3.66E-03	2.76E+03	2.60E+00
LAT	LON	NAME	STATE	COUNTRY	SOURCE	IASI (kg/s)	EDGAR IND (kg/s)	EDGAR AGR (kg/s)	AREA (km²)	IASI (kg/ha/yr)



Annex 2.7. Yields of Total Suspended Solids by catchment in tons km^{-2} yr^{-1}. *Horizontal axis is logarithmic; values below 0.1 are not shown. Basin name consists of Country ISO Code followed by Global NEWS Model Basin number. {Note: Reconciliation of Basin numbers with river names will be done in a future update].Country codes: MEX Mexico, USA USA, BLZ Belize, CRI Costa Rica, GTM Guatemala, HND Honduras, NIC Nicaragua, PAN Panama.*

Annex 2.7, continued. *Yields of Total Suspended Solids by catchment in tons km^{-2} yr^{-1}. Horizontal axis is logarithmic; values below 0.1 are not shown. Basin name consists of Country ISO Code followed by Global NEWS Model Basin number. {Note: Reconciliation of Basin numbers with river names will be done in a future update].Country codes: COL Colombia, GUF French Guiana, GUY Guyana, SUR Suriname, VEN Venezuela, BRA Brazil.*



Annex 2.7, *continued. Yields of Total Suspended Solids by catchment in tons km^{-2} yr^{-1}. Horizontal axis is logarithmic; values below 0.1 are not shown. Basin name consists of Country ISO Code followed by Global NEWS Model Basin number. [Note: Reconciliation of Basin numbers with river names will be done in a future update].Watersheds of small islands were not resolved by the model at a spatial resolution of 0.5° X 0.5°. Country codes: TTO Trinidad and Tobago, CUB Cuba, DOM Dominican Republic, HTI Haiti, JAM Jamaica.*

ANNEX 3.1 WATERSHEDS OF THE WIDER CARIBBEAN REGION

Data source: HydroBasins
https://www.hydrosheds.org/page/hydroatlas

Linke, S. et al. 2019. Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. Doi: 10.1038/s41597-019-0300-6, https://www.nature.com/articles/s41597-019-0300-6

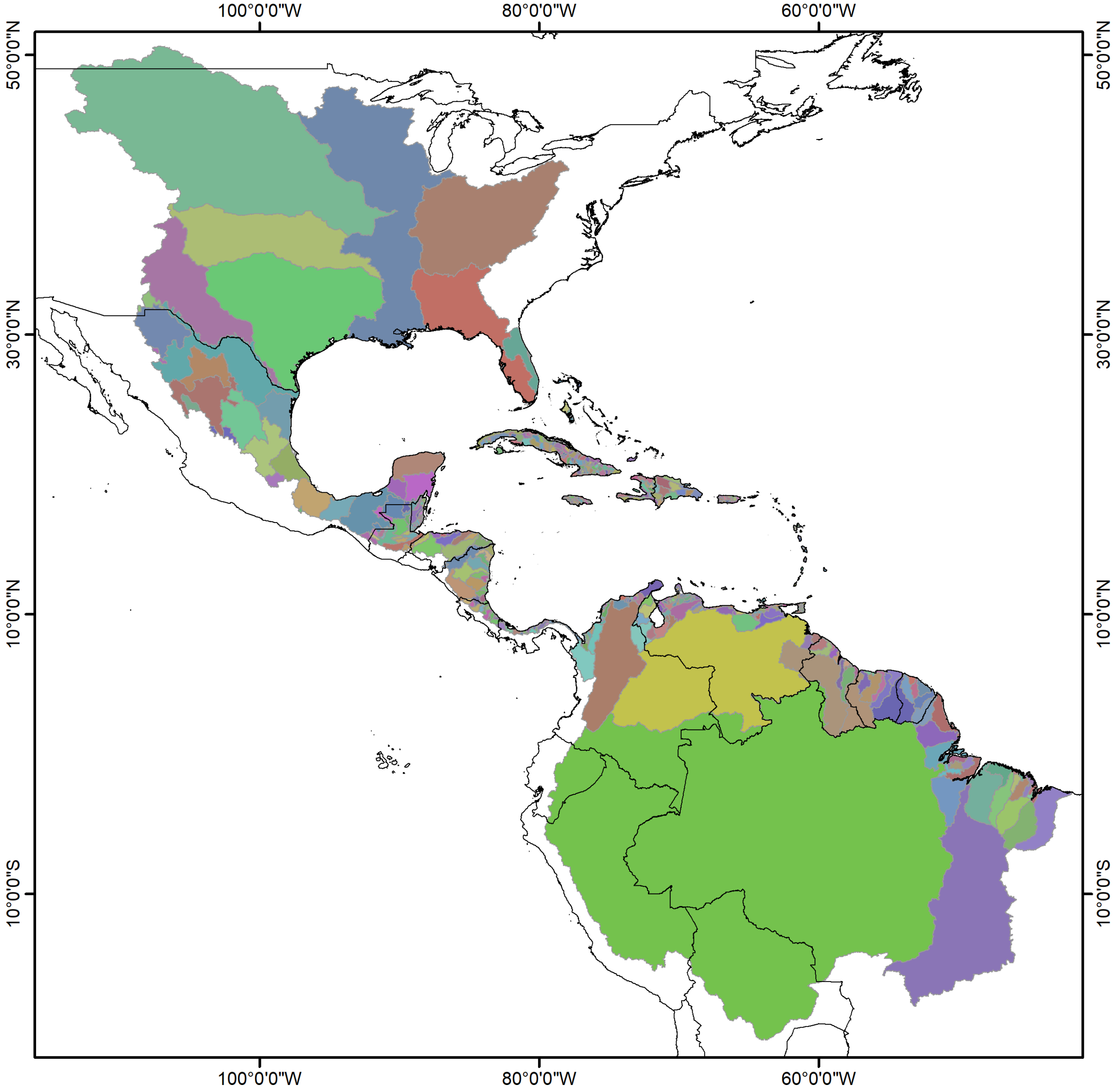
This annex was prepared in collaboration with Mr. Hamish Asmath of the Trinidad and Tobago Institute of Marine Affairs Geomatics Unit.

The aim is to provide a preliminary mapping of watersheds draining into the Wider Caribbean Region, including those that drain to the North Brazil Shelf Large Marine Ecosystem. Ultimately, the watershed maps should be linked with modeled watershed data including nutrient loads, which are critical in updating nutrient pollution reduction strategies at multiple scales of implementation. Most importantly, the mapping aims to facilitate watershed-scale empirical and modeling studies that can help in reducing nutrient pollution at source.

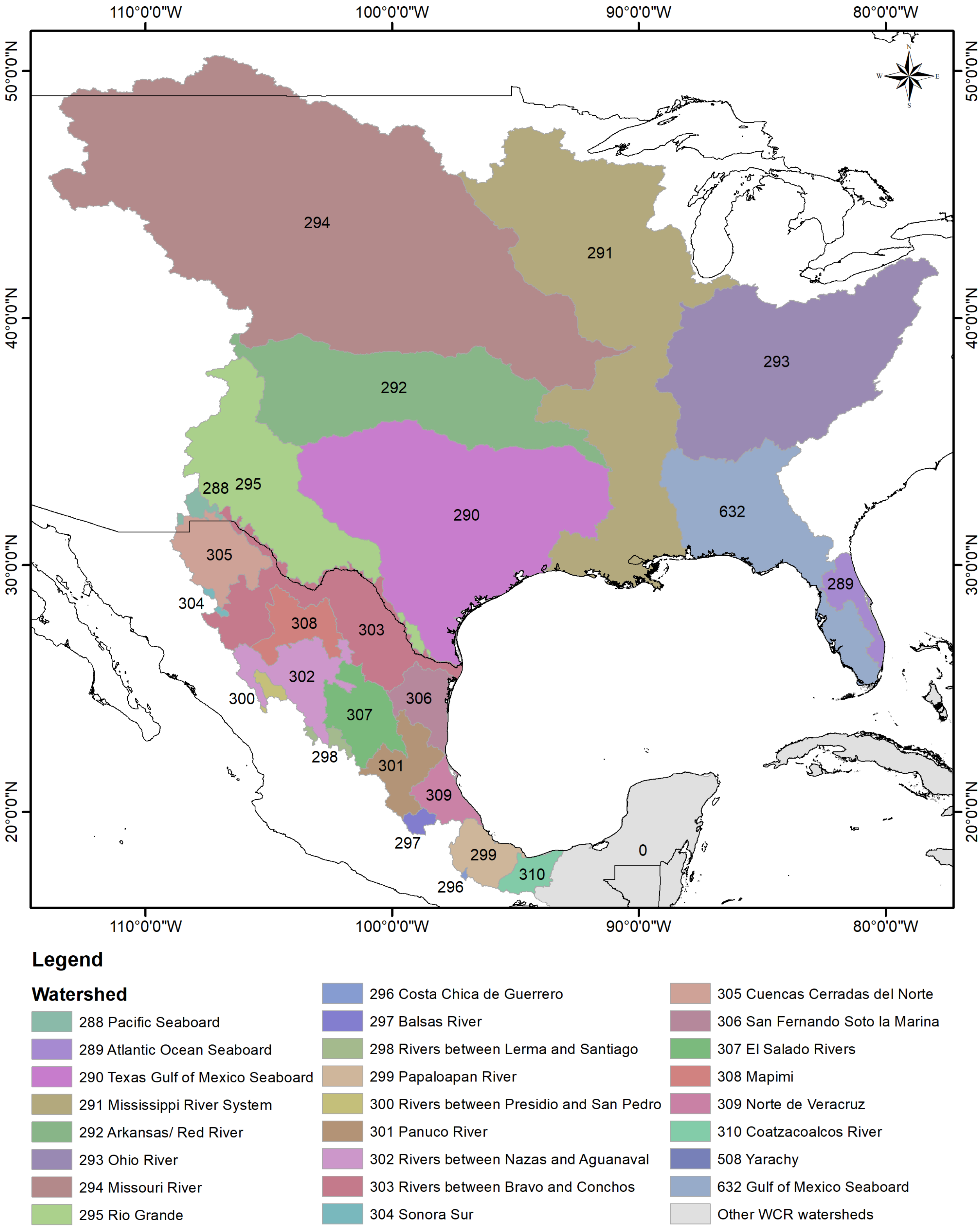
The following maps with preliminary nomenclature of river basins are noted in the table below including the level of watershed resolution at which data from the HydroBasins global dataset was resolved.

Map Filename	**Resolution**	**WCR Subregion**
WCR Watersheds		Subregion I-V, North Brazil Shelf LME
CONTINENTAL WATERSHEDS	**Levels 3-6**	
NA (North America) Watersheds		Sub-region I
CA 1 (Central America) Watersheds		Sub-region II
CA 2 Watersheds		Sub-region II
CA 3 Watersheds		Sub-region II
CA 4 Watersheds		Sub-region II
SA (South America) Watersheds all		Sub-region III
SA Watersheds Guyana to Brazil		Sub-region III
SA Watersheds North Colombia		Sub-region III
SA Watersheds North Venezuela		Sub-region III
INSULAR WATERSHEDS		
Bahamas	Level 9	Sub-region V
Cuba	Level 8	Sub-region V
Hispaniola	Level	Sub-region V
Jamaica	Level 8	Sub-region V
Puerto Rico and USVI	Level 9	Sub-region IV
Trinidad and Tobago	Level 12	Sub-region IV
Eastern Caribbean 1	Level 12	Sub-region IV
Eastern Caribbean 2	Level 12	Sub-region IV
Eastern Caribbean 3	Level 12	Sub-region IV
Southern Caribbean	Level 12	Sub-region IV

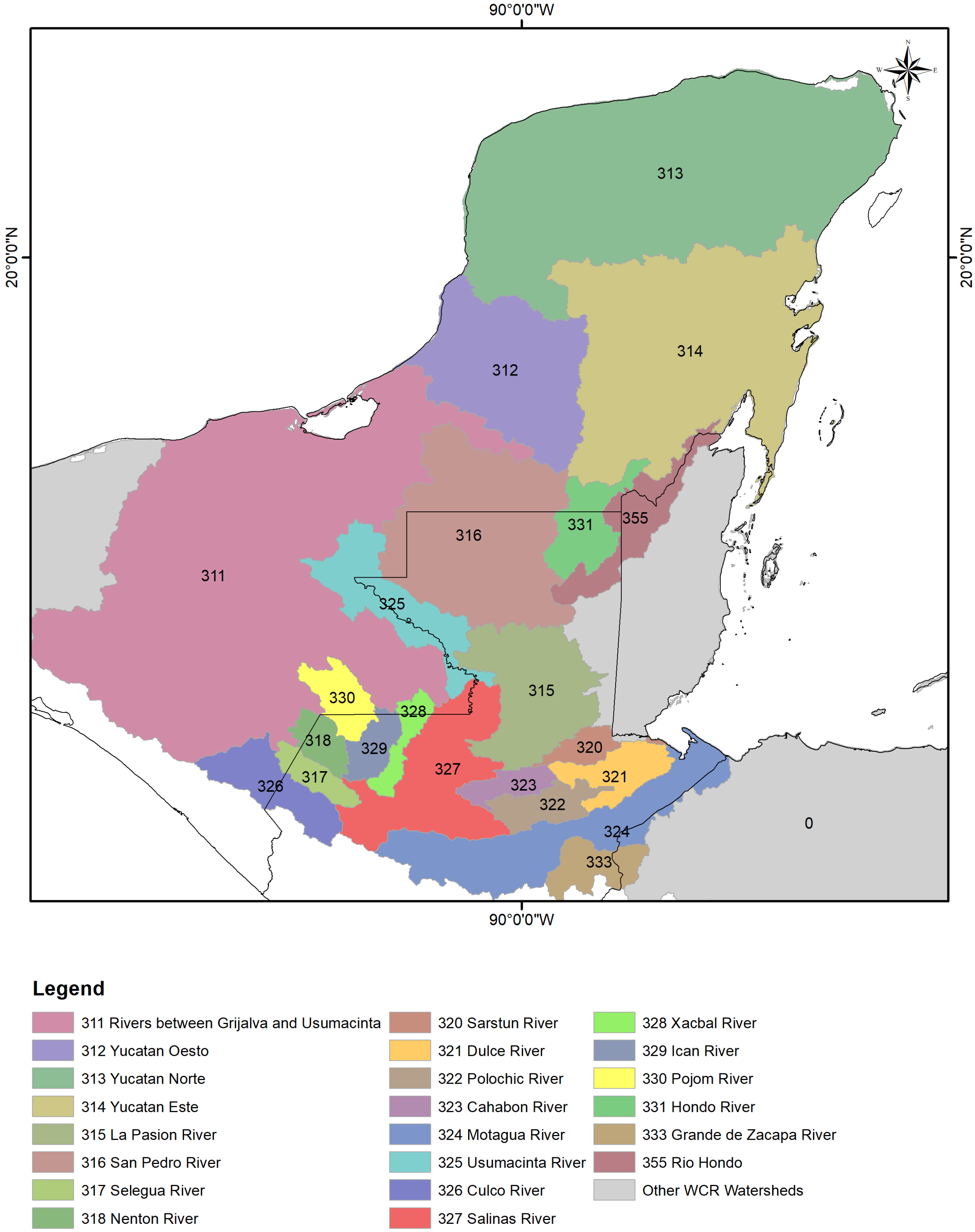
WCR WATERSHEDS



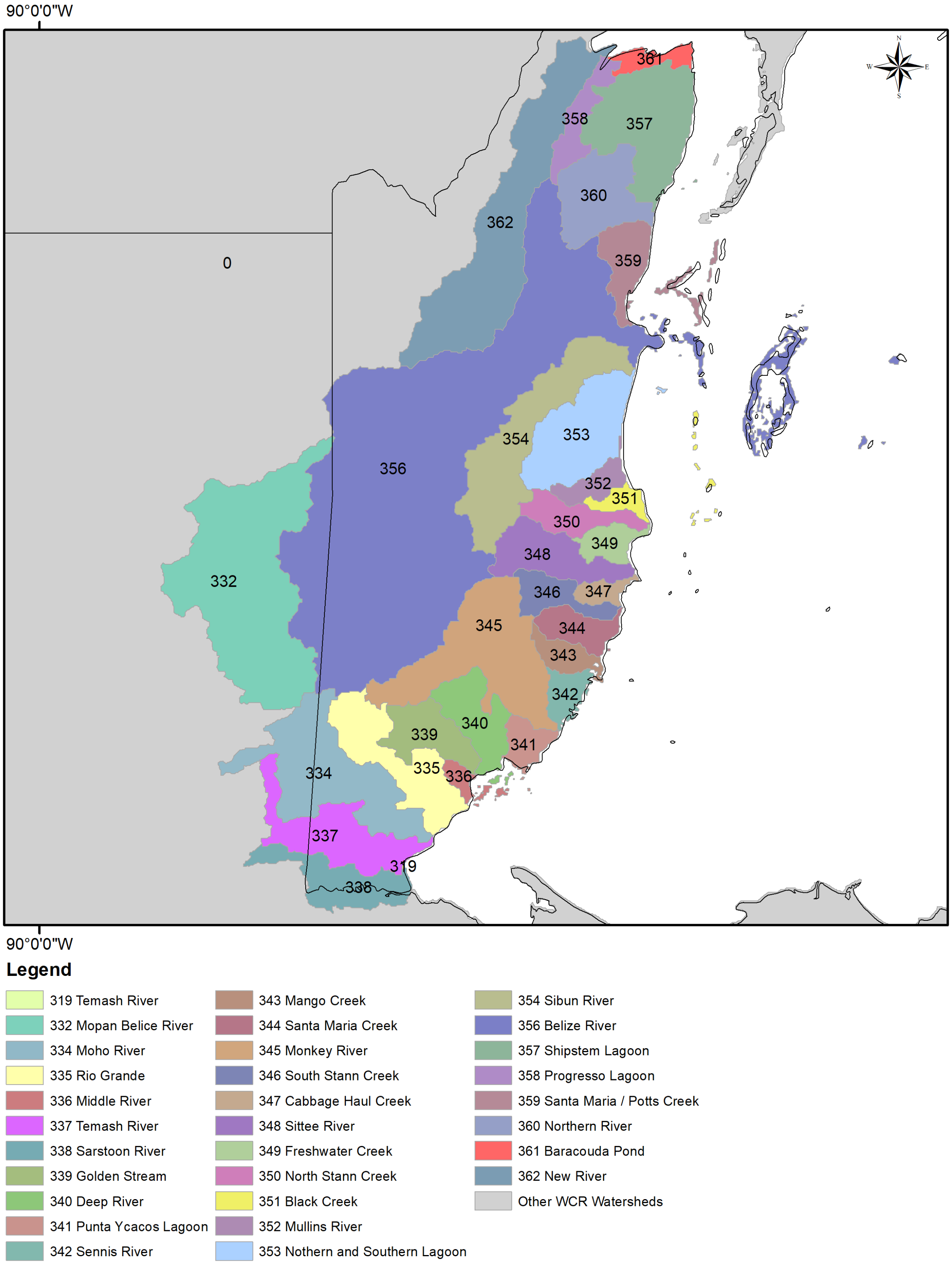
NORTH AMERICA WATERSHEDS: Mexico, United States of America



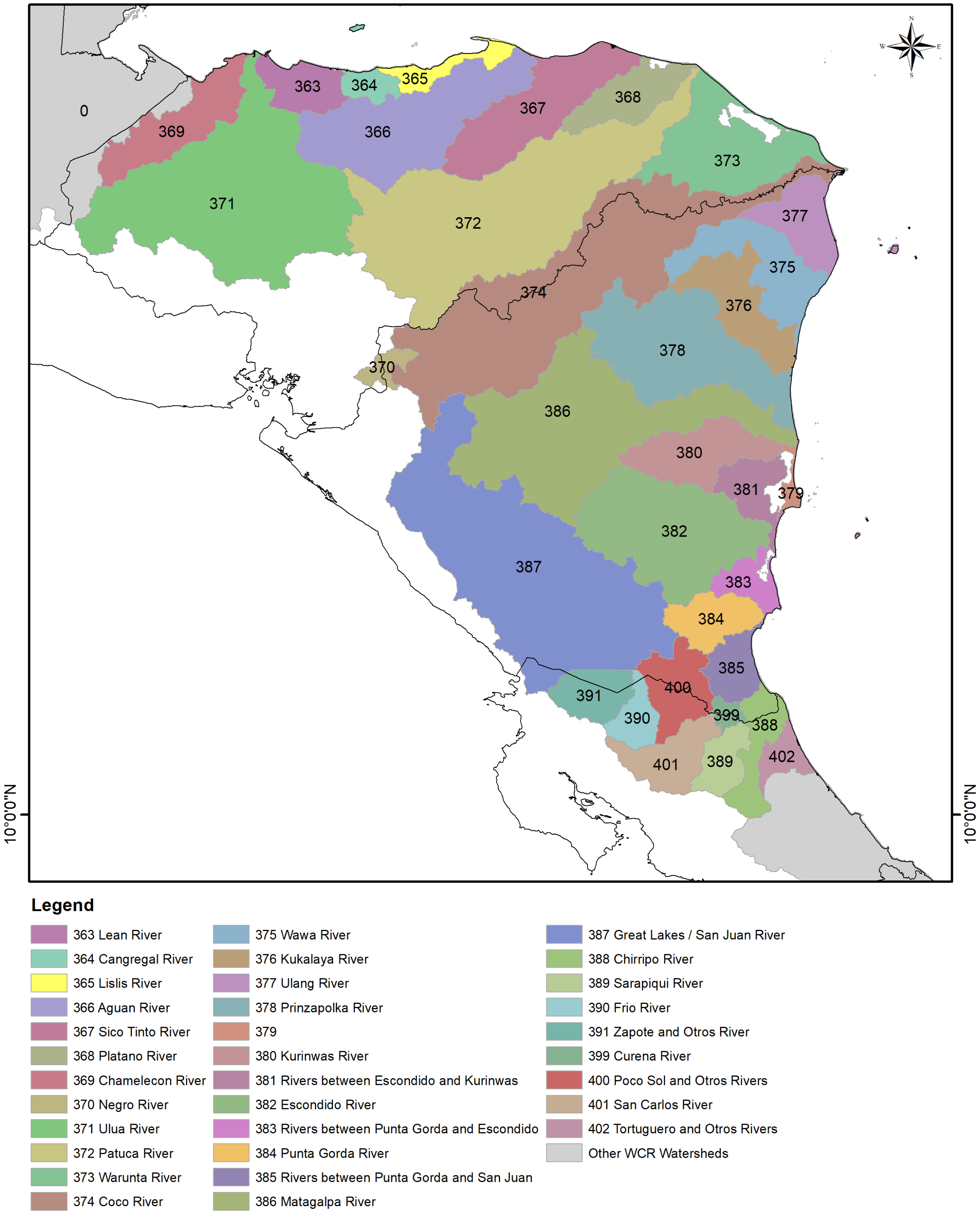
CENTRAL AMERICA 1: Yucatan Peninsula (MEX), Guatemala



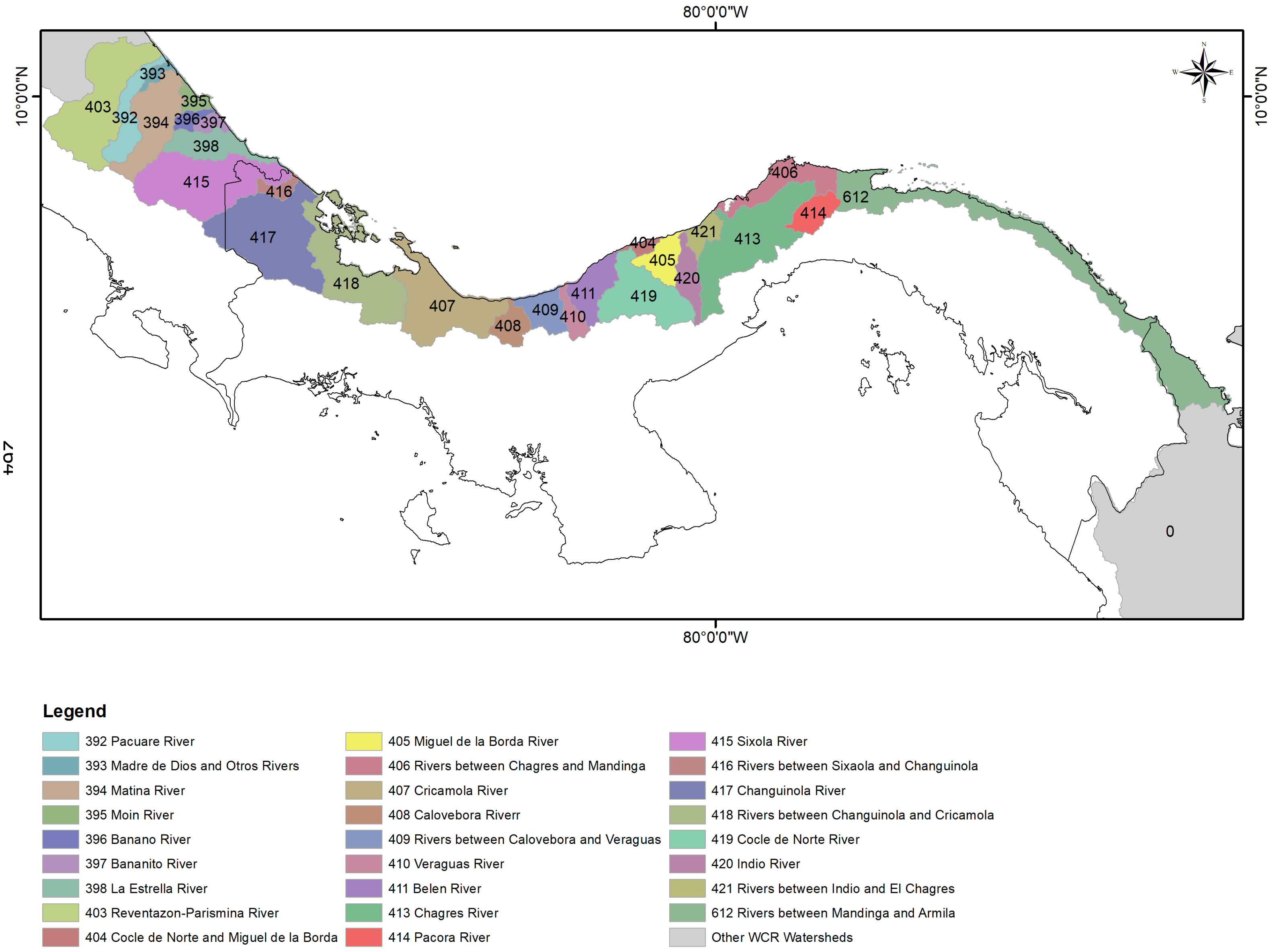
CENTRAL AMERICA 2: Belize



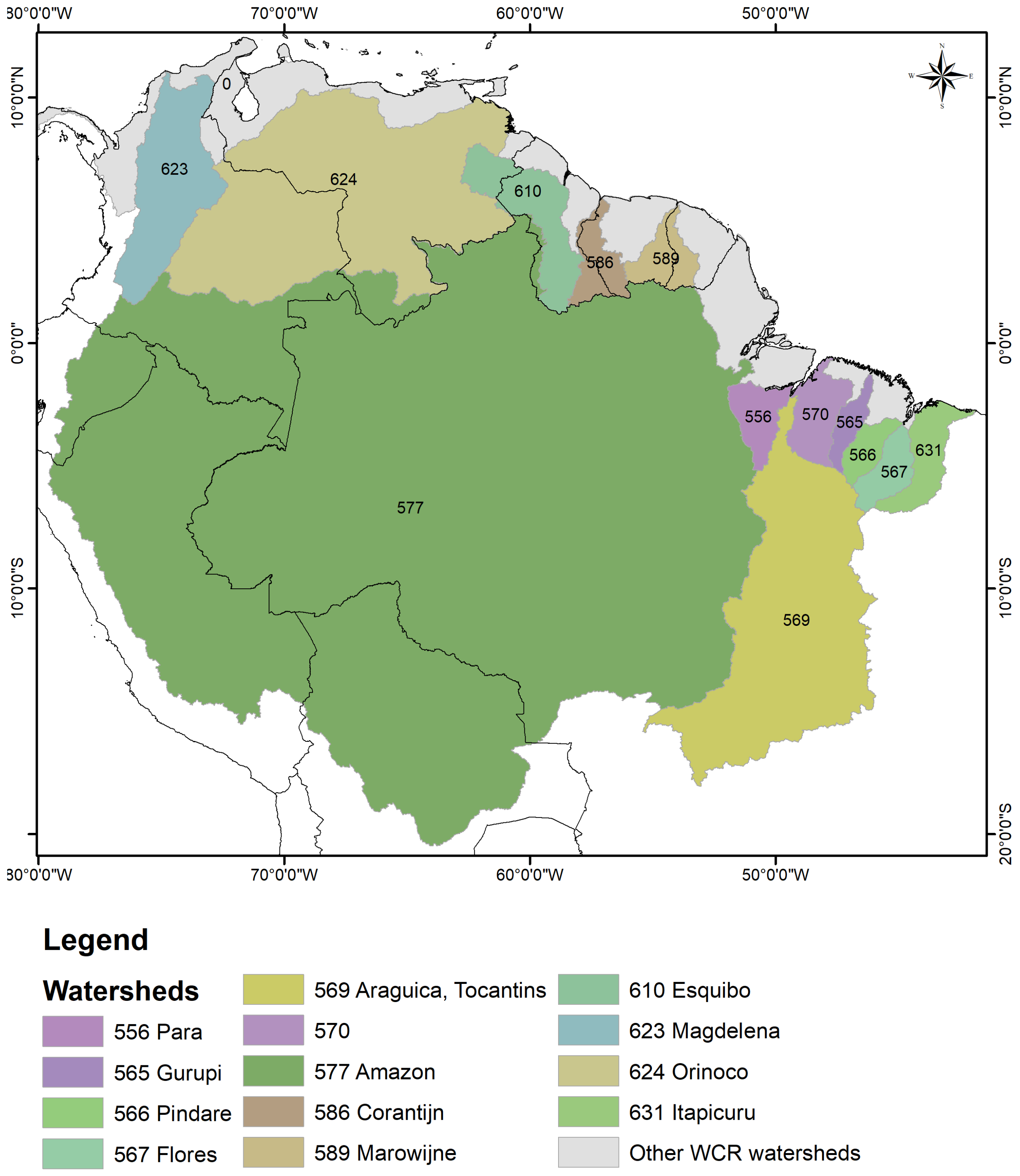
CENTRAL AMERICA 3: Honduras, Nicaragua, Costa Rica



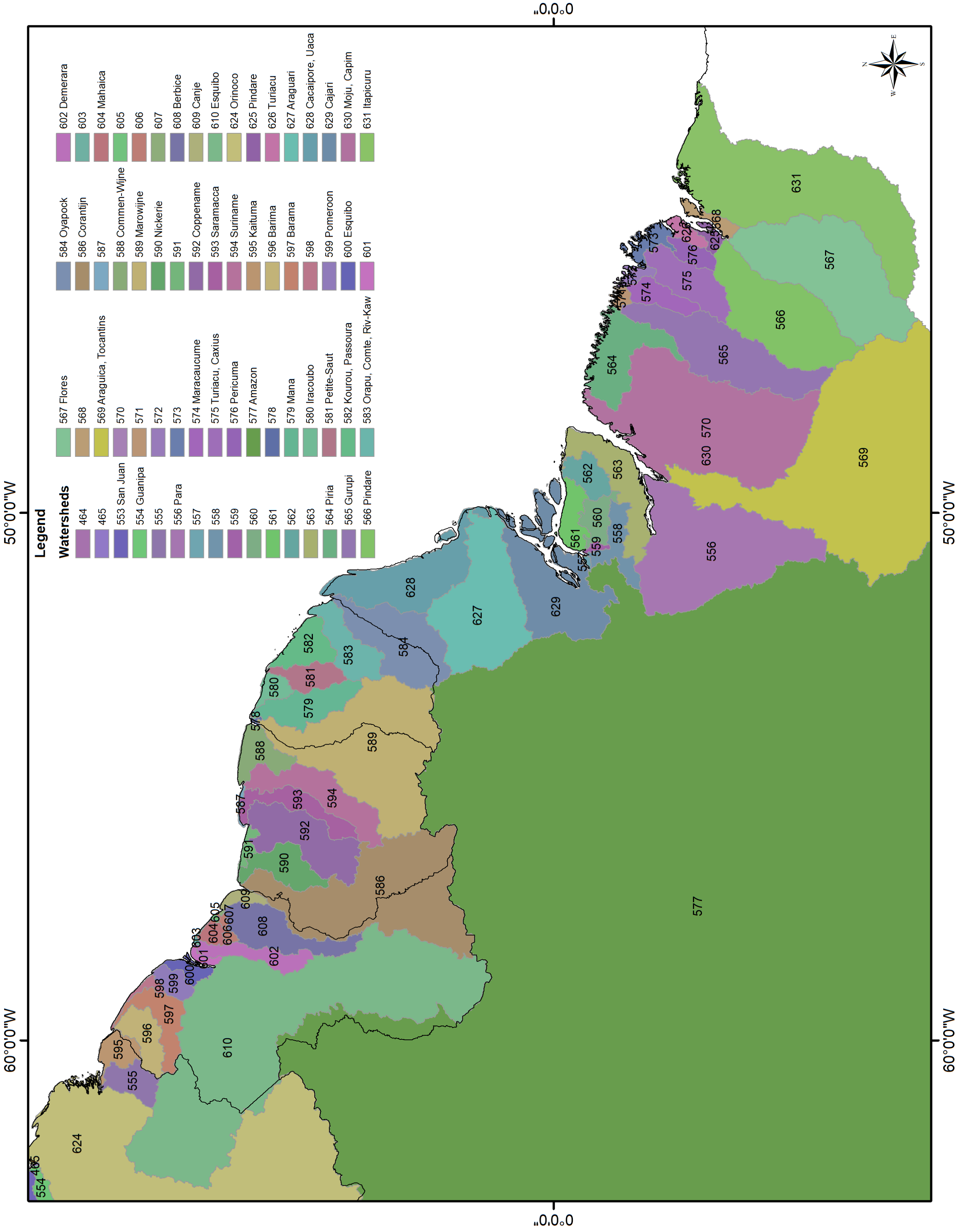
CENTRAL AMERICA 4: Panama



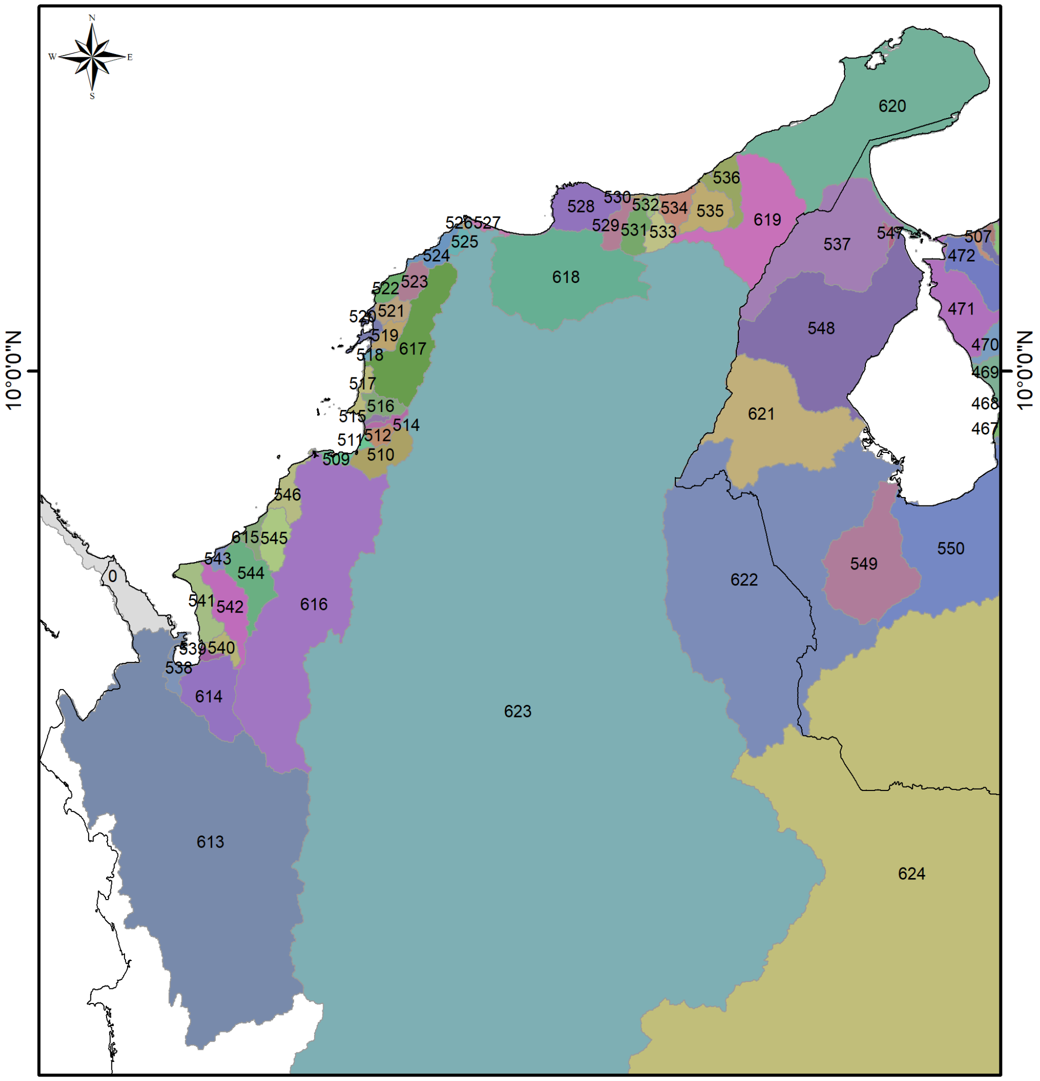
SOUTH AMERICA: ALL WCR WATERSHEDS



SOUTH AMERICA: Guyana to Brazil



SOUTH AMERICA: North Colombia

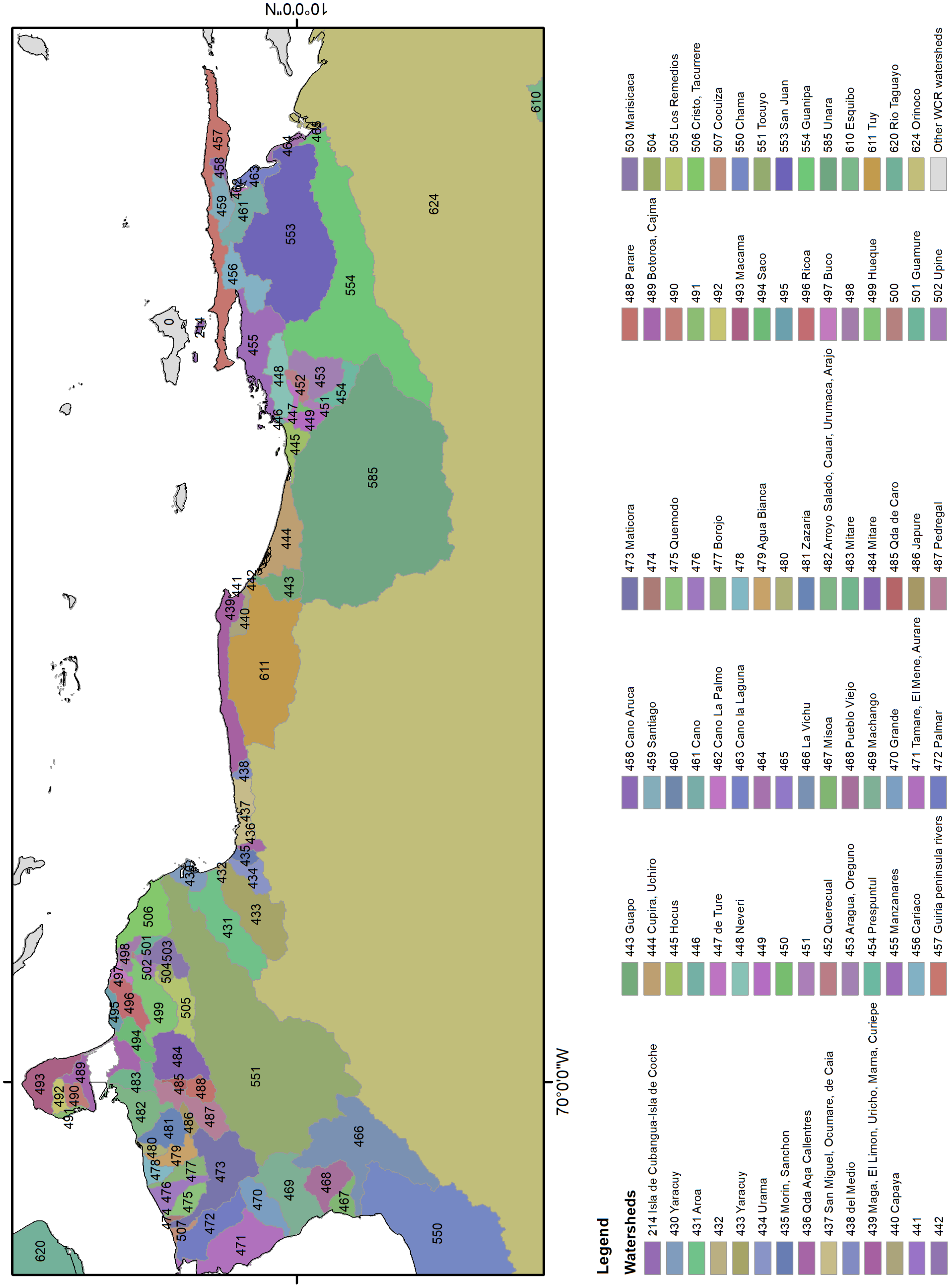


Legend

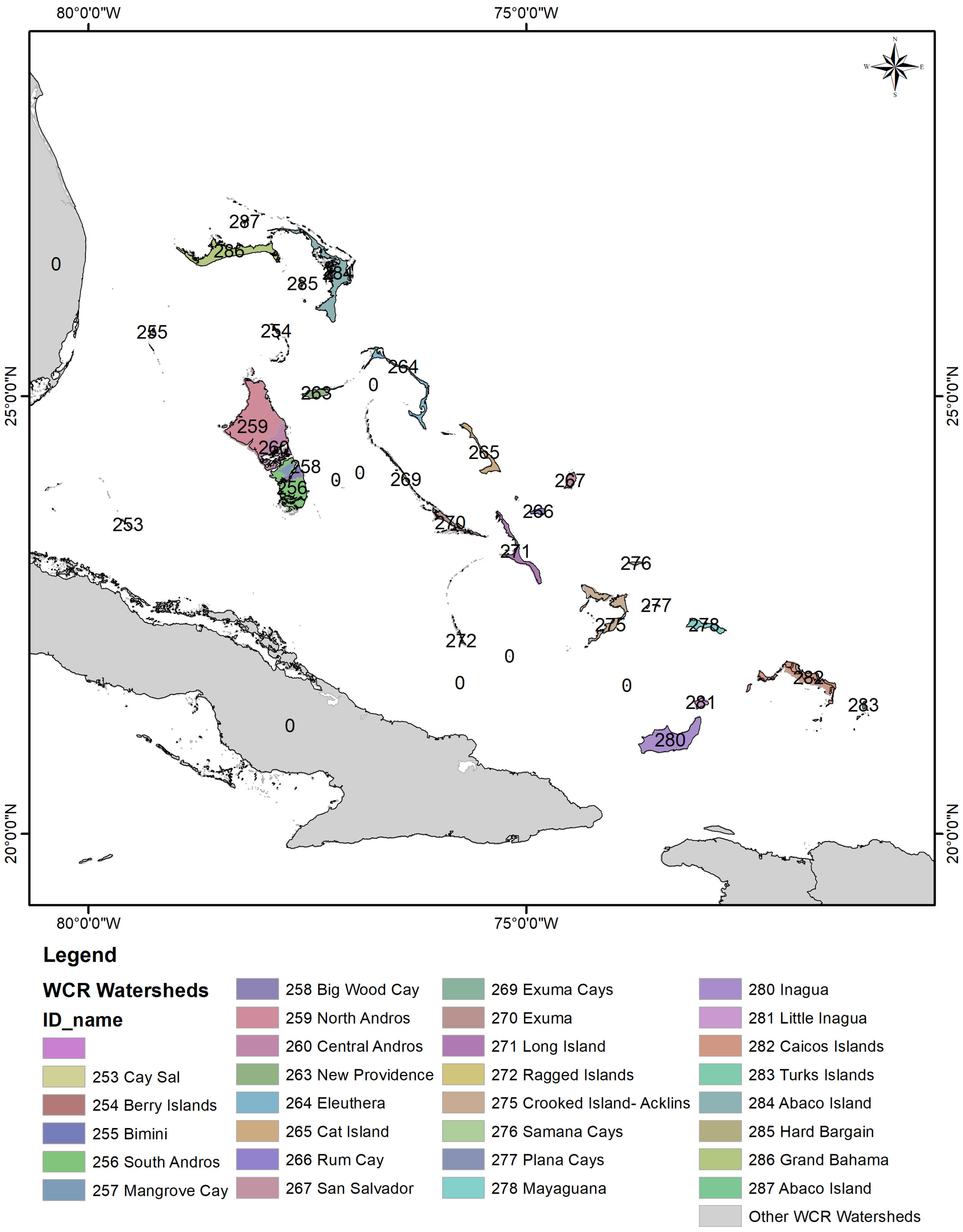
Watersheds

- 466 La Vichu
- 467 Misoa
- 468 Pueblo Viejo
- 469 Machango
- 470 Grande
- 471 Tamare, El Mene, Aurare
- 472 Palmar
- 473 Maticora
- 474
- 475 Quemodo
- 476
- 507 Cocuiza
- 509 Hondo
- 510 Ay Petaca
- 511 Ay Pechilin
- 512 Ay Grande
- 513
- 514
- 515
- 516 Ay Cascajo
- 517
- 518
- 519
- 520 Canal del Dique, Cga de Tesca o la Virgen
- 521
- 522
- 523 Ay Grande
- 524 Ay Piojo, Caja, Cana
- 525 Ay Sierra Palma
- 526
- 527
- 528 Toribio, Guachaca
- 529
- 530
- 531 Don Diego
- 532
- 533 Ancho
- 534 Dibulla (Jerez)
- 535 Tapias
- 536 Barbacoas
- 537 Los Cajones
- 538 Bzo Leon
- 539 Cn Viejo
- 540 Gudaualito
- 541 Caiman Nuevo, Cga Marimonda, Cga de Salado
- 542 Mulatos
- 543 Iguana
- 544 San Juan
- 545 Canalete
- 546 Mangle
- 547
- 548 Palmar
- 549 Escalante
- 550 Chama
- 613 Rio Atrato
- 614 Leon
- 615
- 616 Rio Sinu
- 617 Canal del Dique
- 618 Rio Fundacion
- 619 Rio Rancheria
- 620 Rio Taguayo
- 621 Rio de Oro
- 622 Rio Cataturmbo, Guaramilo
- 623 Magdelena
- 624 Orinoco
- Other WCR watersheds

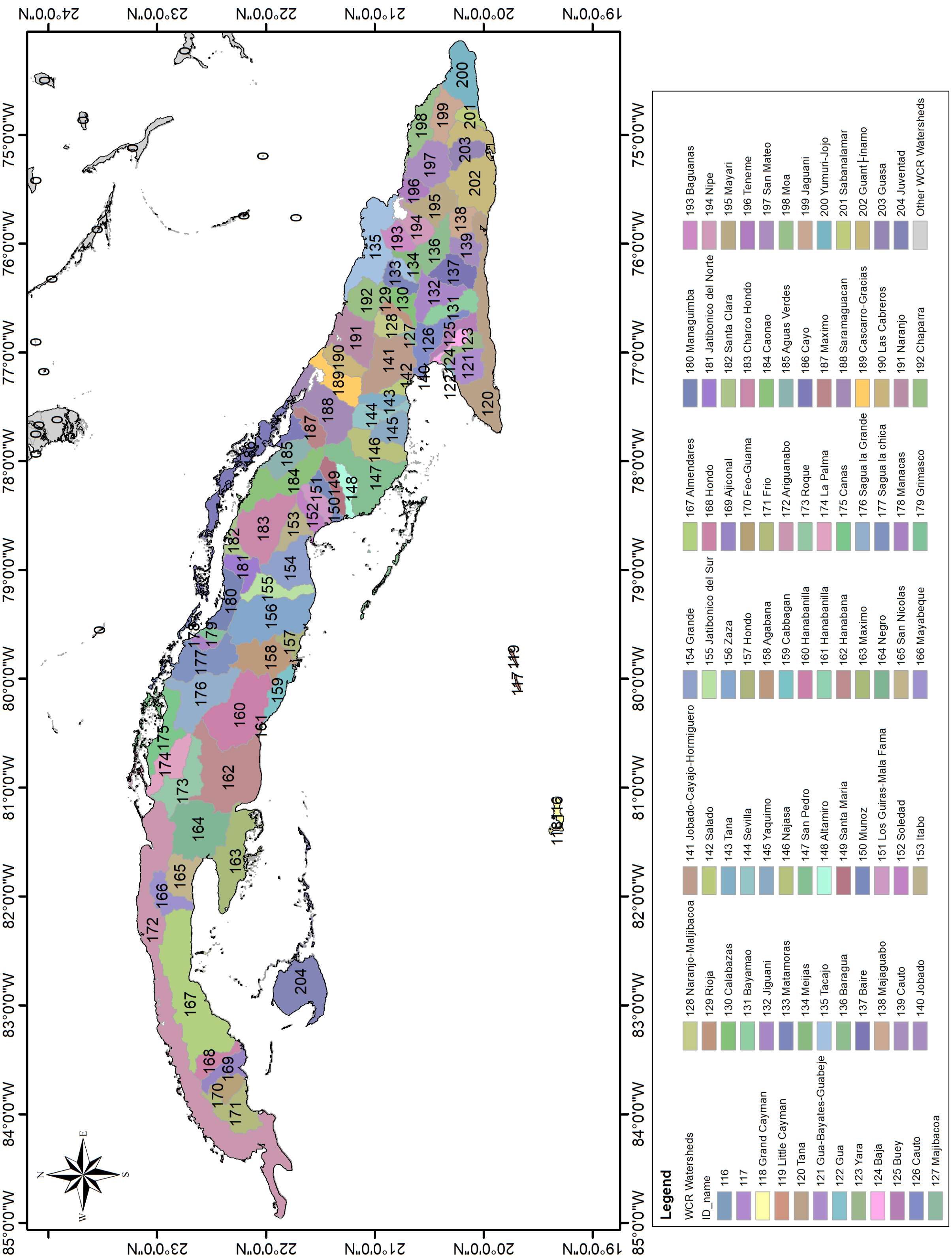
SOUTH AMERICA: North Venezuela



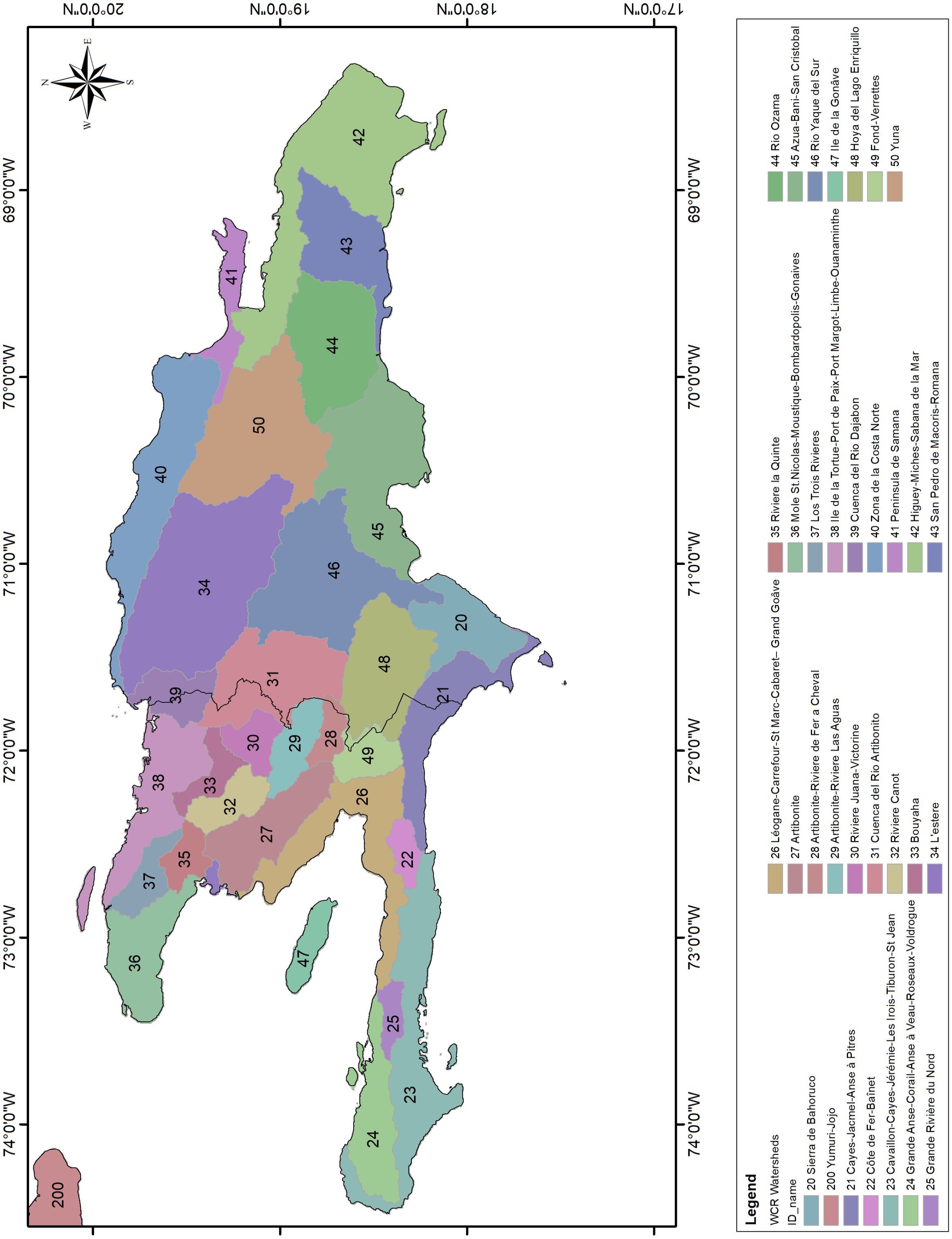
Insular Watersheds: Bahamas



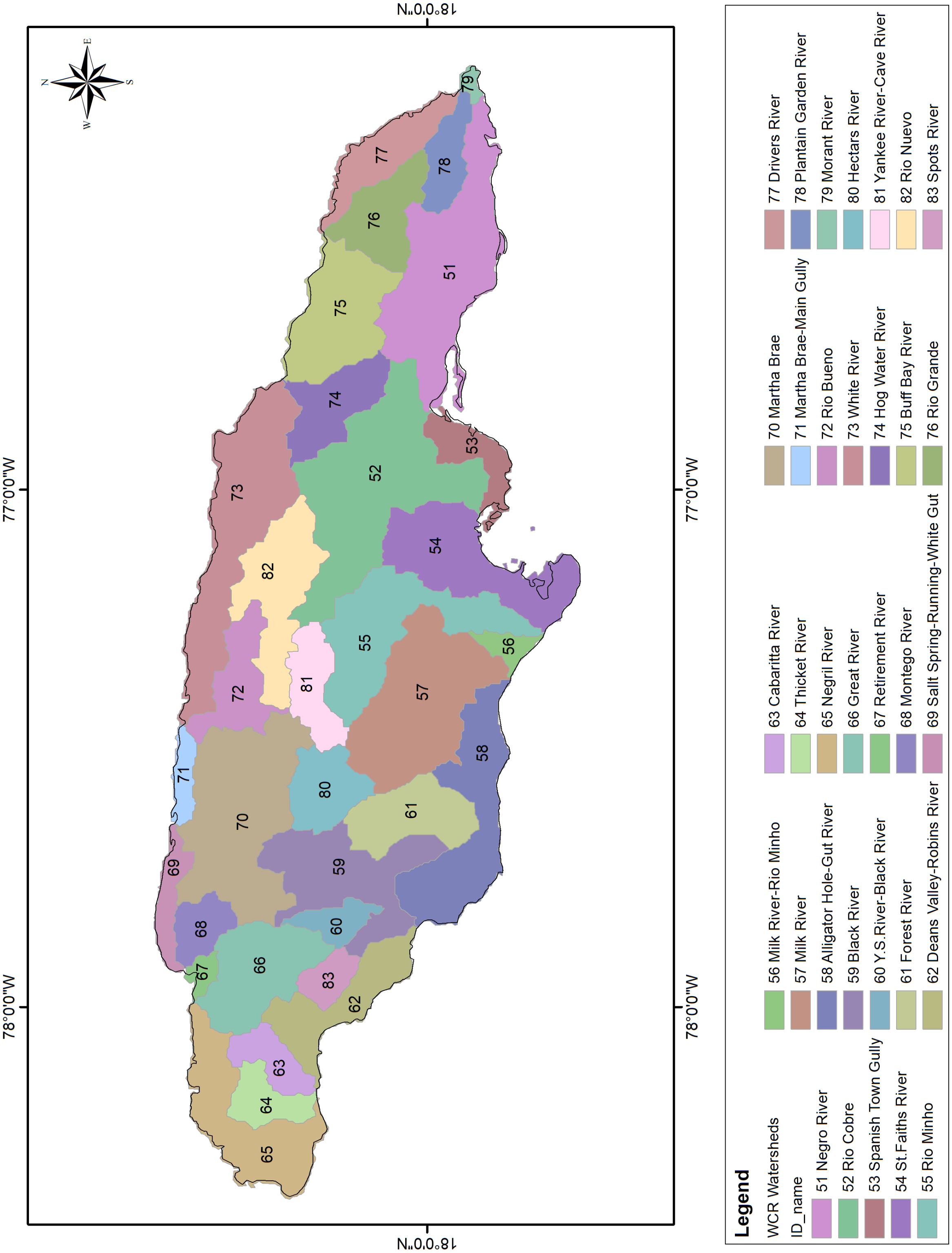
Insular Watersheds: Cuba



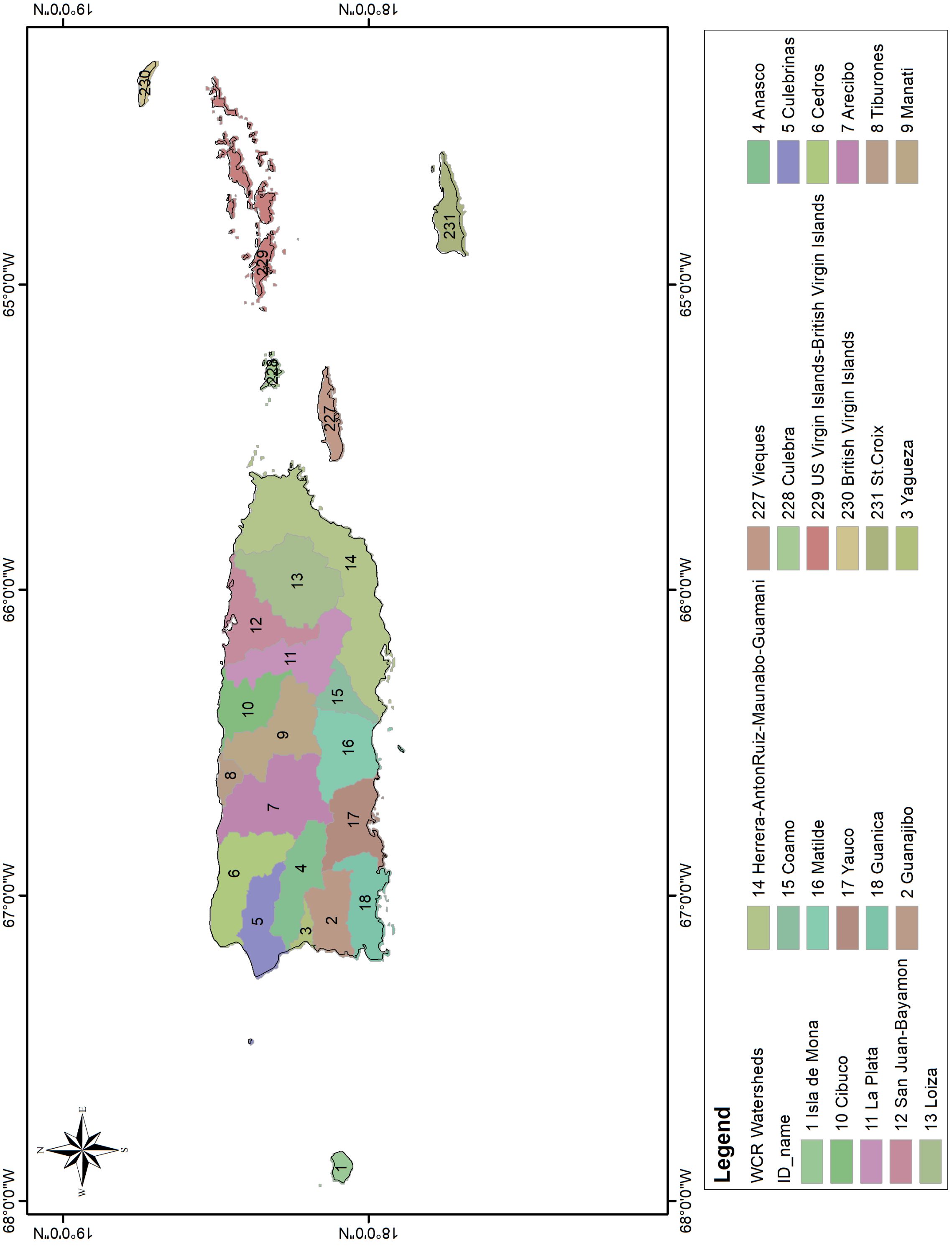
Imsular Watersheds: Haiti, Dominican Republic



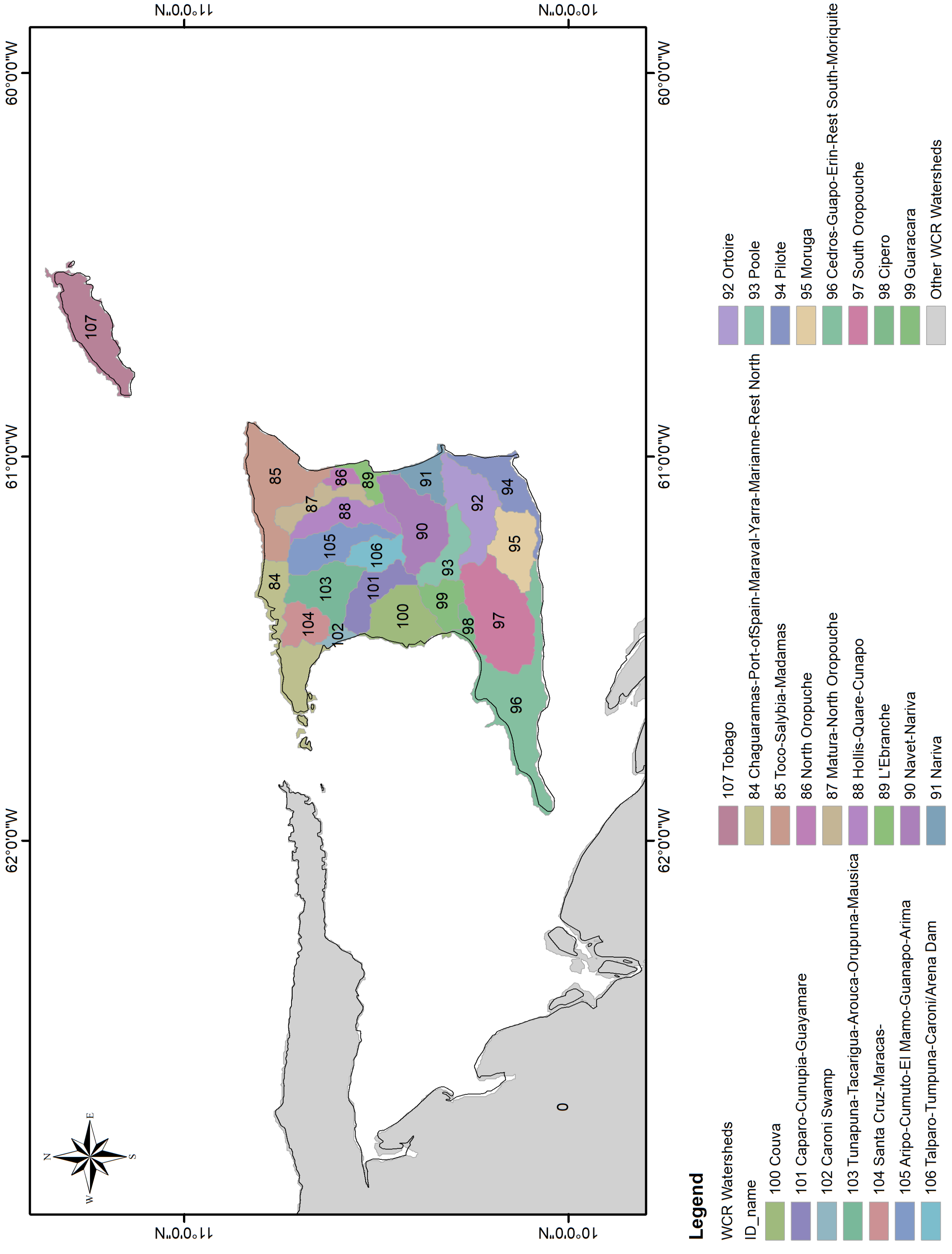
INSULAR WATERSHEDS: Jamaica



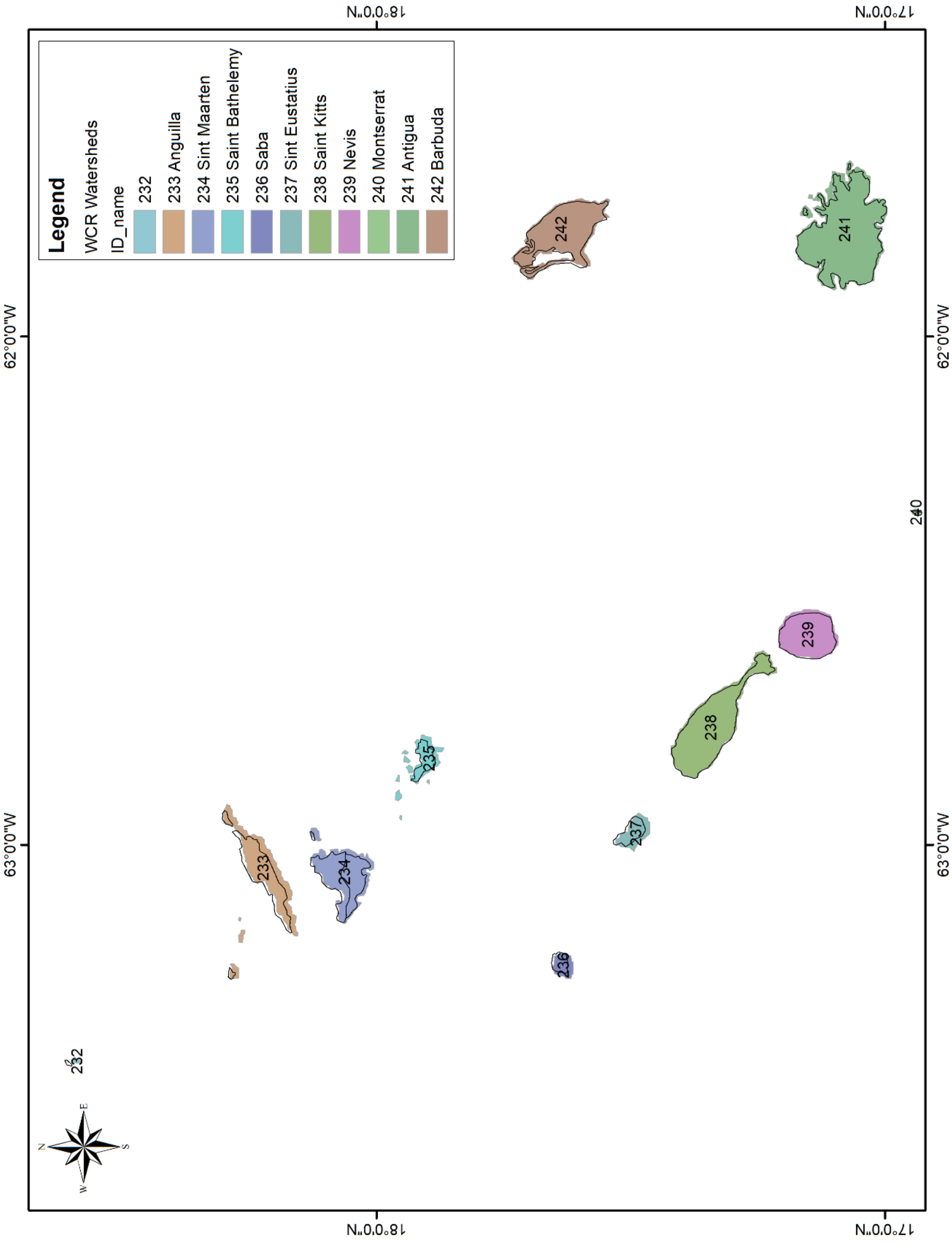
INSULAR WATERSHEDS: Puerto Rico, US Virgin Islands



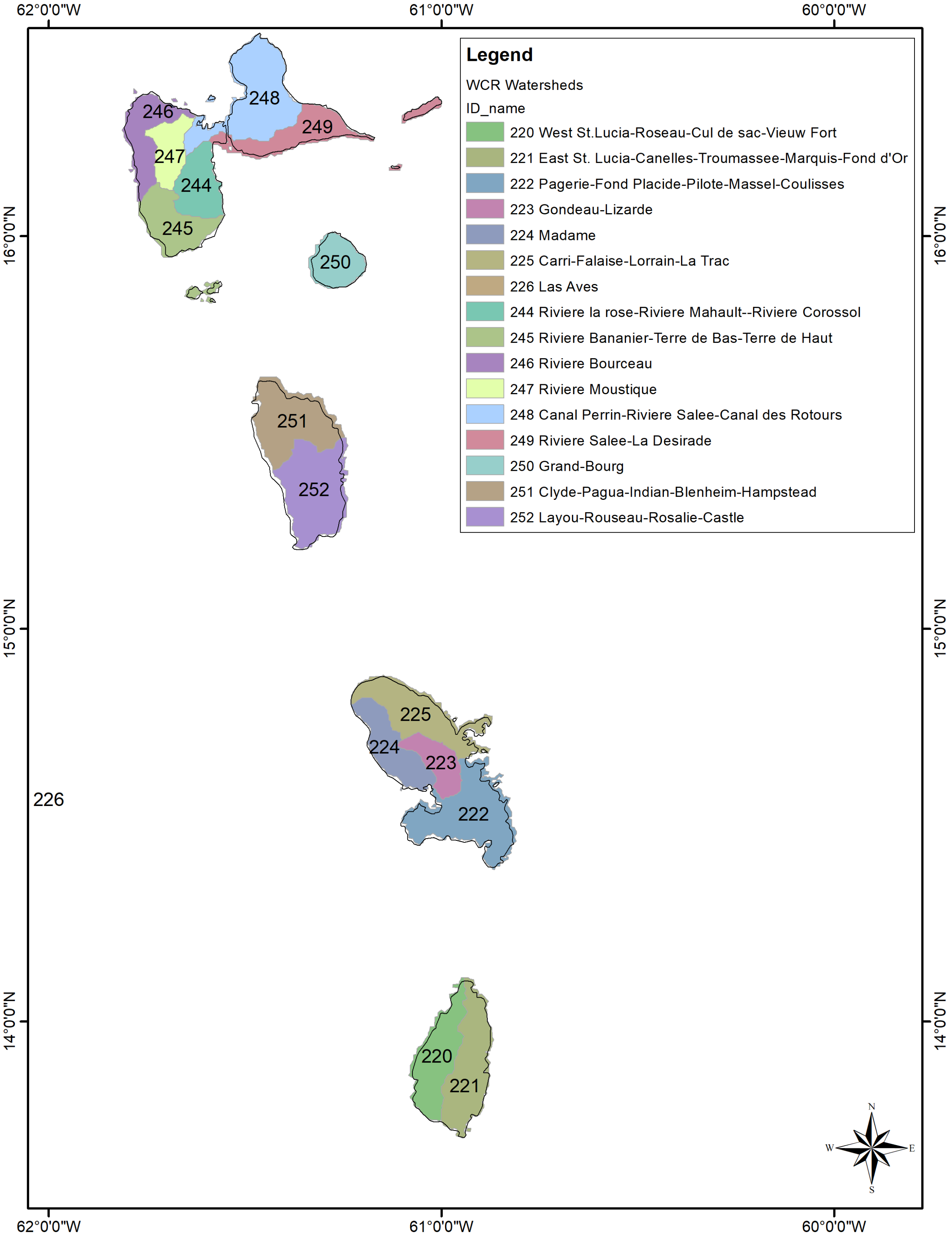
INSULAR WATERSHEDS: Trinidad and Tobago



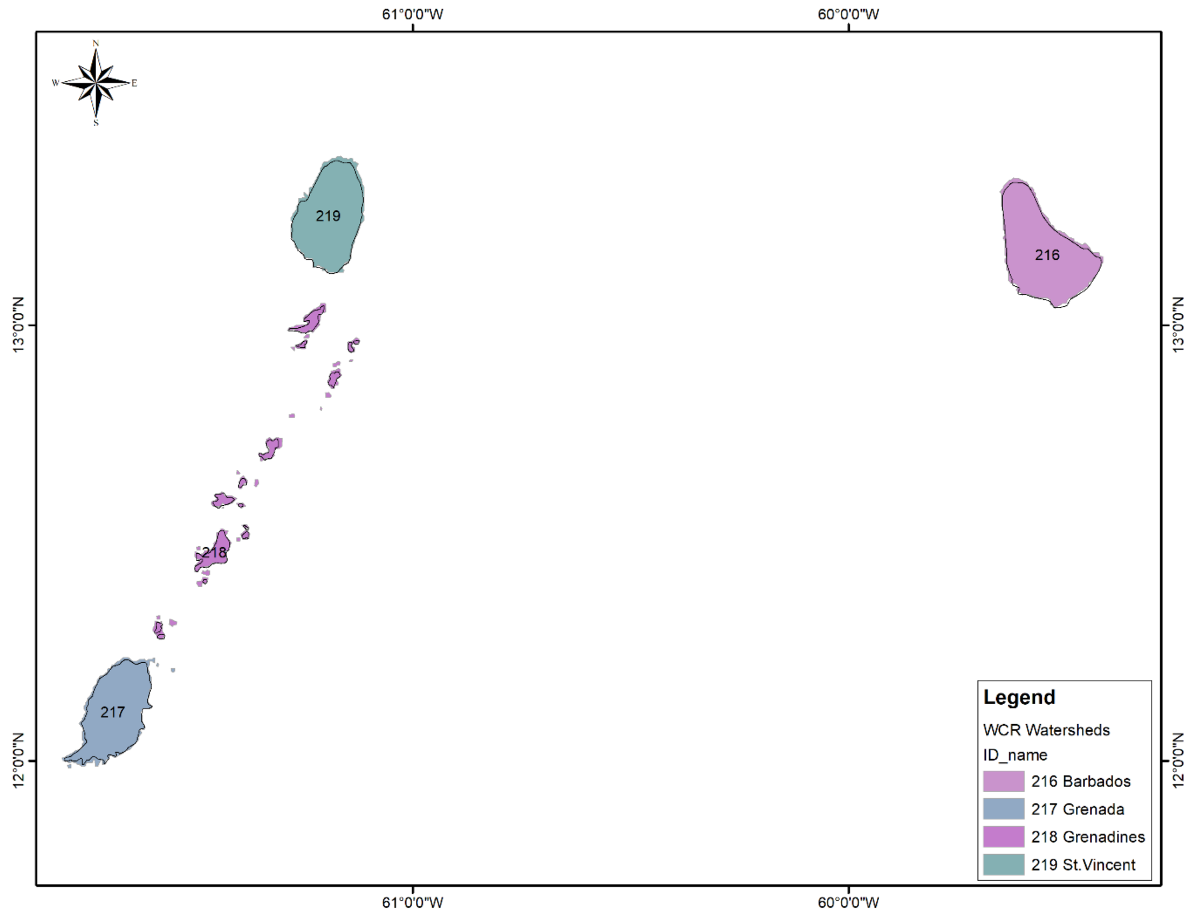
Insular Watersheds: Anguilla, Sint Maarten, Saba, Sint Eustatius, Saint Kitts and Nevis, Montserrat, Antigua and Barbuda



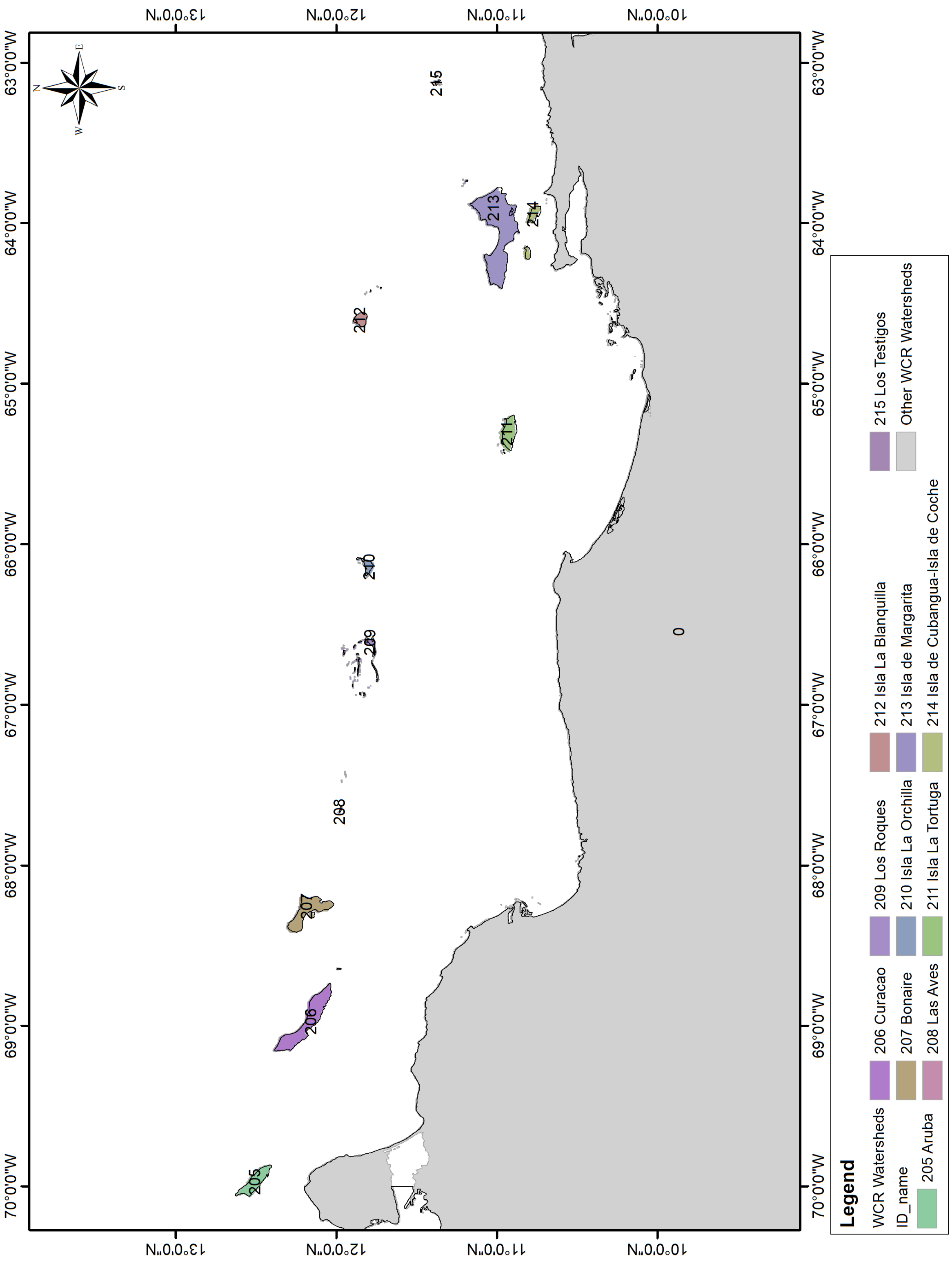
INSULAR WATERSHEDS: Guadeloupe, Dominica, Martinique, Saint Lucia



INSULAR WATERSHEDS: Barbados, Grenada, Saint Vincent and the Grenadines



INSULAR WATERSHEDS: Aruba, Bonaire, Curacao



ANNEX 3.2 TRANSBOUNDARY RIVER BASINS IN THE WIDER CARIBBEAN REGION

DATA SOURCE: http://twap-rivers.org/indicators/

River Basin information sheets available at:

http://twap-rivers.org/#results-data-portal (web-based)
http://geftwap.org/publications/vol-6-annex-a (compilation, Northern America)
http://geftwap.org/publications/vol-6-annex-b (compilation, Central America & Caribbean)
http://geftwap.org/publications/vol-6-annex-c (compilation, Southern America)

The table provides a summary of risk assessments of transboundary river basins in the Wider Caribbean Region, conducted by the Transboundary River Basins Component of the GEF-funded Transboundary Waters Assessment Programme. The technical underpinnings of the assessment can be found at the website and publications noted above.

Water system information sheets are available for each of the 26 transboundary river basins in the WCR. These maybe accessed as downloadable documents through the website, or as part of regional compilations noted above.

1	2	3	4	5
VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

RIVER BASIN	RIVER BASIN CODE	Country	Area [000' km2]	Population [000']	Runoff [mm/year]	Discharge [km3/year]	4. Nutrient Pollution	5. Wastewater Pollution	Basin Risk Category (average)
Mississippi	MISS		3208	78174	221	709.76	4	2	2.87
Mississippi	MISS_USA	United States	3182	78161	223			2	2.71
Mississippi	MISS_CAN	Canada	26	13	7			1	2.50
Rio Grande (N Amer)	RGNA		538	10969	23	12.11	3	3	3.20
Rio Grande (N Amer)	RGNA_MEX	Mexico	224	7788	26			4	3.21
Rio Grande (N Amer)	RGNA_USA	United States	315	3181	20			2	3.00
Belize	BLZE		8	110	629	5.34	2	5	2.64
BLZE_BLZ	Belize	Belize	6	74	618			5	2.69
BLZE_GTM	Guatemala	Belize	2	36	670			5	2.62
Candelaria	CDLR		15	168	331	4.84	2	4	2.33
Candelaria	CDLR_GTM	Guatemala	2	10	303			5	2.36
Candelaria	CDLR_MEX	Mexico	12	158	349			4	2.36
Grijalva	GJLV		126	8302	1011	127.11	2	4	2.87
Grijalva	GJLV_BLZ	Belize	0	0	-1			5	2.88
Grijalva	GJLV_GTM	Guatemala	47	3405	1176			5	2.86
Grijalva	GJLV_MEX	Mexico	79	4897	934			4	2.86
Hondo	HOND		13	163	244	3.10	2	4	2.07
Hondo	HOND_BLZ	Belize	3	29	276			5	2.46
Hondo	HOND_GTM	Guatemala	5	53	347			5	2.23
Hondo	HOND_MEX	Mexico	5	81	187			4	1.93
Chamelecon	CHAM		4	1382	645	2.86	3	5	3.00
Chamelecon	CHAM_GTM	Guatemala	0	0	-1			5	3.57
Chamelecon	CHAM_HND	Honduras	4	1382	645			5	2.93
Changuinola	CGNL		3	68	1230	3.96	2	5	2.40
Changuinola	CGNL_CRI	Costa Rica	0	4	-1			5	3.00
Changuinola	CGNL_PAN	Panama	3	64	1230			4	2.46
Coco/Segovia	COCO		25	895	1050	25.73	2	5	2.47
Coco/Segovia	COCO_NIC	Nicaragua	19	818	957			5	2.50
Coco/Segovia	COCO_HND	Honduras	6	77	1514			5	2.21
Moho	MOHO		1	17	1870	2.22	2	5	2.50
Moho	MOHO_BLZ	Belize	1	4	-1			5	3.00
Moho	MOHO_GTM	Guatemala	0	12	1870			5	2.46
Motaqua	MOTQ		16	3846	836	13.60	4	5	3.00
Motaqua	MOTQ_GTM	Guatemala	14	3676	930			5	2.93
Motaqua	MOTQ_HND	Honduras	2	170	584			5	2.57
San Juan	SJUA		41	3443	1213	50.18	3	5	3.27
San Juan	SJUA_NIC	Nicaragua	28	2483	827			5	3.29
San Juan	SJUA_CRI	Costa Rica	13	960	1886			5	3.07
Sarstun	SRTU		2	78	-1	-1.00	2	5	3.11
Sarstun	SRTU_BLZ	Belize	0	2	-1			5	3.11
Sarstun	SRTU_GTM	Guatemala	2	75	-1			5	3.00
Sixaola	SIOL		3	48	1622	4.63	2	5	2.73
Sixaola	SIOL_CRI	Costa Rica	2	38	2212			5	2.64
Sixaola	SIOL_PAN	Panama	1	10	442			4	2.64
Temash	TEMA		0	3	1534	0.72	2	5	2.73
Temash	TEMA_GTM	Guatemala	0	1	-1			5	2.88
Temash	TEMA_BLZ	Belize	0	3	1534			5	2.64
Amacuro	AMCR		4	1	932	3.47	2	5	2.29
Amacuro	AMCR_VEN	Venezuela	3	0	883			5	2.29
Amacuro	AMCR_GUY	Guyana	1	1	1031			5	2.20
Barima	BRMA		1	0	649	0.60	2	5	2.64
Barima	BRMA_GUY	Guyana	0	0	-1			5	2.88
Barima	BRMA_VEN	Venezuela	1	0	649			5	2.36
Catatumbo	CTTB		27	1809	719	19.71	4	5	2.64
Catatumbo	CTTB_VEN	Venezuela	11	440	605			5	2.64
Catatumbo	CTTB_COL	Colombia	17	1369	907			5	2.62
Corantijn/Courantyne	CRTY		64	111	712	45.57	2	5	2.29
Corantijn/Courantyne	CRTY_BRA	Brazil	0	0	-1			5	2.75
Corantijn/Courantyne	CRTY_SUR	Suriname	37	8	752			5	2.38
Corantijn/Courantyne	CRTY_GUY	Guyana	26	103	622			5	2.15
Essequibo	ESQB		154	205	1013	156.24	2	5	2.57
Essequibo	ESQB_GUY	Guyana	115	41	1111			5	2.92
Essequibo	ESQB_BRA	Brazil	0	0	-1			5	2.75

1	2	3	4	5
VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Essequibo	ESQB_VEN	Venezuela	39	164	733			5	**2.36**
Maroni	MRNI		66	43	866	57.27	2	5	**2.43**
Maroni	MRNI_BRA	Brazil	0	0	-1			5	**2.44**
Maroni	MRNI_GUF	French Guiana	28	36	948			5	**2.38**
Maroni	MRNI_SUR	Suriname	38	7	804			5	**2.31**
Oiapoque/Oyupock	OYPK		26	11	1393	36.20	2	5	**2.29**
Oiapoque/Oyupock	OYPK_BRA	Brazil	13	6	1459			5	**2.36**
Oiapoque/Oyupock	OYPK_GUF	French Guiana	13	5	1334			5	**2.15**
Orinoco	ORIN		934	12165	1183	1105.46	2	5	**3.07**
Orinoco	ORIN_VEN	Venezuela	587	8298	1001			5	**3.14**
Orinoco	ORIN_GUY	Guyana	0	0	-1			5	**3.00**
Orinoco	ORIN_COL	Colombia	346	3867	1505			5	**2.92**
Orinoco	ORIN_BRA	Brazil	1	0	-1			5	**2.63**
Amazon	AMZN		5888	32164	1111	6540.45	2	5	**2.87**
Amazon	AMZN_BOL	Bolivia	713	7707	475			5	**3.00**
Amazon	AMZN_ECU	Ecuador	132	2785	736			5	**2.79**
Amazon	AMZN_GUF	French Guiana	0	0	-1			5	**2.71**
Amazon	AMZN_SUR	Suriname	0	0	-1			5	**2.71**
Amazon	AMZN_PER	Peru	961	10979	616			4	**2.64**
Amazon	AMZN_COL	Colombia	341	1740	2201			5	**2.38**
Amazon	AMZN_BRA	Brazil	3677	8946	1262			5	**2.29**
Amazon	AMZN_VEN	Venezuela	52	2	2254			5	**2.29**
Amazon	AMZN_GUY	Guyana	13	4	879			5	**1.92**
Artibonite	ATBN		9	1456	307	2.72	4	5	**3.43**
Artibonite	ATBN_HTI	Haiti*	6	1313	325			5	**3.23**
Artibonite	ATBN_DOM	Dominican Republic	3	143	254			5	**2.90**
Massacre	MASS		1	152	30	0.02	4	5	**3.30**
Massacre	MASS_HTI	Haiti	0	127	30			5	**3.64**
Massacre	MASS_DOM	Dominican Republic	0	25	-1			5	**2.88**
Pedernales	PDNL		0	23	-1	-1.00		5	**2.50**
Pedernales	PDNL_HTI	Haiti	0	19	-1			5	**2.89**
Pedernales	PDNL_DOM	Dominican Republic	0	4	-1			5	**2.57**

ANNEX 3.3 *SARGASSUM* COASTAL INUNDATION REPORTS:
Mar 31-Apr 6, 2020; Mar 30-Apr 5, 2021

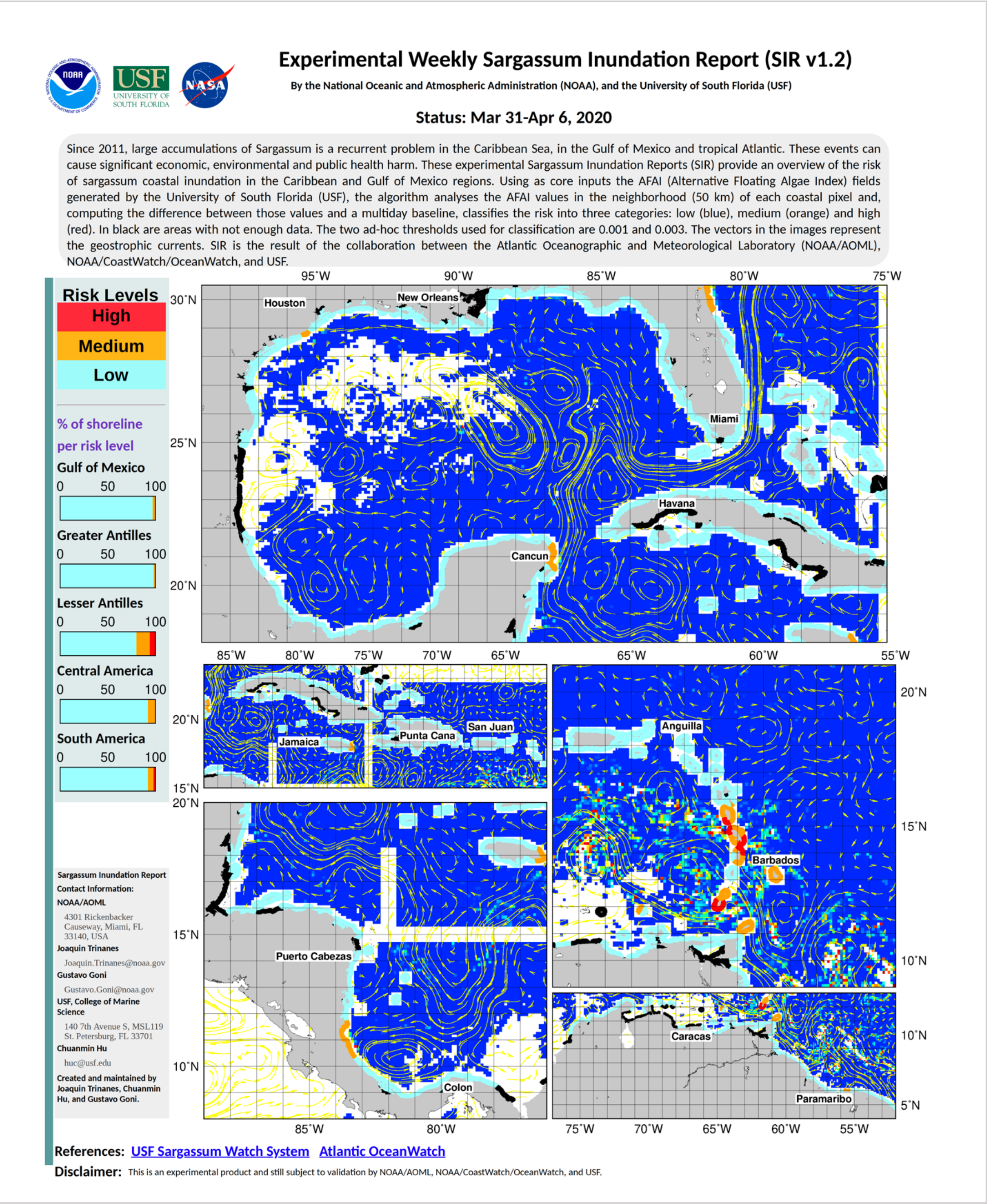
SOURCE: https://www.aoml.noaa.gov/phod/*sargassum*_inundation_report/pdf/SIR_20200525.pdf

This annex provides two weekly reports, over a one-year interval, on *Sargassum* coastal inundation in the Wider Caribbean Report.

Purpose of the weekly reports:

"Since 2011, large accumulations of *Sargassum* is a recurrent problem in the Caribbean Sea, in the Gulf of Mexico and tropical Atlantic These events can cause significant economic, environmental and public health harm. These experimental *Sargassum* Inundation Reports (SIR) provide an overview of the risk of *Sargassum* coastal inundation in the Caribbean and Gulf of Mexico regions. Using as core inputs the AFAI (Alterna282tive Floati282ng Algae Index) fields generated by the University of South Florida (USF), the algorithm analyses the AFAI values in the neighborhood (50 km) of each coastal pixel and, compu282ting the difference between those values and a multi-282day baseline, classifies the risk into three categories: low (blue), medium (orange) and high (red). In black are areas with not enough data. The two ad-hoc thresholds used for classificati282on are 0.001 and 0.003. The vectors in the images represent the geostrophic currents. SIR is the result of the collabora282tion between the Atlan282tic Oceanographic and Meteorological Laboratory (NOAA/AOML), NOAA/CoastWatch/OceanWatch, and USF. "

For the purpose of the nutrient strategy, the weekly risk reports provide an objective way to potentially assess environmental, social and economic impacts of the nuisance macroalgae on resident populations and their blue economies. These weekly inundation risk reports have been produced since June 2019.



Experimental Weekly Sargassum Inundation Report (SIR v1.2)

By the National Oceanic and Atmospheric Administration (NOAA), and the University of South Florida (USF)

Status: Mar 31-Apr 6, 2020

Since 2011, large accumulations of Sargassum is a recurrent problem in the Caribbean Sea, in the Gulf of Mexico and tropical Atlantic. These events can cause significant economic, environmental and public health harm. These experimental Sargassum Inundation Reports (SIR) provide an overview of the risk of sargassum coastal inundation in the Caribbean and Gulf of Mexico regions. Using as core inputs the AFAI (Alternative Floating Algae Index) fields generated by the University of South Florida (USF), the algorithm analyses the AFAI values in the neighborhood (50 km) of each coastal pixel and, computing the difference between those values and a multiday baseline, classifies the risk into three categories: low (blue), medium (orange) and high (red). In black are areas with not enough data. The two ad-hoc thresholds used for classification are 0.001 and 0.003. The vectors in the images represent the geostrophic currents. SIR is the result of the collaboration between the Atlantic Oceanographic and Meteorological Laboratory (NOAA/AOML), NOAA/CoastWatch/OceanWatch, and USF.

Sargassum Inundation Report

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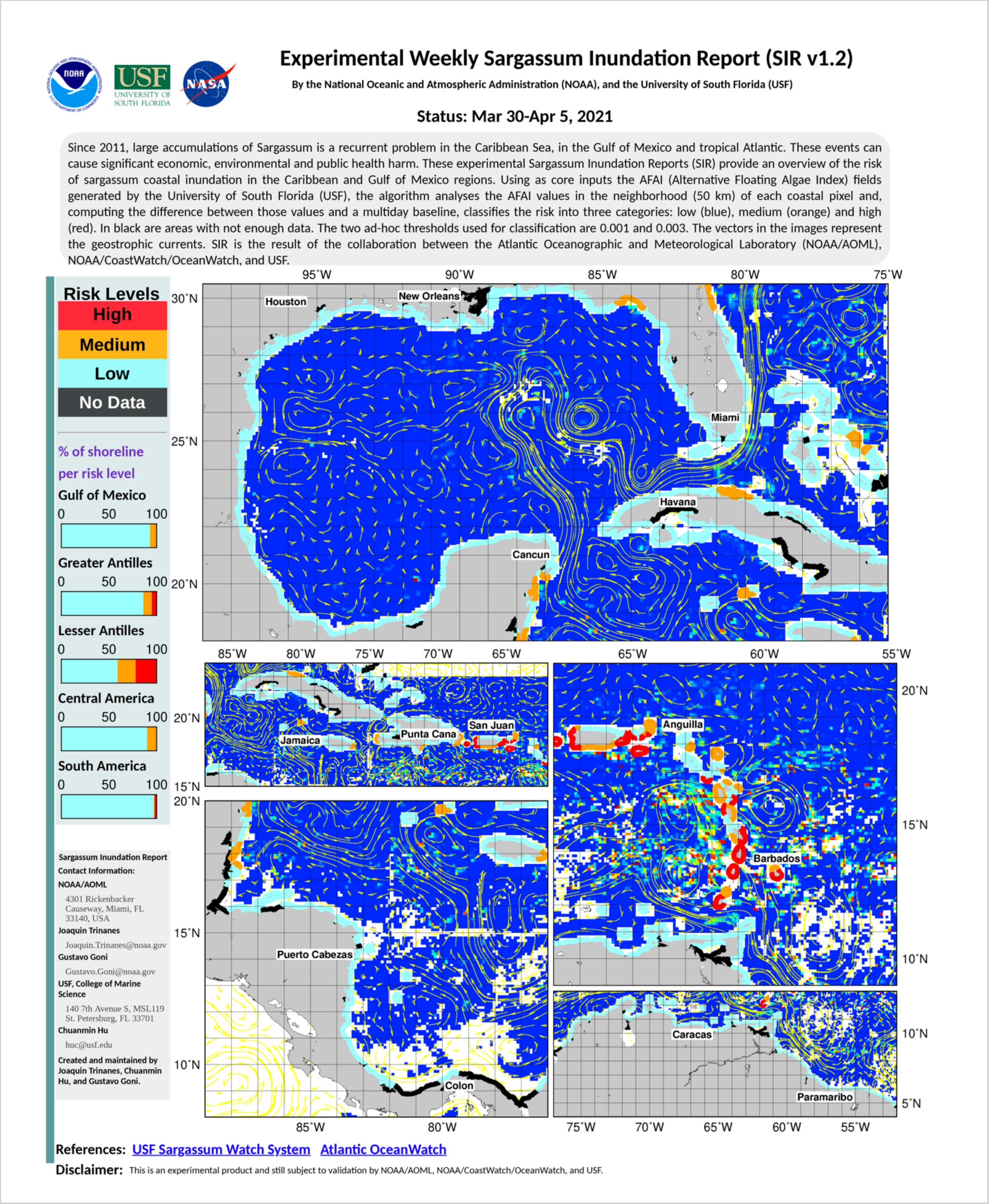
References: USF Sargassum Watch System Atlantic OceanWatch

Disclaimer: This is an experimental product and still subject to validation by NOAA/AOML, NOAA/CoastWatch/OceanWatch, and USF.



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Annex 4.1. Governance instruments and activities related to pollution in WCR countries/territories, January 2021.

Blank cells indicate activity is not conducted or data was not available.

Country/ Territory	Nutrient pollution reduction strategy	Fertilizer management	Domestic wastewater/Sewage treatment and management[1]	Tourism wastewater treatment /management[2]	Industrial wastewater management	Groundwater/Freshwater Resources Management	Pollution management policy (nutrients not explicit)	Nutrient pollution policy and legislation	Institutional framework (environment, nutrient management)	Multi-sectoral body for nutrient management and pollution	Integrated environmental management policy	Domestic wastewater effluent standards and limits (nutrients)	Industrial wastewater effluent standards and limits (nutrients)	Coastal water quality nutrient standards and regulations	Laboratory capacity	Coastal water quality monitoring[3]	Monitoring of nutrients in rivers	Monitoring of nutrients in groundwater	Monitoring of nutrients in domestic wastewater effluent	Monitoring of nutrients in industrial effluent	(Nutrient) pollution education & outreach programme	Private sector engagement
Mexico		x	x				x		x		x	x	x	x	x	x		x				
USA	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Sub-region II																						
Belize			x				x				x											
Costa Rica		x	x				x		x		x	x	x		x							
Guatemala		x	x				x		x		x	x	x									
Honduras		x	x				x		x		x	x	x									
Nicaragua		x	x				x		x		?	x	x		x							
Panama		x	x				x		x		?	x	x		x	X?						
Sub-region III																						
Colombia		x	x				x		x	x	x	x	x	x	x	x						
French Guiana	x (EU)		x				x	x	x			x	x	x	x	x	x	x	x	x?	x	
Guyana			x				x	x	x			x	x		x					x		
Suriname			x														x					
Venezuela			x				x							?	x							
Brazil		x	x				x			x?		x	x?		x	x?	x?	x?				x
Sub-region III islands																						
Aruba			x													x						
Bonaire			x																			
Curacao			x																			

Sub-region IV																						
Anguilla			x																			
Antigua and Barbuda			x	x			x	x				x	x	x	x	x				x		
Barbados			x	x			x	x			x	x	x	x	x	x		x	x	x		
British Virgin Islands																						
Dominica			x	x												x						
Grenada			x	x			x						x		x	x						
Guadeloupe	x (EU)		x				x	x				x	x	x	x	x	x	x	?	?	x	
Martinique	x (EU)		x				x	x				x	x	x	x	x	x	x	x	x?	x	
Montserrat			x																			
Saint Kitts and Nevis			x	x				x			x	in prep	in prep	in prep	x	x		x				
Saint Lucia			x	x							x	x	?	x		x						
Saint Vincent & Grenadines			x								x					x						
Trinidad and Tobago			x								x	x	x	x	x	x						
US Virgin Islands			x													x						
Sub-region V																						
Bahamas			x				x					in prep	in prep	in prep	in prep	in prep						
Cayman Is			x																			
Cuba		x	x				x		x		x	x	x	x	x	x						
Dominican Republic		x	x				x		x		?	x	x	x	x	x						
Haiti			x																			
Jamaica	x?		x				x		x			x	x	x	x	x			x	x	x	
Puerto Rico			x									x?			x	x						
Turks & Caicos Islands			x																			

[1] Assumption that all the countries have some degree of wastewater treatment

[2] Peters 2015

[3] Including countries/territories for which data was available for the SOCAR assessment. In most countries, monitoring is sporadic

Annex 4.2. Maximum permissible limits for nutrients in wastewater discharge standards or regulations for the Spanish-speaking countries (CIMAB, 2020). See CIMAB (2020) for acronyms and abbreviations.

COUNTRY	STANDARDS OR REGULATIONS FOR WASTEWATER DISCHARGE TO THE COASTAL ZONE AND / OR INLAND WATER (YEAR)	NUTRIENTS INCLUDED[9]	MAXIMUM PERMISSIBLE LIMITS BY NUTRIENTS	COMMENTS
COLOMBIA	Resolution 0883 “by which the parameters and maximum permissible limit values are established in the specific discharges to marine water bodies” (2018).	• Orthophosphate ($P-PO_4^{3-}$)[10] • Total phosphorus (P) • Nitrate ($N-NO_3^-$)[11] • Nitrite ($N-NO_2^-$) • Ammonia nitrogen ($N-NH_3$)[12] • Total nitrogen (TN)	$P-PO_4^{3-}$: 0.3 mg L^{-1} P: 0.4 mg L^{-1} $N-NO_3^-$: 0.1 mg L^{-1} $N-NO_2^-$: 0.02 mg L^{-1} $N-NH_3$: 0.3 mg L^{-1} N: 1.0 mg L^{-1}	For discharge of domestic, industrial, trade and service activities watewaters.
			$P-PO_4^{3-}$: 1.5 mg L^{-1} P: 2.0 mg L^{-1} $N-NO_3^-$: 1.0 mg L^{-1} $N-NO_2^-$: 0.5 mg L^{-1} $N-NH_3$: 5 mg L^{-1} N: 10 mg L^{-1}	For wastewaters coming from agroindustry and livestock activities.
			N: 10.0 mg L^{-1}	For wastewaters coming from productive hydrocarbons activities (refinement)
			P: 2.0 mg L^{-1} N: 10.0 mg L^{-1}	Non-domestic wastewater from activities associated with the production of foodstuffs.
			P: 15.0 mg L^{-1} N: 30.0 mg L^{-1}	Malt and beer production.
			$P-PO_4^{3-}$: 0.4 mg L^{-1} P: 0.3 mg L^{-1} $N-NO_3^-$: 0.1 mg L^{-1} $N-NO_2^-$: 0.02 mg L^{-1} $N-NH_3$: 0.3 mg L^{-1}	For non-domestic wastewater and industrial activities, and different services rather than the above.

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[9] The names and the expressions (chemical formula) of the different nutrients appear likewise they are included in the standards or regulations specified in previous column.

[10] The chemical term used in this standard for the orthophosphate is mainly refer to the phosphorous included in the mention ion.

[11] The chemical expressions used in this standard for nitrate and nitrite in general are utilize in both cases to refer to the nitrogen contained in the respective ions.

[12] In this case, the standard specifies that ammonia nitrogen is refer to nitrogen in the form of soluble ammonia ($N-NH_3$).

			N: 1 mg L^{-1}	
	Resolution 0631 "Whereby the parameter and maximum permissible limit values are established in specific discharges to surface water bodies and public sewer systems and other provisions are issued" (2015).	• Orthophosphate ($P\text{-}PO_4^{3-}$) • Total phosphorus (P) • Nitrate ($N\text{-}NO_3^-$) • Nitrite ($N\text{-}NO_2^-$) • Ammonia nitrogen ($N\text{-}NH_3$) • Total nitrogen (TN)	The aforementioned nutrients are included as indicators to be monitored (indistinctly from each other) in all types of domestic and non-domestic wastewater to discharge to the into surface water bodies and into sewer. However, they do not presento permissible limit values defined in any case. The wastewater generator is only asked to characterize it and report to a competent authority.	
COSTA RICA	Nº 33601-MINAE-S Regulation of wastewater discharge and reuse (2007).	• Phosphates (PO_4^{-3})[13] • Total Nitrogen (TN)[14]	PO_4: 25 mg L^{-1} TN: 50 mg L^{-1}	For the discharge to receiving body that according to the definition of the regulations includes coastal-marine water bodies, as well as inland waters. Nutrients are considered complementary parameters, but mandatory for wastewater of a special type, in particular for those coming from livestock, fishing, as well as fertilizers manufacture and other agrochemicals.
			PO_4: 25 mg L^{-1} TN: 50 mg L^{-1}	For discharge to the sanitary sewer.
CUBA	Cuban Standard 27 " Land water and sewerage discharge of watewaters. Specifications" (2012).	• Total Phosphorus (TP)[15] • Total Kjeldahl Nitrogen (TKN)	TP: 2 mg L^{-1} TKN: 5 mg L^{-1}	For disharges into inland waters according to the following classification: Class A: Rivers and reservoirs for public supply and food processing.
			TP: 4 mg L^{-1} NTK: 10 mg L^{-1}	Class B: Rivers and reservoirs for agricultural irrigation, aquaculture, recreational activities and industrial use.
			TP: 10 mg L^{-1} TKN: 20 mg L^{-1}	Class C: Rivers and reservoirs of lower values destined for navegation and other uses not contemplated in A and B.
		For sewer discharges non-included nutrients		
	Cuban standard 521 "Wastewater discharge to	• Total Nitrogen (Kjeldahl + Nitrate) (TN)	TN: 10 mg L^{-1} TP: 5 mg L^{-1}	The limits are established according to the classification of the marine receiving body due to its use in six classes (6):

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[13] This standard does not specify the chemical formulation of the compound. Phosphate is assumed as PO_4^{3-}

[14] Total nitrogen assumed as TN for this standard and where is not specified.

[15] Total phosphorus assumed as TP, both for the standard and for others not specified.

	coastal and marine area. Specifications" (2007).	• Total Phosphorus (TP)		Class A: Marine areas of ecological conservation or protected zones.
			Discharges are not allowed	Class B: Marine areas used for bathing (direct contact) and where coral reefs appears.
			TN: 20 mg L^{-1} TP: 7 mg L^{-1}	Class C: Marine areas where fishing take place.
			TN: 40 mg L^{-1} TP: 10 mg L^{-1}	Clase D: Marine areas where waters are used for industrial objective as for example energy generation.
			TN: 20 mg L^{-1} TP: 5 mg L^{-1}	Class E: Marine areas in bays where maritime-port activities are carry out.
			TN: 40 mg L^{-1} TP: 10 mg L^{-1}	Clase F: Marine areas for the navigation and other uses.
GUATEMALA	Government agreetment Nr. 236-2006: "Regulation of the discharge and reuse of wastewater and the sludge disposal" (2006).	• Total nitrogen (TN) • Total Phosphorus (TP)	TN : 20 mg L^{-1} TP : 10 mg L^{-1}	For wastewaters discharges to receiving bodies, the regulation establishes that by 2024 all generating entities must comply with these limits. New generating entities have to comply with them from the beginning.
			TN : 20 mg L^{-1} TP : 10 mg L^{-1}	For municipal wastewater discharges to receiving bodies of entities not connected to the public sewer. The regulation establishes that by 2029 all generating entities must comply with these limits.
			TN : 40 mg L^{-1} TP : 10 mg L^{-1}	For the discharge of special wastewater (industrial, agricultural, livestock, hospital) to the public sewer, the regulation establishes that by 2024 all generating entities must comply with these limits. New generating entities have to comply with them from the beginng.
HONDURAS	Agreement 058 "Technical Standards for wastewater discharges to receiving bodies and sanitary sewers" (1996).	• Total Kjeldahl Nitrogen (TKN) • Ammonia Nitrogen (N-NH$_3$)[16] • Total Phosphorus (TP)	TKN: 30.0 mg L^{-1} N-NH$_3$: 20.0 mg L^{-1} TP: 5.0 mg L^{-1}	To discharge at receiving bodies.

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[16] In this standard is not specified, the chemical formulation of the referred element. It is assumed that ammonia nitrogen correspond to nitrogen in form of soluble ammonia (N-NH$_3$).

		For discharges in sanitary sewers, it does not include nutrients, however, it clarifies that the sewer operator and / or treatment plant will define the values of parameters not included, so that the final discharge to the receiving body complies with the provisions of this standard.		
MEXICO	NOM-001-ECOL-1996, which establishes the maximum permissible limits for pollutants in wastewater discharges into national waters and properties (1996).	- Total Nitrogen (TN) - Total Phosphorus (TP)	TN: 15 mg L^{-1} TP: 5 mg L^{-1}	For the discharge into rivers, which are classified into three (3) types according to the use. The maximum permissible monthly limits for the most restritive use are shown (protection of aquatic life)
			TN: 15 mg L^{-1} TP: 10 mg L^{-1}	For discharges in natural or artificial reservoirs which are classified into two (2) types according to the use. The maximum permissible monthly limits for the most restrictive use (public urban use) are shown.
			TN: 15 mg L^{-1} TP: 5 mg L^{-1}	For discharge in coastal waters which are classified into three (3) types (A, B and C), according to their use. The maximum permissible monthly limits for estuaries (C) are shown since it establishes limits for waters used for recreation (B) or for fishing exploitation and navigation (A).
NICARAGUA	Decree 21 "Regulation that establishes the provisions for wastewater discharge" (2017).	- Total Phosphorus (TP) - Total Kjeldahl Nitrogen (TKN) - Ammonia Nitrogen ($N\text{-}NH_3$)[17] - Phosphate (PO_4) - Nitrogen of nitrate ($N\text{-}N0_3$)	TP: 12 mg L^{-1} TKN: 60 mg L^{-}	For discharges to the sanitary sewer network.
			TN: 45 mg L^{-1} TP: 15 mg L^{-1}	For discharges from sanitary sewer treatment systems.
			TN: 30 mg L^{-1} TP: 10 mg L^{-1}	For discharges from domestic wastewater treatment systems.
				For discharges from the folowing industries to the receiving bodies[18]:
			TN: 30 mg L^{-1}	1. Slaughterhouses
			TN: 45 mg L^{-1}	2. Dairy Industry

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[17] In this standard is not specified, the chemical formulation of the referred element. It is assumed that ammonia nitrogen correspond to nitrogen in form of soluble ammonia ($N\text{-}NH_3$).

[18] Decree 21 establishes as a receiving body all streams or natural reservoirs of water, basins, channels, marine areas or public property, where wastewater is discharge, as well as the land where wastewater is infiltrated or injected.

			N-NH_3: 5 mg L^{-1} Soluble phosphate: 0.5 mg L^{-1} N-$N0_3$: 20 mg L^{-1}	3. Aquaculture
			N-NH_3: 10 mg L^{-1} TP: 2 mg L^{-1}	4. Textil manufacturing
			TKN: 30 mg L^{-1}	5. Pharmaceutical industry
			TP: 5 mg L^{-1}	6. Thermoelectric plants
			N-NH_3: 15 mg L^{-1} TP: 5 mg L^{-1}	7. Oil refining and petrochemicals
			N-NH_3: 12 mg L^{-1}	8. Iron and steel
				For discharges from the agro-industry to receiving bodies:
			TKN: 50 mg L^{-1} PO_4: 20 mg L^{-1}	1. Swine and caprine farms
			TN: 50 mg L^{-1}	2. Livestock
			TP: 15 mg L^{-1}	3. Soaps and detergents
			TN: 50 mg L^{-1}	4. Cofee beneficits
PANAMA	Technical Regulation DGNTI - COPANIT 35 - 2019: "Environment and health Protection. Security. Water quality. Discharge of liquid effuents to continental and marine water bodies" (2019).	• Total Phosphorus (P) • Total Nitrogen (N) • Ammonia Nitrogen (N-NH_3) • Nitrate (NO_3)	TP: 10 mg L^{-1} TN: 15 mg L^{-1} N-NH_3: 3 mg L^{-1} NO_3: 10 mg L^{-1}	The regulation specified in an annex the parameters to assess according to the economic activity of the issuing establishment. The total phosphorus and nitrogen appear in the vast majority of economic activities with these limits.
	Technical Regulation DGNTI-COPANIT 39 – 2000: “Discharge of liquid effluents directly to wastewater collection systems” (2000).	• Total Phosphorus (P) • Ammonium ion (NH_4^+)[19] • Total Nitrogen (N)	P: 10 mg L^{-1} NH_4^+: 80 mg L^{-1} N: 100 mg L^{-1}	

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[19] The regulation explicitly refers to ammonia nitrogen as ammonium ion (NH_4^+)

DOMINICAN REPUBLIC	"Environmental Standard on the control of discharges to surface waters, sanitary sewers and coastal waters." (2012)	• Ammonium Nitrogen (N-NH$_4$) • Ammonium Nitrogen (N-NH$_4$) plus nitrates (NO$_3$) • Orthophosphate (P-PO$_4$) • Total Phosphorus (PT) • Total Nitrogen (NT)	N-NH$_4$: 10 mg L^{-1} N-NH$_4$ + NO$_3$: 18 mg L^{-1} P-PO$_4$: 3 mg L^{-1}	For municipal wastewater discharges into surface waters (rivers, lakes, reservoirs, among others). Set the limits according to the population tax dutie. Limits are shown for populations greater than 10,000 inhabitants. For populations less than 10,000 inhabitants, it does not establish limits for nutrients.
			N-NH$_4$: 30 mg L^{-1} N-NH$_4$ + NO$_3$: 50 mg L^{-1} P-PO$_4$: 8 mg L^{-1}	For municipal wastewater discharges in coastal waters. Limits are shown for populations greater than than 10,000 inhabitants. For populations less than 10,000 inhabitants, it does not establish limits for nutrients.
			TP: 10 mgL^{-1} TN: 40 mgL^{-1}	For industrial wastewater discharges to sewer.
			N-NH$_4$: 10 mg L^{-1} TP: 2 mgL^{-1}	For industrial discharges to surface waters. The limits are shown for all types of industries, although specifies nutrients for some industries as sugar, soft drinks, coffee, thermoelectric, among others, with values very similar to those presented.

Annex 5.1. Objectives of the WCR Regional Nutrient Pollution Reduction Strategy and Action Plan

The general objective of the Strategy is to establish a collaborative framework for the progressive reduction of the negative impacts of nutrient loading on coastal and marine ecosystems in the Wider Caribbean Region and has the specific objectives:

i. To assist in defining regional standards and criteria for nutrient discharges including regional indicators for monitoring nutrient discharges to the marine environment;

ii. To support institutional, policy and legal reforms relating to nutrients and sediments management including supporting integrated, high-priority interventions to reduce discharge of untreated sewage, nutrients and sediments, agrochemical run-off, and promote resource recovery of treated wastewater;

iii. To contribute to relevant regional and global commitments, including United Nation Environmental Assembly (UNEA) Resolutions on marine pollution, the Cartagena Convention for the Protection of the Marine Environment of the Wider Caribbean Region and SDGs 6 and 14;

iv. To identify high priority areas for further action based on most affected ecosystem types and most important socio-economic impacts;

v. To assist in defining new areas of research relating to nutrient pollution in the Wider Caribbean Region;

vi. To assist in establishing the pollution baseline and informing the development of national and/or regional projects including those funded by the Global Environment Fund (GEF);

vii. To facilitate building in-country capacity to access funding to implement best practices/interventions for nutrient reduction;

viii. To contribute to the operationalization of the Caribbean Platform for Nutrients Management;

ix. To facilitate knowledge exchange and transfer on best practices and case studies relating to nutrients and sediments management including South-South cooperation and GEF International Waters(IW) Learn;

x. To contribute to leveraging of additional financing for on-ground investment in best practices to reduce the influx of land-based nutrient pollution to the Caribbean Large Marine and North Brazil Shelf Ecosystems;

xi. To expand the baseline developed under the State of Convention Area (Pollution) Report and identify most important “regionally relevant” pollution sources in terms of the transboundary nature of both sources and impacts.

Annex 5.2. Draft compendium of strategies and management practices for nutrient pollution

The compendium describes strategies and best management practices (BMPs) to control point and nonpoint source of nutrient pollution and address the environmental and socio-economic impacts.

Main information sources for the compendium:

GPNM BMP Database: http://nutrientchallenge.org/bmp-database

HELCOM. 2007. Examples of measures for reducing phosphorus and nitrogen losses from agriculture. In HELCOM Baltic Sea Action Plan. HELCOM, Finland.

IADB 2019. The Role of Green Infrastructure in Water, Energy and Food Security in Latin America and the Caribbean: Experiences, Opportunities and Challenges. Authors: Crisman, T.L. and Muñoz Castillo, R. IADB

Louisiana Nutrient Reduction and Management Strategy lnteragency Team. 2019. Louisiana Nutrient Reduction and Management Strategy: Protection, Improvement, and Restoration of Water Quality in Louisiana's Water Bodies. Coastal Protection and Restoration Authority of Louisiana, Louisiana Department of Agriculture and Forestry, Louisiana Department of Environmental Quality, and Louisiana Department of Natural Resources. December 2019. Baton Rouge, LA.

Mississippi Department of Environmental Quality. 2012. Mississippi’s strategies to reduce nutrients and associated pollutants. Jackson, MS.

Sutton M.A., Bleeker A., Howard C.M., Bekunda M. et al. 2013. Our Nutrient World: The challenge to produce more food and energy with less pollution. Global Overview of Nutrient Management. Centre for Ecology and Hydrology, Edinburgh on behalf of the Global Partnership on Nutrient Management and the International Nitrogen Initiative.

UNEP CEP 1994. Guidelines for sediment control practices in the Insular Caribbean. CEP Tech. Report 32. UNEP-CEP, Kingston.

UNEP CEP 1998. Best management practices for agricultural non-point sources of pollution. CEP Tech. Report 41. UNEP-CEP, Kingston.

MANAGEMENT PRACTICES

NON-POINT SOURCES AND POINT SOURCES OF NUTRIENTS

Note:

- See Annex 1 for N and P reduction efficiency for a range of management practices – only indicative, since efficiency will depend on crop and site-specific factors.
- The level of improvement shown for some of the practices is taken from Louisiana Nutrient Reduction and Management Strategy Interagency Team, 2019. This is only indicative and will depend on site-specific factors.

PILLAR 1: SUSTAINABLE NUTRIENT MANAGEMENT IN AGRICULTURE/LIVESTOCK FARMING
Objective 1.1. Improved nitrogen use efficiency in crop production
Nutrient management/nutrient use efficiency to reduce agricultural nutrient loading Nitrogen or fertilizer use efficiency aims at increasing crop production and optimizing the use of external resources (specifically fertilizers) by matching nutrient supply with crop requirements. It contributes to improving food security and minimizing nutrient losses and eutrophication. Requires implementation of BMPs that optimize fertilizer use. To reduce the risks of nutrient pollution, fertilizers should be applied only when needed, and applications should be limited to the necessary area and the minimum recommended amount. NUE can lead to substantial improvement. BMPs for nutrient management/NUE are described below.
‘4R’ Nutrient Management Stewardship 1. Right fertilizer: Select fertilizers on the basis of the crop, the yield and the soil characteristics to ensure that the necessary quantities of the essential crop nutrients are only available when required for uptake by the crop. A number of products have emerged that have the potential to increase overall N use efficiency (e.g., slow release fertilizers, nitrification inhibitors, urease inhibitor, enhanced efficiency fertilizers, organic fertilizers). 2. Right amount: Determine the optimum amount of fertilizer needed by specific crops (Refer to Information on N and P requirements of specific crops in Annex X). The precision agriculture method of variable rate technology (VRT) provides the means to change the rate of fertilizer application through mapping the soil characteristics of a farm and determining the appropriate rate and amount of application for a given area of land. 3. Right time of application: Ensure that the necessary quantities of the essential nutrients are only available when required for uptake by the crop. Apply fertilizer according to weather forecasts or seasonal weather patterns to avoid spreading of mineral fertilizers and manure during high-risk periods (e.g., heavy rains) to reduce the availability of nitrate for loss through leaching and of phosphorus for loss in surface runoff. 4. Right placement: Using low-emission application and precision placement methods to reduce leaching into water courses. These methods will help to prevent the exposure of fertilizers to surface runoff and drain flow losses. For example, reducing surface application and incorporation of nitrogen and phosphorus into the soil by methods such as tilling, injection techniques, fertigation, and mulching, prior to planting. Phosphorus is stable once it is mixed into the soil. Since nitrogen is very mobile it should be applied frequently in small amounts tailored to the crop’s immediate needs and growth pattern. A broadcast method of fertilizer application should not be used during strong winds. Avoid the application of fertilizers and manure to high-risk areas (e.g., hillsides, area draining into a nearby water course) to prevent the mobilization and transfer of nitrate and phosphorus to watercourses. This method is most

effective against losses of phosphorus where the primary mechanism of transport is surface runoff.

Natural fertilizers**.** Manure and other waste or by-product materials can be used as natural fertilizers, which minimizes the need for chemical fertilizers. For example, farms that grow coffee can use a mixture of coffee bean shells and animal manure to make fertilizers. Although the natural fertilizer might need to be supplemented with chemical fertilizers, the amount of chemical fertilizer needed is reduced. This approach also helps address the issue of waste disposal from crop processing. Under the GEF Rep-Car project, in Costa Rica pineapple stubble was crushed and converted into an organic bokashi-type fertilizer (organic fertilizer obtained from fermentation), which is subsequently incorporated into the soil.

Integrated weed, pest and disease management**:** Minimizes yield losses while reducing impacts on the environment. For example, in the GEF/UNEP-CEP Rep-Car project, measures to control weeds and pests were integrated with other practices, reducing the amount of fertilizers needed and improving crop production.

Nutrient Management Plan. The following practices, components, and sources of information should be considered (adapted from USEPA, 1993):

- Use of soil surveys and soil testing to determine soil productivity and identify environmentally sensitive areas. Soil testing should include pH, phosphorus, potassium, and nitrogen data. Soil and plant analyses help in determining the types of fertilizers needed to produce a high yield of a crop with minimal environmental impacts. For example, fertilizer application can be based on the results of a soil test (for pH, phosphorus, potassium, and nitrogen) combined with the crop nutrient requirements (if known). Calculating nutrient balances provides information on the efficiency of nutrient utilization and helps to identify the cropping phases in which nutrients are lost.
- Plant tissue testing.
- Use of proper timing, formulation, and application methods for nutrients that maximize plant utilization of nutrients and minimize loss to the environment.
- Use of cover crops and buffer areas.
- Control of nutrient losses from fields through a combination of erosion and sediment control measures.

Objective 1.2. Improved nutrient management in livestock farming

Animal feeding

1. Dietary management: Reducing dietary nitrogen and phosphorus intakes- Managing animal diets by using easily digestible feeds, feeding to well-established nutritional requirements, and using additives that increase feed nutrient digestibility.

2. Phase feeding of livestock: Greater division and grouping of livestock on the basis of their feed requirements allows more precise formulation of individual rations.

3. Grazing Management**: I**ncludes determining the maximum number of animals per hectare based on the amount of manure that can be safely applied per hectare of land. For a sound grazing management system to function properly and to provide for a sustained level of productivity, the following should be considered (USEPA, 1993).

Manure and waste management

A complete manure management system involves collection, storage (temporary or long-term), and ultimate disposal or use. A manure management plan should establish fertilizer plans to use manure effectively.

Improving fertilizer value by reducing losses*:* Minimizing emissions from animal housing, manure storage and handling, manure treatment, and from land application of manure.

Improving fertilizer value by manure processing*:* Technologies to process manures into organic fertilizers that are easier to store, transport, handle, and apply. E.g., Pelletization of drier manures (poultry litter and manures that have already been treated and separated) for direct use as organic fertilizers or that enrich manures by addition of inorganic fertilizer nutrients (e.g., ‘P-enriched compost’) to create more balanced fertilizers; composting solid manure; slurry separation (the liquid part with lower nutrient concentration can be utilized at the production site and the solid with high dry matter content and high nutrient concentration can be transported to the other farms). An added benefit is reduced cost of purchasing chemical fertilizer, reduced pest resistance, and promoting integrated pest management (links well to work of FAO).

Disposal of dead livestock**.** Dead livestock should be disposed of properly to reduce the potential for ground and surface water contamination from pathogens and nutrients, and also reduce risk to human health. They should be removed from streams or fields and isolated until disposal is possible. Proper disposal methods include composting and incineration.

Erosion and Sediment Controls for Livestock Areas

Deferred Grazing. Also called rotational grazing, removes livestock from an area for a prescribed period of time. This practice reduces nutrient loads from manure and allows vegetation to recover. It can also be used as a planned grazing system, in which two or more grazing units are alternately rested and grazed for a planned period of time (USEPA, 1993).

Heavy Use Area Protection. Heavy use areas can be protected by establishing vegetative cover, surfacing the area with suitable materials, or installing structures. This practice may result in a general improvement of surface water quality through the reduction of erosion and sedimentation. Heavy use areas include livestock feeding, shade, and watering areas; pathways leading to water bodies; and similar areas that livestock frequently use. Also important for reducing flooding and its risks to human communities.

Livestock Exclusion. The exclusion of livestock from areas such as waterways and stream banks to reduce the amount of sediment and manure that can enter surface waters.

Integrated farming

Integrated farming- crop production, livestock, fish (see Foundation Center for the Investigation in Sustainable Systems of Agricultural Production CIPAV). Wastes and crop residues can be digested in a biodigester to produce fuel for household cooking and electricity.

Silvopasture (substantial improvement): The deliberate integration of trees, forage, and grazing domesticated animals on the same land. These systems are intensively managed for both forest products and forage, providing both short- and long-term income sources. Well-managed silvopastures employ agronomic principals, typically including introduced or native pasture grasses, fertilization and nitrogen-fixing legumes, and rotational grazing systems that employ short grazing periods that maximize vegetative plant growth and harvest.

PILLAR 2. NUTRIENT MOBILIZATION FROM NONPOINT SOURCES

Objective 2.1. Reduced agricultural runoff

Water management to reduce nutrient losses in runoff from agriculture to aquatic systems (rivers and groundwater) by reducing erosion and sediment production

Reduce nutrient losses through site-specific mitigation measures, including erosion control measures, cover crops, tillage management, best practices for fertilizer and manure applications, and buffer strips. Water management practices reduce erosion and nutrient losses in runoff by minimizing or slowing water flow off the fields, and also conserve water. Water management on farms involves two aspects: 1) managing irrigation of crops; and 2) managing the surface and ground water flow (hydrology) to maximize resource use and minimize environmental damage. Water management practices increase water residence time on watershed soils to increase the potential for infiltration and denitrification without reducing crop productivity. These practices can be integrated with nutrient reduction management practices to reduce nutrient loadings and/or increase denitrification to waterbodies. Also focuses on minimizing the amount of exposed soil and the time the soil is exposed, making the soil less susceptible to erosion.

Conservation practices

1. Plant cover (moderate to substantial improvement): Protects the topsoil against the erosive forces of wind, rain and runoff. Timber, native vegetation, and grassed areas have significantly less runoff than exposed ground or impervious surfaces such as pavement, sidewalks, and parking lots. Without plant cover, nitrate can be lost through leaching by excessive rainfall and phosphorus through sediment transport in surface runoff. The method is relatively easy to implement. The costs depend on the chosen plant, area and the possibility to use the farmer's own machinery or a contractor. (See below for details on erosion control).

2. Recycle nutrients in runoff back onto yards, golf courses, green spaces, timber acreage, cropland, etc., to reduce nutrient input requirements (with input management) and satisfy grass, sod, timber, crop water requirements.

3. Irrigation water management: Irrigation water management is the practice of timing and regulating irrigation water applications in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. It means applying water according to crop needs in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site. Irrigate the crop as needed, using precision methods, such as drip irrigation, combined with soil water harvesting methods and soil conservation practices. Each crop will have a set of specific crop coefficient and will predict different water use for different crops and growth stages.

4. Groundwater: Implement practices to protect groundwater from nutrient inputs. The most common groundwater contaminant from fertilizers and organic soil amendments is nitrogen. The nitrate form of nitrogen (NO3-N) dissolves very easily in water and can leach downward, particularly through coarse-textured (sandy) soils. The US EPA has set the maximum contaminant level (MCL) for nitrate-nitrogen in drinking water at 10 mg/L. Recommended nutrient criteria for nitrogen and phosphorus in streams and rivers have been established by US EPA for protecting beneficial ecological uses and preventing nuisance plant growth for different geographic regions of the country.

(Dzurella, K.N., Medellin-Azuara, J., Jensen, V.B. et al. 2012. Nitrogen Source Reduction to Protect Groundwater Quality. Technical Report 3 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis).

Contour Farming (slight to moderate improvement). Use of ploughing, planting, and other management practices along established land contours. Contour farming reduces erosion and sediment production, thereby reducing the transport of nutrients to receiving water bodies.

Water diversions. Drainage channels constructed across the slope with a supporting ridge on the lower side to control downslope runoff, thereby preventing or reducing erosion and enhancing infiltration into the groundwater. Maintaining drainage channels prevents or reduces erosion and takes up nutrients.

Terracing. Constructed earthen embankments that slow the rate of runoff and reduce erosion by breaking the slope into numerous flat surfaces separated by slopes that are protected with permanent vegetation or are constructed from stone or other materials. Terracing is carried out on very steep slopes and on long, gentle slopes where terraces are very broad. Simple terracing systems such as intermittent terraces, convertible terraces, orchard terraces, and hillside ditches are alternatives to the more expensive bench terrace. Intermittent terraces are used for larger tree crops, while orchard terraces are narrower terraces built for a single tree or bush. Terracing can increase the area of land in production.

Wind Erosion Control. Wind erosion controls reduce erosion and nutrient runoff due to wind transport of sediment by protecting crops against winds and stabilizing soil vulnerable to erosion. Common wind breaks include shrubs and trees planted in borders or along property boundaries. Once established, wind breaks become permanent.

Sediment Fencing: When built across the slope, fencing (usually for livestock) with the proper vegetation along the fencerow slows down runoff and causes deposition of coarser-grained materials. It serves as a sediment trap, reducing the amount of sediment carried downslope. Fencing can be placed to protect water bodies from livestock activity and, with the proper vegetation along the fencerow, serves as a trap to sediments and solid waste.

Field Borders (slight to moderate improvement). Strips of perennial herbaceous vegetation or shrubs (typically grasses) established along the edges of fields. They slow runoff and trap coarser sediment, but generally are not effective for fine sediments. This method is mainly suited for gentle slopes and areas of lower rainfall.

Filter Strips (moderate to substantial improvement). Areas of vegetation for removing sediment, organic matter, and other pollutants from runoff. Like field borders, filter strips trap coarser-grained sediment and might not be effective on suspended fine-grained materials. Filter strips are most effective when downslope runoff flows across them as sheet flow, resulting in the deposition of sediment and polluted runoff.

Grassed Waterway or swales (slight to moderate improvement). Natural or constructed channels that are vegetated, graded, and shaped to inhibit channel erosion. Grassed waterways require little maintenance, but they must be graded to channel the runoff away from the site.

Sediment Basin (substantial improvement). Constructed to remove and store sediment from runoff during rainfall events. Runoff flows to the basin and is held for a period of time, allowing the sediment to drop out of suspension. Sediment basins must be cleaned out periodically for proper functioning.

Controlled sub-surface drainage: Recycle nutrients in runoff back onto the fields, yards, golf courses, green spaces, timber acreage, cropland, etc., to reduce nutrient input requirements (with input management) and satisfy grass, sod, timber, and crop water requirements.

Other erosion and sediment control

Conservation Cover/Stabilization Practices (moderate to substantial improvement): Conservation cover/stabilization practices including riparian herbaceous cover establish and maintain perennial vegetative cover to protect soil and water resources on land that is not under agricultural production. Vegetative cover reduces erosion potential by (1) shielding the soil surface from the impact of rainfall, (2) slowing runoff velocity and allowing sediment deposition, (3) physically holding soil in place with plant roots, and (4) increasing infiltration rates by improving the soil's structure and porosity through the incorporation of roots and plant residues. Natural vegetation preservation is particularly beneficial in floodplains, wetlands, steep slopes, and other areas where erosion controls are difficult to establish, install, or maintain. Conservation cover/stabilization practices are also suggested for use in drainage structures on agricultural lands where canals or ditches are used to remove excess water. The slopes and bottoms of the canals and ditches should be planted with suitable ground cover vegetation to prevent erosion and promote uptake of excess nutrients that might otherwise run off.

Conservation Tillage

- *Residue and tillage management – no till (Moderate to substantial improvement)*
- *Residue and tillage management – reduced till (slight to moderate improvement)*

Minimum or no till maintains organic matter and preserves good soil structure, reduces erosion and improves infiltration and retention of water and thereby decreases total phosphorus concentrations in surface runoff. Reduced tillage consists of either minimizing tillage to a coarse finish with machinery or hand tools or tilling only the rows or digging holes for crops like banana. Reduced tillage systems incorporate some pesticides and fertilizers when applied to the soil surface, reducing their runoff. The no-till method consists of planting crops without prior seedbed preparation into an existing cover crop, sod, or crop residues, with no subsequent tilling operations. No-till planting is the most effective conservation method to protect against soil erosion.

Cover Crop and Catch Crops (slight to moderate improvement): Fast-growing crops that are grown simultaneously with or between successive plantings of the main crop. Include close-growing grasses, legumes, and small grains grown primarily for seasonal protection and soil improvement. Maintaining a cover crop prevents or reduces erosion and takes up nitrogen. In addition, a cover crop traps and recycles nutrients for use by later crops- the overall volume of fertilizer application may decrease because the vegetation (if nitrogen-fixing, such as legumes) will supply nutrients. A cover crop planted between the rows of a cash crop also controls weeds.

Buffer Zones/Riparian Forest Buffer (substantial improvement): Establishing vegetated and unfertilized buffer zones alongside watercourses reduces erosion and the movement of nutrients into watercourses. They also intercept overland flow from agricultural areas just before it reaches the watercourse. The vegetation slows surface water runoff, allowing sediment to drop out of suspension before entering receiving waters. Soluble nutrients can also be taken up by plants in the buffer zone. Buffer zones should be free-draining and with adequate porosity to intercept surface runoff. The efficiency of buffer zones in removing suspended solids and nutrients is affected by the width of the zone, gradient of the drained field, soil type and particularly by the variety and density of zone vegetation. See Green infrastructure below.

Critical Area Planting (slight improvement): Planting vegetation (trees, shrubs, vines, grasses, and legumes) on highly erodible or critically eroding areas. During the initial stages of planting, large quantities of sediment and associated chemicals may be transported by runoff prior to plant establishment.

Mulching (slight to moderate improvement): A temporary soil stabilization or erosion control practice in which materials such as cut grass, wood chips, wood fibers, or straw are placed on the soil surface to temporarily stabilize disturbed areas until a seeded crop or vegetation is established. Mulching reduces the direct impact of rain, maintains maximum soil infiltration, and decreases the quantity, velocity, and transport capacity of runoff water. Mulching is also an effective water conservation tool. It is inexpensive and easy to implement. Mulching provides a method of weed control, and organic mulch is biodegradable. On steep or highly erodible slopes, mulch should be used with some type of anchoring system, such as netting. Mulching is also an alternative to tilling or hoeing, which has been a common form of weed control. Mulching materials can also be obtained from the crop itself (Crop residue use)**.** Mulch can intercept light rains, which evaporate prior to reaching the crop roots. In addition, decaying mulch can immobilize fertilizers and reduce the availability of nutrients to plants.

Crop Residue Use (see Mulching)**:** Crop residues (such as leaves and remnant stalks) left or spread on cultivated fields protects soil during critical erosion periods. Crop residues reduce erosion by intercepting rainfall, thereby decreasing soil dispersion and soil compaction. Microbial and bacterial action within the residue takes up nutrients and pesticides, delaying their entrance to surface waters.

Delayed Seedbed Preparation: All crop residue and naturally occurring vegetation can be maintained on the soil surface until shortly before the succeeding crop is planted. This reduces the period that the soil is exposed and susceptible to erosion. Delayed seedbed preparation maintains vegetative cover as long as is practical to minimize splash erosion and nonpoint source pollution during critical erosion periods such as the rainy season. Additionally, moisture is conserved, water quality improved, and soil infiltration increased.

Indigenous Weed Management (green manuring)

Strip Cropping: Growing crops in a systematic arrangement of strips or bands across the general slope (not on the contour) to reduce water erosion. Crops are arranged so that a strip of grass or close-growing crop is alternated with a clean-tilled crop or fallow. This method is mainly suited for gentle slopes and areas of lower rainfall.

<u>Conservation Cropping (slight to moderate improvement):</u> A sequence of crop rotations designed to provide adequate organic residue for maintenance of the physical condition of soil (especially in relation to its suitability for planting or growing a crop). This practice reduces erosion by increasing organic matter, resulting in a reduction of sediment and associated pollutants to surface waters. Legumes and grasses are the typical plants used in the rotation, together or individually, reduces runoff and provides a source of organic nitrogen, thereby reducing fertilization needs. As the grasses and legumes grow, they will take up more phosphorus. They also provide an opportunity for animal waste management because manures and other wastes may be applied for an extended period of time due to the nutrient uptake by the grass and legume species. Select the right crop cultivar, planted at right spacing and right time, within the right crop rotation.

Green infrastructure

- *Wetland construction (moderate to substantial improvement)*
- *Wetland creation, restoration, enhancement (moderate improvement)*

Some of the BMPs described above are green infrastructure (e.g., buffer zones; rain gardens, bioswales - landscape features that collect polluted stormwater runoff, soak it into the ground, and filter out pollution). Green infrastructure (a subset of nature based solutions), utilizing ecosystems or their structural and functional components, can be implemented rapidly and provide a cost-effective treatment equivalent to gray infrastructure (IADB 2019). Green infrastructure has historically focused on constructed wetlands for wastewater treatment but has recently evolved into a broader approach involving multiple, integrative technologies to address urban sustainability in water, energy and food (IADB 2019). Created and restored wetlands significantly reduce the transport of TN and TP in treated wastewater and urban and agricultural runoff and have therefore become a well-established eutrophication remedy (e.g. Land et al. 2016, Nilsson et al. 2020). However, more research is needed on the effects of hydrologic pulsing on wetlands. There is also a lack of evidence for long-term (>20 years) performance of wetlands. (See for example, Land et al. 2016, Nilsson et al. 2020).

While green infrastructure can operate as stand-alone technologies, they are increasingly integrated with gray (concrete) infrastructure to produce hybrid solutions to meet increasing demands from individual sectors of the nexus, promote interactions among sectors, and improve overall management efficiency (IADB 2019). Whenever possible, only native species of plants should be used in constructed wetlands. Wetlands are expensive to construct, may often involve the loss of some agricultural land, and require maintenance. For them to operate at peak efficiency, vegetation must be harvested and/or sediments removed periodically. (See IADB 2019 for a review of green infrastructure in LAC). In addition to improving water quality, wetlands reduce the severity of floods downstream by retaining water and releasing it during drier periods and protect stream banks. Wetlands can have a recreational/ecotourism value as well as a biodiversity value.
(good opportunity for small pilot projects)

(IADB 2019. The Role of Green Infrastructure in Water, Energy and Food Security in Latin America and the Caribbean: Experiences, Opportunities and Challenges. Crisman, T.L. and Muñoz Castillo, R. IADB)

Objective 2.2. Reduced urban and stormwater runoff

1. Assess nutrient loads from non-agricultural (urban/suburban, industrial, commercial) sources.
2. Determine what nutrient load reductions are achievable and cost-effective by source type through various BMPs for both water quantity and water quality.
3. Establish nitrogen and phosphorus stormwater permit limits based on the results.
4. Integrate green infrastructure management practices- bioswales, rain gardens, permeable pavement, pixilated parking, biofiltration, alternative curbs, urban reforestation, parkways, and conservation development- as part of current incentives for development. Retention and detention. Capture stormwater runoff in lagoons for reuse/recycle for irrigation, etc.
5. Separate stormwater - stop the use of combined sewers, prevent/reduce stormwater infiltration into the sewerage system, disconnect illegal drainage connections to the sewers.
6. Develop awareness, outreach and education programmes on reducing stormwater runoff and nutrient loading from non-agricultural sources.

Pillar 3: Domestic wastewater effluent discharge including from tourism (point sources)
(See CReW project reports)

Objective 3.1. Domestic wastewater effluent within established standards for nutrients

Reduce nutrient loadings (nitrogen and phosphorus) from point source discharges (of domestic wastewater) into waterbodies.

Improve wastewater treatment effectiveness

1. Increase the efficiency and effectiveness of existing wastewater treatment facilities through operational changes in existing facilities to treating nutrients in wastewater at the source (primary treatment involves physical removal of floatable or settable solids; secondary treatment involves biological removal of dissolved solids; tertiary treatment includes processes to remove nutrients. high cost)
2. Implement approaches that will either reduce nutrient loads in the influent to the treatment system or modify influent quality to improve treatment effectiveness and/or efficiency.
3. Decentralized, onsite treatment systems with zero discharge.
4. Integrated onsite/instream treatment systems for some streams where instream structures or characteristics can reduce nitrogen loading through denitrification and sequester phosphorus loads in sediments.

Alternative treatment technologies for wastewater systems and specific measures
Including:

- New and cost-effective wastewater treatment technologies
- Individual onsite/home systems
- Wastewater to wetlands
- Reuse and recycling opportunities and options (e.g. grey water to agriculture crop irrigation, for cooling, irrigation, or dust control on construction sites or road construction or other non-drinking water uses, under a strict public and environmental health regulatory regime)
- Land application of residual solids generated at wastewater treatment facilities (Biosolids from sewage and manure for use as fertilizers)

(Important to monitor recycled products for reuse to ensure they meet acceptable standards and are free of heavy metals, or emerging contaminants before use).

- Banning the use of detergents containing phosphorus

Sewage outfalls
Review locations of facility outfalls and assess alternative outfall locations that could minimize nutrient effects on the marine environment.

Establish numeric nitrogen and phosphorus criteria and limits

1. Establish quantitative nitrogen and phosphorus limits that are achievable and cost-effective, and meet ecological criteria. To be addressed in the LBS Protocol and at national levels.
2. Monitor nitrogen and phosphorus concentrations and flow in both the effluent discharge and downstream to document nutrient load reductions and associated instream effects.

(CReW+: reduction of 147 kg N per day; 31 kg P per day through improved wastewater treatment in rural and peri-urban hotspots using low tech and IWWM solutions processing 3500 m3 per day
The calculations are based on the parameters for strong-medium concentrations as per the FAO document on wastewater characteristics and effluent quality parameters (www.fao.01 doer ff0551E/t055Ie03.htm) and the parameters on the document "Wetland nutrient removal: a review of the evidence" (www.h drol-ea1th-s st-sci.net/8/673/2004/hess-8-673-2004)

PILLAR 4: INDUSTRIAL EFFLUENT

Objective 4.1. Industrial effluent within established standards for nutrients

Strategies and BMPs will depend on the type of industry. An Industrial Wastewater Treatment Technology Database was developed by the US EPA and is available at https://watersgeo.epa.gov/iwtt/guided-search. See also the GEF CReW (2016b) Wastewater Policy Toolkit. Adoption of process-based systems such as ISO 14001 for environmental management systems.
PILLAR 5. MARINE SOURCES OF NUTRIENTS
Objective 5.1. Reduced nutrient pollution from maritime sources and activities
MARPOL Annex IV requires ships to be equipped with approved sewage treatment plant or approved sewage comminuting and disinfecting system or a sewage holding tank, and the provision by countries of adequate port reception facilities for sewage. Existing treatment technologies available to cruise lines include traditional Type II Marine Sanitation Devices and Advanced Wastewater Treatment Systems (AWTS). However, these onboard systems are not designed to remove nutrients, but to remove pathogens, suspended solids, BOD, etc. Strategies and BMPs relevant to domestic wastewater effluents will be applicable to ship-generated waste in the reception facilities. Other strategies include process-based systems such as ISO 14001 for environmental management systems, eco-certification and ecolabeling (particularly relevant to the cruise ship industry).
PILLAR 6: COASTAL WATER QUALITY
Objective 6.1. Coastal water quality within environmental standards (for ecological function and designated human uses)
The above strategies and BMPs will contribute to reducing nutrient pollution and restoring coastal water quality. Ecosystem-based approaches (e.g., integrated watershed and coastal area management, integrated coastal zone management, marine spatial planning); reducing erosion and runoff and establishing vegetative buffer zones along water courses and along the coast - mangrove forests, salt marshes and seagrass beds; restoration and protection of coastal vegetation, which must be accompanied by measures to address sea-based sources such as shipping, tourism, marine industries, and atmospheric deposition of nutrients to the ocean.
PILLAR 7: PRODUCTIVE COASTAL AND MARINE HABITATS
Objective 7.1. Reduced ecological impact of nutrient pollution in coastal waters ***Objective 7.2. Reduced threat to critical marine habitats and biodiversity from nutrient pollution*** *(link to the Regional Habitats Strategy)*
See BMPs for Objective 6.1 and the Habitats Strategy. Addressing other stressors on marine habitats including climate change impacts will be key in restoring and building the resilience of marine habitats.
PILLAR 8: HUMAN WELLBEING AND THE BLUE ECONOMY
Objective 8.1. Reduced risks to human health and wellbeing from nutrient pollution ***Objective 8.2. Improved livelihoods*** ***Objective 8.3. Reduced risks to the blue economy from nutrient pollution (economic losses)***
Addressing the problem at its source; addressing data and knowledge gaps on socio-economic impacts; establishing a monitoring, forecasting and early warning system. Regular monitoring of the level of toxins in fish and shellfish; process harvested fish and shellfish to reduce toxicity to an acceptable level, for example, removal of viscera before marketing.
PILLAR 9. EFFECTIVE IMPLEMENTATION OF THE RNPRSAP

Objective 9.1. Establish enabling conditions for addressing nutrient pollution and its impacts in the WCR

See section 5.5.8 for details

OTHER CONSIDERATIONS

Atmospheric deposition
1. Promote urban forests and the forest reserve programmes to filter and remove atmospheric nitrogen species.
2. Implement green infrastructure practices to reduce nitrogen runoff in stormwater.

Sustainable forestry practices

Forestry BMPs aim at managing forest roads, logging, site preparation/reforestation, silvicultural chemicals, fire management, forest wetlands

Land-use Planning

(see IWCAM report on land use planning and watershed restoration)

Proper land use is important in controlling nonpoint source pollution. Proper land use planning involves designating areas suitable for various types of development (including agricultural development) or conservation. For example, areas on steep slopes may be appropriate for only minimal agricultural development and agricultural crops that do not require removal of all the natural vegetative cover. Areas with highly erodible soils should not be clear-cut. Prime agricultural land should be left for agriculture and not used for residential or commercial development. This prevents forcing agriculture to less desirable locations where cultivation may result in environmental degradation (e.g., steep slopes).

Non-traditional management practices for nutrient reduction

New waste treatment technologies that digest poultry litter and animal manure to generate methane for heating poultry/confined animal facilities and co-generating electricity (Biogas production)

Poultry litter and dead bird management; use of new or emerging technologies for reducing poultry litter and animal manures (digesting a mixture of municipal garbage, food processing, and livestock litter waste); nutrient management plans for golf courses, public lands, and other non-agricultural facilities that fertilize extensively; promote composting of waste and partner with local farmers markets, nurseries, lawn care businesses, landscaping companies, restaurants, and construction companies to use this compost.

High tech precision agriculture

Gathering and analyzing data from sensors, tractors and satellites to track crop health and make planting decisions and guide fertilizer use to improve the efficiency of farmers' businesses. This

Selecting nonpoint source management practices

- Review watershed characteristics (Watershed Characterization in section 3), including areas where BMPs are currently in place, and target sites or hot spots where BMP implementation could contribute to nutrient reductions.
- Identify nutrient reduction BMPs that may generate nutrient reductions through proper application and maintenance in the region.
- Prioritize nutrient reduction BMPs based upon performance potential measured by professional knowledge, existing research, literature, and monitoring data as well as added economic and environmental benefits using criteria such as:

    a. BMP category – Avoid, Capture, Trap (ACT);
    b. Suites of BMPs that go together and can be bundled for implementation;
    c. Constituent of concern – sediment, nutrients, water;
    d. Expected percent reduction;
    e. Impacts, if any;
    f. Cost to install and maintain;
    g. Time to install;
    h. Area of land required for implementation;
    i. Compatibility/incompatibility with other BMPs; and
    j. Direct/indirect benefits to individual or business paying for implementation.

Selection of BMPs is also dependent on local soil and climate conditions, crop type, management conditions, and other site-specific factors.

Cost-effectiveness

1. For each cost element, by crop, identify alternative approaches for reducing costs, increasing yield, and/or profit (e.g., variable rate fertilizer application, alternative nitrogen forms).
2. Consider emerging technology to time fertilizer application for maximum uptake or need by plants.
3. Improve irrigation scheduling for fields to maximize plant uptake and minimize runoff:
    a. Emphasize reuse/recycling of nutrients in irrigation runoff or surface water.
    b. Evaluate soil moisture/plant turgor probes or sensors for scheduling irrigation.
4. Document decreased costs/increased revenue among farmers who have implemented input management practices/plans in production.
5. Review emerging markets, genetic modifications, and alternative crops with increased yield and/or reduced production costs appropriate for WCR farms.
6. Develop input management plans streamlined and applicable for large producers.
7. Identify specific farmers and farms to pilot input management practices and document benefits.

Annex 5.3. Estimated Crop $\mathrm{NUE_N}$ and Full-chain $\mathrm{NUE_N}$ per country for 2008 (baseline) as compared with an aspirational target for 2020, based on a 20% relative improvement from the 2008 values.

The right-hand columns show the equivalent total savings per country (kton N /year) achieved by the aspirational goals. For countries where the baseline values exceed the eventual target values, the nutrient saving is set at zero in the last two columns.

- indicates data not available. N_r input per person is calculated as the sum of fertilizer input, combustion fixation as NO_x, biological N fixation and import at a national level. (Sutton *et al.*, 2013)

Countries	Estimated annual N input per person	Crop $\mathrm{NUE_N}$	Full-chain $\mathrm{NUE_N}$	Crop $\mathrm{NUE_N}$	Full-chain $\mathrm{NUE_N}$	N saving from aspirational Crop $\mathrm{NUE_N}$ goal	N saving from aspirational Full-chain $\mathrm{NUE_N}$ goal
	Baseline (2008)	Baseline (2008)	Baseline (2008)	Aspirational Goal (2020)	Aspirational Goal (2020)		
	kg N / person	%	%	%	%	(ktonne N /yr)	(ktonne N /yr)
Antigua and Barbuda	7	10	83	12	50	0	0
Bahamas	20	-	-	-	-	0	0
Barbados	9	6	36	7	43	0	1
Belize	19	34	27	41	32	1	1
Brazil	46	30	14	36	17	878	1043
Colombia	31	11	17	14	20	108	151
Costa Rica	24	13	16	16	19	12	19
Cuba	12	21	36	25	43	12	21
Dominican Republic	14	14	25	17	30	13	18
Guatemala	17	19	20	23	25	26	32
Haiti	3	-	-	-	-	-	-
Honduras	20	16	22	19	27	17	19
Jamaica	8	32	56	38	50	1	0
Mexico	27	37	24	44	29	231	363
Netherlands Antilles	53	-	-	-	-	-	-
Nicaragua	19	38	25	45	30	9	13
Panama	17	17	31	20	37	4	7
Suriname	14	-	-	-	-	-	-
Trinidad and Tobago	26	-	-	-	-	-	-
Venezuela (Bolivarian Republic of)	28	13	22	15	26	61	83

ANNEX 5.4. MONITORING FRAMEWORK

Proposed monitoring framework incorporating global targets and indicators and available regional targets and indicators, for each objective. The global targets and indicators need to be downscaled to the regional and national levels. Missing targets and indicators are to be developed, based on the best available data and refined as improved data becomes available. A sub-set of core indicators may need to be selected. The timeframe for initial implementation of the strategy is 2021-2030, in line with the Agenda 2030 timeframe. However, the timeframe is flexible to accommodate differences in context and circumstances among the countries with respect to nutrient pollution and its management and activities/targets that can be achieved within a shorter timeframe. The timeframe will be adjusted during implementation of the RNPRSAP.

BASELINE (to be established where missing)	**TARGETS**	**INDICATORS** (downscale to national level; core and secondary indicators to be defined)	**INDICATIVE TIMEFRAME**
Pillar 1: Nutrient management in agriculture/livestock farming			
Objective 1.1. Improved nitrogen use efficiency in crop production			
	Halve nitrogen waste from all sources by 2030 (Colombo Declaration on Sustainable Nutrient Management). A goal to reduce nitrogen waste by a standard amount offers a more equitable approach, whereby countries currently wasting more nitrogen would need to take more ambitious steps. For example, in a country wasting 80%, halving nitrogen waste across the economy would need to reduce total nitrogen losses from all sources to 40% of inputs (absolute reduction of 40%). By contrast, a country wasting only 50% would require an absolute reduction of 25% (Sutton et al. 2013	•Fertilizer application rate (weight/ha) by crop type •Partial Nutrient Balance (kg nutrient removed/kg nutrient applied) and Partial Factor Productivity (t yield/kg nutrient applied). •Fertilizer imports - weight/yr Others to be defined	2030
	SDG Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices	Sub-indicator of SDG 2.4.1: Proportion of agricultural area under productive and sustainable agriculture.	2030

	that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality. Sustainable Nitrogen Management Index SNMI (SDG 2): long-term objective for this indicator is a value of 0	UNECLAC complementary indicator for SDG 2.4: Intensity of fertilizer use (apparent consumption by cultivated area) SNMI is a one-dimensional ranking score that combines two efficiency measures in crop production: Nitrogen use efficiency (NUE) and land use efficiency (crop yield).	
	SDG 2.3.1. At least four specific nutrient management measures taken to mitigate environmental risks (FAO 2020).	Management of fertilizers (Fertilizer pollution risk; related sub-indicator on Soil health). Others: No. best management practices (BMP) installed/no. farms; No. farms /area under BMPs	2030
	SDG 12. Production-based nitrogen emissions: long-term objective for this indicator is a value of 2.	Production-based nitrogen emissions kg/capita (Reactive nitrogen emitted during the production of commodities, which are then either exported or consumed domestically. Reactive nitrogen corresponds to emissions of ammonia, nitrogen oxides and nitrous oxide to the atmosphere, and of reactive nitrogen potentially exportable to water bodies, all of which can be harmful to human health and the environment).	2030
See Annex 5.3 for 2008 Nitrogen use efficiency (NUE) baseline for some WCR countries	GPNM: Each country aims to improve its Crop NUE and Full chain NUE by 20% as a step towards achieving an eventual Crop NUE target of at least 70% and a Full chain NUE of 50% relative to its baseline, by 2020	Crop NUE: the nutrients in harvested crops in a country as a percentage of the total nutrient input to that country (sum of mineral fertilizer input plus crop biological nitrogen fixation). Full-chain NUE: the nutrients in food available for human consumption in a country as a % of the total nutrient inputs to that	2030

		country (sum of fertilizer inputs, BNF in crops and grass, import in fertilizer, feed and food).	
	Target 17 (Post-2020 Global Biodiversity Framework): By 2030, redirect, repurpose, reform or eliminate incentives harmful for biodiversity, including [X] reduction in the most harmful subsidies, ensuring that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity	17.0.2. Potentially harmful elements of government support to agriculture (environmentally harmful subsidies) as a percentage of GDP. (Other: Value of incentives/yr)	2030
	Socio-economic targets (improvements in crop yield, income, cost saving, etc.)	Crop yield, income, costs (annual)	2030
Objective 1.2. Improved nutrient management in livestock farming			
	See Objectives 1.1 and 2.1	See Objectives 1.1 and 2.1	
Pillar 2: Nutrient mobilization from nonpoint sources			
Objective 2.1. Reduced agricultural runoff			
	Halve nitrogen waste from all sources by 2030 (GPNM-Colombo Declaration on Sustainable Nutrient Management).	As above for SDG 12. Production-based nitrogen emissions kg/capita Others to be defined. • Fertilizer application rate (weight/ha) by crop type • Partial Nutrient Balance (kg nutrient removed/kg nutrient applied) and Partial Factor Productivity (t yield/kg nutrient applied). • Fertilizer imports - weight/yr	2030
	SDG target 2.4 (also relevant to Objective 1.1): By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and	Sub-indicator of 2.4.1: Prevalence of soil degradation: The combined area affected by any of the four selected threats (soil erosion, reduction in soil fertility, salinization of irrigated land, waterlogging to soil health) is negligible (less than 10 percent of the total agriculture area of the farm) (FAO 2020).	2030

	other disasters and that progressively improve land and soil quality.		
	SDG Target 15.2: Promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.	Indicator: 15.2.1: Progress towards sustainable forest management (preventing erosion and loss of nutrients). SDG 15.1.1: Forest area as a proportion of total area	2030
	SDG Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.	Indicator 15.3.1: Proportion of land that is degraded over total land area (supplementary indicator, UNECLAC 2018)	2030
	UNFCCC Strategic Objective 1: Improve the condition of affected ecosystems, combat desertification/land degradation, promote sustainable land management and contribute to land degradation neutrality.	SO 1-1: Trends in land cover. SO 1-2: Trends in land productivity or functioning of the land. SO 1-3: Trends in carbon stocks above and below ground.	2030
Current N and P loads in watersheds (Beusen model) Water quality (current N and P levels in rivers and groundwater)	CBD Post-2020 Framework Target 6: By 2030, reduce pollution from all sources, including reducing excess nutrients [by x%] to levels that are not harmful to biodiversity and ecosystem functions and human health. • 6.1. Reduction of pollution from excess nutrients N and P levels in rivers and groundwater at natural levels.	6.0.1. Proportion of water with good ambient water quality (freshwater and marine) • 6.1.1. Nitrogen balance (in rivers from SDG indicator 6.3.2 and in oceans from SDG indicator 14.1.1) • 6.1.2. Phosphate balance (in rivers from SDG indicator 6.3.2 and in oceans from SDG indicator 14.1.1) • 6.1.3. Fertilizer use 6.1.1.1. Trends in Loss of Reactive Nitrogen to the Environment Others: Nutrient concentrations and loadings in watersheds (e.g., nitrate leaching to groundwater kg/ha/yr; soil loss t/ha/yr):	2030

		N load in rivers and groundwater P load in rivers and ground water Sediment load % N load reduction/yr over baseline % P load reduction/yr over baseline % sediment reduction (volume of sediments reaching aquatic system) % erosion reduction (area)	
Objective 2.2. Reduced urban/stormwater runoff to coastal areas			
	SDG Target 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.	11.6.1. Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities. 11.6.2. Annual mean levels of fine particulate matter in cities (population weighted).	2030
	SDG Target 11.7: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.	SDG Indicator 11.7.1: Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities. Other: Proportion of built up and green areas	2030
	Others to be developed, based on the best available data, and refined as improved data becomes available	To be developed, based on the best available data and information	
Pillar 3: Domestic wastewater effluents			
Objective 3.1. Domestic wastewater within established effluent standards			
Current nutrient levels in effluents Current volume of wastewater treated per year and level (primary, secondary, tertiary)	Regional criteria and limits for N and P in domestic wastewater effluent, and associated target(s) to be established under the LBS Protocol.	% discharge compliant with N and P effluent standards for domestic wastewater, by municipal and industrial source. N and P loads and concentrations in wastewater effluent.	2030

	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. The long-term objective for this indicator is a value of 100 (100% wastewater adequately treated).	SDG 6.3.1. Volume of anthropogenic wastewater that receives treatment (safely treated). The percentage of collected, generated, or produced wastewater that is treated, normalized by the population connected to centralized wastewater treatment facilities. Scores were calculated by multiplying the wastewater treatment summary values, based on decadal averages, with the sewerage connection values to arrive at an overall total percentage of wastewater treated. Other: Volume treated/untreated domestic wastewater released/year Proportion treated wastewater reused/recycled	2030
	All domestic wastewater discharged to the coastal and marine environment treated at tertiary level to remove N and P. Domestic effluent standards (Need for LBS Protocol to consider nutrient discharge standards/criteria/guidelines for domestic wastewater).	N and P levels in wastewater effluent % effluent by volume compliant with effluent standards for domestic wastewater % wastewater flows treated to national standards	2030
	LBS protocol, Annex II: Effluent limit for discharge of Total Suspended Solids (TSS) in domestic wastewater into Class I waters of 30 mg l^{-1}, and Class II waters of 150 mg l^{-1}.	Volume of TSS discharged in domestic wastewater.	

Pillar 4: Industrial effluent			
Objective 4.1. Industrial effluent within established standards for nutrients			
	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.	6.3.1: Proportion of domestic and industrial wastewater flows safely treated. The long-term objective for this indicator is a value of 100 (% of wastewater treated). 6.3.2: Proportion of bodies of water with good ambient water quality.	2030
	SDG Target 12.4. 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 (does not specifically address nutrients)	SDG Indicator 12.4.1. Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement (does not specifically address nutrients)	2030
	SDG Target 12.5. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	SDG Indicator 12.5.1. National recycling rate, tons of material recycled Proxy indicator of 12.5.1. Proportion of recycled waste in relation to total collected waste (UNECLAC 2018)	2030
	To be established: Harmonized regional and national criteria and limits for N and P in industrial effluent (under the LBS Protocol)	To be established	TBD
	100% industrial effluent treated before discharge (The LBS Protocol calls for pre-treatment of industrial waste that ends up in a domestic wastewater treatment system).	Volume of industrial effluent treated before discharge/yr N and P concentration and loads in industrial discharge	2030
Pillar 5: Marine sources			
Objective 5.1. Reduced nutrient pollution from maritime activities			

	To be established (similarities with domestic wastewater)		
Pillar 6: Coastal water quality			
Objective 6.1. Coastal water quality within environmental standards for nutrients			
SOCAR baseline (few countries)	Regional targets to be established: Coastal waters (Class I and nutrient hotspots) restored to good status (or natural levels) See SOCAR report for criteria for good, fair and poor status with respect to DIN and DIP (criteria and limits to be reviewed and approved by member states) (Reinforces the need for classifying receiving waters based on ecosystem and human health considerations)	Coastal water quality indicators (national coastal water quality monitoring): N (DIN) P (DIP) Chl a DO (bottom waters) Turbidity/Suspended solids Water transparency/Secchi disc depth	2025
	SDG 14.1. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including nutrient pollution	Indicator 14.1.1: (a) Index of coastal eutrophication potential (ICEP); and (b) % Chl-a deviations (from remote sensing).	2025
	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.	6.3.1. Proportion (%) of bodies of water (rivers, groundwater and coastal waters) with good ambient water quality.	2030
Pillar 7: Healthy coastal and marine habitats			
Objective 7.1. Reduced ecological impact of nutrient pollution in coastal waters ***Objective 7.2. Reduced threat to critical marine habitats and biodiversity from nutrients*** *(link to Regional Habitats Strategy)*			

	SDG 6.6. Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	SDG 6.6.1. Change in the extent of water-related ecosystems over time. Area of mangroves: Complementary UNECLAC indicator for SDG 14.2 (UNECLAC 2018)	2025
	SDG 14.2. Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	SDG 14.2.1 Number of countries using ecosystem-based approaches to managing marine areas.	2025
	Regional targets to be established: Reduction in the incidence of algal blooms, HABs, *Sargassum* outbreaks, fish kills, etc. by 2030	Marine habitat indicators (see Habitats Strategy) Areal extent of *Sargassum* in the ocean; weight of *Sargassum* removed from beaches; No. and extent of algal blooms/yr; No. HAB events/yr; No. mass mortality events (fish kills)/yr; Area and duration of hypoxic zone (Clear link to eutrophication needs to be established)	2030
	Other relevant targets and indicators are given in the Regional Strategy and Action Plan for the Valuation, Protection and/or Restoration of Key Marine Habitats in the Wider Caribbean.		
Pillar 8a: Human health and wellbeing			
Objective 8.1. Reduce risks to human health and wellbeing from nutrient pollution			
	SDG 3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.	• SDG 3.9.2. Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene • SDG 3.9.3 Mortality rate attributed to unintentional poisoning	2030

		Others: • Number of persons affected and type of illnesses per year • Number of advisories for polluted water per year • Number of shellfish beds and fisheries closures per year • Annual health care costs associated with nutrient pollution impacts	
Objective 8.2. **Improved *livelihoods***			
	Regional target to be developed	• No. persons affected/yr • Loss/increase in income (USD)/yr • Number of new opportunities created (e.g., from reuse and recycling) • Number jobs created/number of beneficiaries	TBD
Objective 8.3. Reduce risk to the blue economy from nutrient pollution			
	Regional target to be developed	• Economic losses/yr (USD) by sector • Job losses/yr by sector • Number of new opportunities/new industries created • Change in revenue (linked to reduced nutrient pollution) • Annual economic cost of mitigating nutrient pollution and addressing its impacts	TBD